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Paper

Estimated Radiation Doses Received by New Mexico Residents from the 1945 Trinity Nuclear Test

Steven L. Simon,[1] André Bouville,[2] Harold L. Beck,[3] and Dunstana R. Melo[4]

Abstract—**The National Cancer Institute study of projected health risks to New Mexico residents from the 1945 Trinity nuclear test provides best estimates of organ radiation absorbed doses received by representative persons according to ethnicity, age, and county. Doses to five organs/tissues at significant risk from exposure to radioactive fallout (i.e., active bone marrow, thyroid gland, lungs, stomach, and colon) from the 63 most important radionuclides in fresh fallout from external and internal irradiation were estimated. The organ doses were estimated for four resident ethnic groups in New Mexico (Whites, Hispanics, Native Americans, and African Americans) in seven age groups using: (1) assessment models described in a companion paper, (2) data on the spatial distribution and magnitude of radioactive fallout derived from historical documents, and (3) data collected on diets and lifestyles in 1945 from interviews and focus groups conducted in 2015–2017 (described in a companion paper). The organ doses were found to vary widely across the state with the highest doses directly to the northeast of the detonation site and at locations close to the center of the Trinity fallout plume. Spatial heterogeneity of fallout deposition was the largest cause of variation of doses across the state with lesser differences due to age and ethnicity, the latter because of differences in diets and lifestyles. The exposure pathways considered included both external irradiation from deposited fallout and internal irradiation via inhalation of airborne radionuclides in the debris cloud as well as resuspended ground activity and ingestion of contaminated drinking water (derived both from rivers and rainwater cisterns) and foodstuffs including milk products, beef, mutton, and pork, human-consumed plant products including leafy vegetables, fruit vegetables, fruits, and berries. Tables of best estimates of county population-weighted average organ doses by ethnicity and age are presented. A discussion of our estimates of uncertainty is also provided to illustrate a lower and upper credible range on our best estimates of doses. Our findings indicate that only small geographic areas immediately downwind to the northeast received exposures of any significance as judged by their magnitude relative to natural radiation. The findings presented are the most comprehensive and well-described estimates of doses received by populations of New Mexico from the Trinity nuclear test.**

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Key words: dose reconstruction; exposure, radiation; fallout; health effects

INTRODUCTION

The Trinity nuclear test was unique in the annals of nuclear science and socio-political and worldwide nuclear testing history due to it being the first test of a nuclear fission weapon and, indeed, the first nuclear explosion in the history of the world. The test took place at 5:29 a.m. on 16 July 1945 about 56 km southeast of Socorro, New Mexico (approximately 33°40′38″N, 106°28′31″W), on what was then the Alamogordo Bombing and Gunnery Range, now part of White Sands Missile Range.

Beyond being the first test, Trinity was a unique event in other ways. Unlike for later nuclear tests, because of the secrecy of the development of the atomic bomb, there was no public notice before the test and no prior evacuations of any nearby communities. In addition, the low detonation height (30.5 m) and relatively light winds (Hawthorne 1979) tended to create significant local fallout. The state of New Mexico was largely rural, though there were farms and ranches in all directions downwind from the White Sands Gunnery range detonation site.

The Trinity detonation was the proof of principle of the theory and mechanical design of the implosion concept developed by the Manhattan Project and used for the weapon to be dropped on Nagasaki in August 1945. For those reasons, at least, Trinity has a definite place in history. Little is known, however, about any health consequences among

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the public as a result of the test. The purpose of this study is to present our assessment of the likely health consequences to residents of New Mexico exposed to radioactive fallout from the Trinity detonation. While in recent years there has been considerable concern about the health consequences among regional New Mexico populations, the magnitude of these consequences, derived from well-buttressed scientific inquiry and analysis, has been absent until now. The impacts, in terms of both dose and health consequences from other nuclear test sites, including those in Nevada, Marshall Islands, French Polynesia, and Kazakhstan (see for example, Anspaugh and Church 1986; Stevens et al. 1990; Kerber et al. 1993; Land et al. 2008, 2010, 2015; Drozdovitch et al. 2008; Gilbert et al. 2010), have been studied, leaving the first nuclear test, i.e., Trinity, to be the one of the few remaining nuclear tests conducted near resident populations to have never been studied in great detail. Because the magnitude of exposures received by local populations in New Mexico, as well as the spatial pattern and local heterogeneity, were heretofore not well known, the primary goal of this study was to conduct a detailed analysis of the radiation exposure of residents of New Mexico from the Trinity fallout. This paper summarizes the findings from the dose assessment conducted for that purpose.

OVERALL GOALS AND DEFINITIONS

As noted, the overall purpose of this paper is to report the findings of the Trinity dose assessment for New Mexico residents. For years, a major concern by New Mexico populations has been the magnitude of doses received. But as is typical for exposures in the past, dose reconstruction is challenging. Because organ doses, particularly internal doses, cannot be assessed today by any physical or biological assay, estimates are understandably dependent on models and on the availability of data relevant to the modeling of exposures. The data necessary for the dose reconstruction, as well as exposure models used, are presented in Bouville et al. (2020) and along with diet and lifestyle data (Potischman et al. 2020) compose the necessary components to understand the findings presented here.

In addition to presenting the findings on the magnitude of radiation doses received by regional New Mexico populations from the Trinity detonation, we also report and discuss the heterogeneity of those doses among regional populations resulting from differences in ethnicity, age, and location. Our interest in ethnicity is not because of any known genetically based differences in response to exposure but because recognized differences in diet and lifestyle factors are the determinants of dose.

In this analysis, *dose* refers to best estimates of radiation absorbed dose (mGy) to specific organs of representative persons defined by ethnicity, age, and geographic location. Each of these factors are further defined here, and uncertainty of dose is discussed in a later section.

Five organs (or groups of organs) were considered in the dosimetric analysis. Four were the same as in studies of health risk in the Marshall Islands following nuclear testing, namely (1) colon, (2) active (red) bone marrow (RBM), (3) stomach, and (4) thyroid gland (Land et al. 2010); lung was added to the list of organs to be considered. The five organs are of generally high risk from exposure to radioactive fallout. It was considered beyond the feasibility as well as beyond any prevailing need to assess dose to every organ, such as eye lens and skin. Skin dose and particularly skin burns, which had been reported on cattle in some locations following Trinity, do not substantially contribute to the cancer risk of the five organs (above) that are thought to be at highest risk and that are the subject of the risk assessment for Trinity (Cahoon et al. 2020).

The ethnic groups of interest (i.e., Whites, Hispanics, Native Americans,[5] and African Americans) were defined by the reported ethnicities in the US census of 1940 and 1950. The New Mexico population in 1945 in terms of numbers of persons, age distribution, and geography was derived from US Census reports and is presented in later sections of this report.

The age groups used in this work are simplifications of actual population age distributions but are intentionally consistent with age categories used by the International Commission on Radiological Protection (ICRP) for deriving and reporting dosimetric factors necessary for our calculations. The seven age categories considered were (1) in utero, (2) 0–1 y of age, (3) 1–2 y of age, (4) 3–7 y of age, (5) 8–12 y of age, (6) 13–17 y of age, and (7) adults (18+ y). Dietary data (Potischman et al. 2020), like census data, were not always collected in the same age categories as used for defining dose categories. In such cases, simple linear interpolation was used to recast the data into compatible age categories with those of the ICRP dose coefficients.

The geographic extent of this work is the entire state of New Mexico which, in 1945, included populations in 721 voting precincts in 31 counties.[6] Recognizing that fallout can be deposited at distances of many miles from a detonation site, particularly along the predominant wind direction, we made the decision not to limit the dose assessment to only "close-in" counties. For this reason, we have estimated doses for all the counties of New Mexico. This allowed us to provide long overdue estimates on

[5]The research findings in this paper do not explicitly apply to the people of the Navajo Nation.

[6]While 31 counties existed in New Mexico in 1945, present-day maps show 33. In 1981, Valencia was split into Cibola and Valencia, the former taking 80% of the original Valencia county land area but has only about 25% of the present-day population of both counties together. Los Alamos county was created in 1949.

exposures without preferential treatment or discrimination of any locations. Areas in other states adjacent to New Mexico (e.g., parts of Colorado, Texas, and Oklahoma) may have also received very low levels of exposure from Trinity, though only New Mexico was included in our study.

The intent in this work should be understood to be different from an epidemiological follow-up study designed to quantify the risk per unit dose (e.g., in an analytical dose-response study) or to provide information for administering medical countermeasures (e.g., immediately after a radiation accident), or even one to assess individual-based probability of causation. In such cases, individual dose estimation is needed. Because much of the 1945 population is deceased and cannot be queried about their lifestyle in 1945 and because detailed individual (rather than group) exposure-related information (e.g., diet and lifestyle) is impossible to obtain even among those still alive today, the requirements to estimate dose are unique in this work. The requirements of a risk projection are simply to quantify the average dose to each segment of the population with a unique exposure and risk profile and the number of persons exposed in each population segment.

For the purposes of the Trinity risk projection, reported elsewhere in this issue by Cahoon et al. (2020), we present and summarize best estimates of dose by ethnicity, age, and county to five organs of representative persons of each ethnicity and age category. Clearly the deposition of fallout and the resulting exposure within any individual county close to the test site (Fig. 1) was very heterogeneous. For that reason, and because the US Census provided population data at the level of the voting precinct (i.e., on a much finer geographic scale than the size of counties), our dose assessment methods were applied to representative persons of each ethnicity in each of the 721 precincts in existence in 1945. While the exposure-rate information (Quinn 1987; Cederwall and Petersen 1990) could be interpolated on a geographic scale like that of the precinct sizes, other necessary data, such as specific types of foods available, cannot be discerned reliably with the same high spatial resolution. These restrictions suggest that county-level dose estimates by ethnicity and age are the finest spatial discrimination that are appropriate for us to report today. For these reasons, we weighted our precinct-level dose estimates by the precinct population size (according to age and ethnicity) to produce county-level ethnicity- and age-averaged dose estimates. Those estimates are presented in later sections.

It is important to note that the risk of cancer is the only health endpoint projected (i.e., estimated) in the National Cancer Institute (NCI) study described in this issue. While radiation can clearly play a role in the induction of non-cancer radiation effects (e.g., cataracts) in some populations, the expertise of the NCI dictated the emphasis on cancer risk.

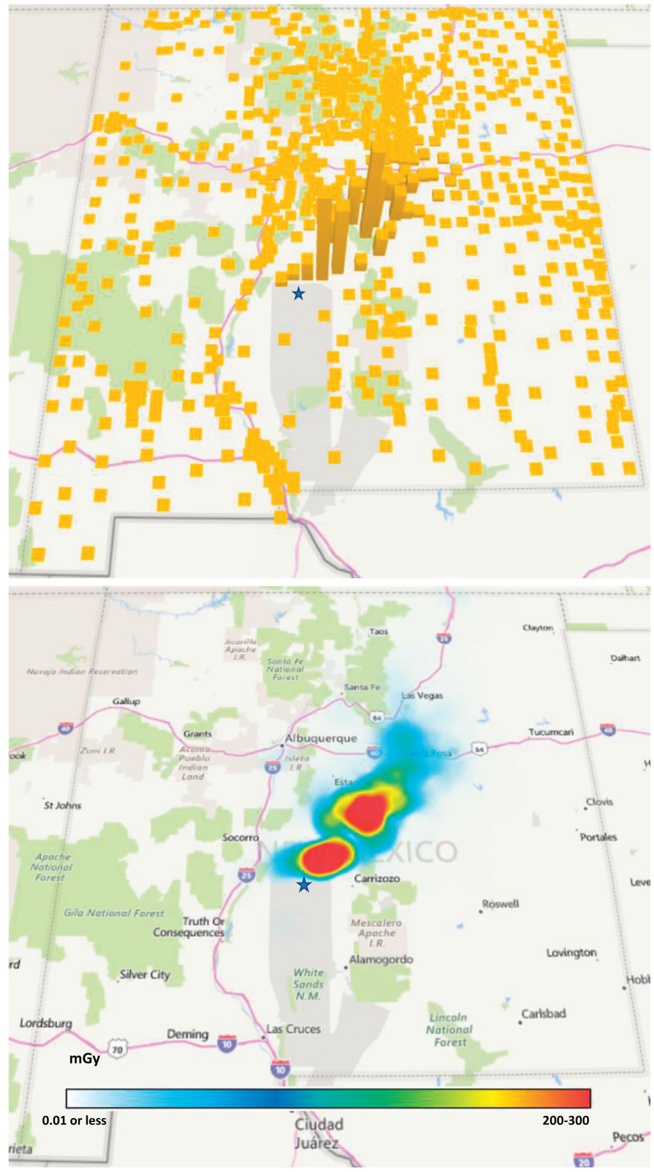

Fig. 1. One-year integral air kerma (outdoor) from fallout deposited by the Trinity detonation (July 16, 1945 to July 15, 1946) at centroid locations of 721 voting precincts and interpolated. Top panel: Air kerma estimates at precinct centroids. Bottom panel: Interpolation map of air kerma. Star on each panel represents approximate location of Trinity detonation. Gray rectangular area directly south of Trinity detonation site is the present-day White Sands Missile Range (in 1945 known as White Sands Proving Ground).

METHODS

Dose reconstruction for a risk projection study only requires estimates of dose to representative persons in subgroups in which the dose and risk might be differentiated. The subgroups in this study that could possibly be distinguished, termed *strata*, were potentially based on ethnicity; sex; age; general geographic region in the state (north/

south); environment type (also called ecozone), which included plains, mountains, or plains/mountains; and population density (urban and rural). As discussed in Potischman et al. (2020), some combinations of attributes that might define unique strata were found to be unnecessary or extraordinarily difficult to define or to characterize. For this dose reconstruction, we rely on six defined data sets as presented in Potischman et al. (2020) that include the combinations of ethnicity (White, Hispanic, Native American, African American), age, ecozone (plains and mountains), and population density (rural/urban).

The doses estimated in this work are those received over the time of 1 y from the date of detonation; i.e., 16 July 1945 through 15 July 1946. Pragmatic considerations dictated the decision to estimate doses only for the first full year after detonation as opposed to the lifetime dose. First, it has been shown that more than 90% of the infinite-time external dose from deposited fallout is received in the first year for fallout transit times up to about 30 h (Simon et al. 1995). It can also be shown that the annual dose from internal irradiation is much greater in the year immediately following the test than in any subsequent year (Bouville et al. 2020). This is primarily a consequence of the short half-lives of the fallout radionuclides that deliver the greatest dose (see Table 1 in Bouville et al. 2020).

Methods to estimate internal dose for longer periods than 1 y are complicated by lack of information on changes in diets and in bioavailability of the environmental contamination over successive years, as well as the requirement to change the biokinetic assumptions of an aging population. It is known, for example, that significant changes in diets in post-war years occurred as a result of widespread economic improvements, the introduction of home refrigerators, and greater transport and movement of regionally-produced foods. These various social, environmental, and inter-individual biological changes over time would add tremendous complexity to conducting a lifetime dose assessment. Given the rapid decay of most of the radionuclides, the component of dose received with each passing year would contribute little to the lifetime dose and would not provide any significant improvement to a dose or risk assessment.

The population number in each of the 31 New Mexico counties in 1945 varied considerably as did the mixture of ethnic groups. Table 1 in this paper provides data on the numbers of persons of each ethnicity and age in the 31 counties as derived and interpolated from the 1940 and 1950 US Census reports (US Census 1940, 1950).

As with any population, there can be exposure pathways that are exclusive to small groups of people but that are not well recognized and/or poorly understood. Such pathways are typically expected to be quite minor in their contribution to the total exposure even though their uncertainty can be substantial. Here we acknowledge that undocumented exposure pathways may exist, particularly for populations that have been less well studied and reported on, such as Native Americans, for example. However, bounding assumptions can usually be made for most pathways based on arguments of the physical amount of contaminated material that might be ingested. In this work, we have assumed, based on our scientific understanding and years of experience conducting assessment of exposure to radioactive fallout, that a group of relatively well-understood pathways of exposure account for the largest proportion of the dose. The important exposure pathways obviously fall under the categories of external and internal irradiation, and internal dose includes components from both ingestion and acute and long-term inhalation.

As described in Bouville et al. (2020), we accounted for the pathways of exposure for the resident populations we believe would most significantly impact the population cancer risk, and we applied the models using strata-specific data. While the individual pathway-specific models are described in the companion paper, for purposes of understanding the doses reported here, we reiterate the exposure pathways and food types quantitatively considered in this work:

1. External irradiation;
2. Consumption of cows' milk;
3. Consumption of mothers' breast milk (specific to nursing infants);
4. Consumption of fresh cheese (from cows' milk);
5. Consumption of fruits and berries;
6. Consumption of fruit vegetables;
7. Consumption of leafy vegetables;
8. Consumption of beef (meat);
9. Consumption of pork (meat);
10. Consumption of mutton (meat);
11. Consumption of river and cistern water;
12. Inhalation of fallout during the period of deposition; and
13. Inhalation of resuspended contaminated dust (entire year).

Consumption of goats' milk might also be expected, though as noted in Potischman et al. (2020), in interviews for this study, the consumption of goats' milk was reported so infrequently that it could not be assumed to have been a commonly consumed food product in this population and, furthermore, could not be quantified on a population basis.

The dose assessment in this work consisted of a number of sequential steps beginning with estimation of the ground deposition density (Bq m^{-2}) for each of the 63 radionuclides considered (see Table 1 of Bouville et al. 2020) using interpolated values of exposure-rate, fallout time-of-arrival, and the refractory to volatile ratio (R/V, see Bouville et al. 2020; Beck et al. 2020) at the centroid location of each

Table 1. Population by county, age, and ethnicity (interpolated from 1940 and 1950 US Census). All cells are rounded whole numbers.

	White								Hispanic							
County	In-utero	0–1 y	1–2 y	3–7 y	8–12 y	13–17 y	Adult	Total	In-utero	0–1 y	1–2 y	3–7 y	8–12 y	13–17 y	Adult	Total
Bernalillo	853	1,137	2,275	6,242	5,155	4,943	30,414	**51,019**	610	814	1,627	4,464	3,687	3,535	21,754	**36,492**
Catron	49	65	130	357	281	247	1,368	**2,497**	35	47	93	255	201	177	978	**1,786**
Chaves	294	392	783	2,150	1,802	1,770	11,181	**18,372**	210	280	560	1,538	1,289	1,266	7,997	**13,141**
Colfax	207	276	553	1,513	1,192	1,047	5,799	**10,587**	148	198	395	1,082	852	749	4,148	**7,573**
Curry	146	195	390	1,069	879	838	5,120	**8,636**	104	139	279	764	629	599	3,662	**6,177**
De Baca	43	57	115	314	247	217	1,204	**2,197**	31	41	82	225	177	155	861	**1,572**
Dona Ana	345	460	920	2,523	2,068	1,956	11,857	**20,130**	247	329	658	1,805	1,479	1,399	8,481	**14,398**
Eddy	326	434	868	2,380	1,946	1,833	11,059	**18,846**	233	310	621	1,703	1,392	1,311	7,910	**13,480**
Grant	241	321	642	1,756	1,383	1,216	6,733	**12,291**	172	229	459	1,256	989	870	4,816	**8,792**
Guadalupe	90	120	240	657	517	455	2,519	**4,598**	64	86	172	470	370	325	1,801	**3,289**
Harding	38	51	102	280	221	194	1,075	**1,963**	27	37	73	201	158	139	769	**1,404**
Hidalgo	57	76	153	419	330	290	1,605	**2,929**	41	55	109	299	236	207	1,148	**2,095**
Lea	256	341	682	1,869	1,529	1,442	8,706	**14,824**	183	244	488	1,337	1,094	1,031	6,227	**10,603**
Lincoln	91	121	242	661	521	458	2,536	**4,629**	65	86	173	473	373	328	1,814	**3,311**
Luna	88	117	233	639	503	443	2,450	**4,473**	63	83	167	457	360	317	1,753	**3,199**
McKinley	133	177	355	971	765	672	3,722	**6,794**	95	127	254	694	547	481	2,662	**4,859**
Mora	115	153	306	837	659	579	3,208	**5,857**	82	109	219	599	471	414	2,295	**4,189**
Otero	136	181	362	990	780	685	3,795	**6,929**	97	129	259	708	558	490	2,715	**4,956**
Quay	151	201	402	1,101	867	762	4,220	**7,703**	108	144	288	787	620	545	3,018	**5,510**
Rio Arriba	271	361	722	1,977	1,557	1,369	7,580	**13,838**	194	258	517	1,414	1,114	979	5,422	**9,898**
Roosevelt	180	240	480	1,315	1,036	911	5,043	**9,206**	129	172	344	941	741	651	3,607	**6,585**
Sandoval	125	166	332	909	716	630	3,486	**6,363**	89	119	238	650	512	450	2,493	**4,551**
San Juan	101	134	268	734	578	508	2,813	**5,136**	72	96	192	525	413	363	2,012	**3,673**
San Miguel	279	373	745	2,043	1,669	1,570	9,454	**16,133**	200	266	533	1,461	1,194	1,123	6,762	**11,539**
Santa Fe	321	429	857	2,353	1,962	1,911	11,968	**19,801**	230	306	613	1,683	1,403	1,367	8,560	**14,163**
Sierra	82	109	217	595	469	412	2,282	**4,166**	58	78	156	426	335	295	1,632	**2,980**
Socorro	196	262	523	1,433	1,129	992	5,493	**10,028**	140	187	374	1,025	807	710	3,929	**7,173**
Taos	199	265	531	1,453	1,145	1,006	5,570	**10,169**	142	190	380	1,039	819	720	3,984	**7,274**
Torrance	111	148	295	808	637	560	3,099	**5,658**	79	106	211	578	455	400	2,217	**4,047**
Union	95	127	253	693	546	480	2,657	**4,851**	68	91	181	496	391	343	1,901	**3,470**
Valencia	207	275	551	1,508	1,188	1,044	5,781	**10,553**	148	197	394	1,078	850	747	4,135	**7,548**

County	Native American								African American							
	In-utero	0–1 y	1–2 y	3–7 y	8–12 y	13–17 y	Adult	**Total**	In-utero	0–1 y	1–2 y	3–7 y	8–12 y	13–17 y	Adult	**Total**
Bernalillo	43	57	113	283	198	182	1,055	**1,931**	11	14	28	82	68	72	715	**990**
Catron	0	0	0	1	0	0	2	**4**	0	0	0	0	0	0	3	**5**
Chaves	0	1	1	3	2	3	16	**27**	8	11	22	64	53	57	562	**777**
Colfax	0	0	0	1	1	1	3	**6**	2	3	5	13	10	9	95	**136**
Curry	1	2	3	8	6	7	41	**68**	4	5	10	30	25	26	260	**360**
De Baca	0	0	0	0	0	0	1	**2**	0	0	0	0	0	0	0	**0**
Dona Ana	2	2	5	12	9	9	52	**91**	12	16	31	84	65	62	655	**925**
Eddy	0	0	0	1	0	0	2	**4**	8	11	22	61	49	50	509	**710**
Grant	1	1	3	7	5	4	25	**47**	2	3	5	14	10	9	97	**139**
Guadalupe	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	1	**2**
Harding	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	1	**2**
Hidalgo	0	1	1	3	2	1	9	**16**	0	0	1	2	1	1	11	**16**
Lea	1	1	2	5	4	4	25	**42**	10	13	27	77	63	66	659	**915**
Lincoln	0	0	0	0	0	0	0	**1**	0	0	1	1	1	1	10	**15**
Luna	0	0	1	2	1	1	6	**11**	1	1	3	7	5	5	50	**72**
McKinley	299	399	798	1,996	1,368	1,144	6,681	**12,687**	3	4	8	21	16	14	151	**217**
Mora	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	1	**1**
Otero	21	28	55	138	95	79	462	**877**	3	4	8	20	15	13	146	**210**
Quay	0	0	0	1	0	0	2	**4**	1	2	3	8	6	5	59	**84**
Rio Arriba	40	53	106	266	182	152	889	**1,688**	0	0	0	0	0	0	2	**3**
Roosevelt	0	0	0	0	0	0	1	**1**	0	0	0	0	0	0	1	**2**
Sandoval	81	108	216	541	371	310	1,810	**3,437**	0	0	0	0	0	0	3	**4**
San Juan	207	276	552	1,381	947	792	4,623	**8,778**	0	0	0	0	0	0	3	**5**
San Miguel	0	0	0	1	0	0	3	**5**	0	1	1	3	2	2	25	**35**
Santa Fe	18	24	48	120	85	83	476	**854**	3	4	7	21	17	18	176	**244**
Sierra	0	0	0	1	0	0	2	**4**	1	1	2	6	5	4	44	**63**
Socorro	7	10	19	49	33	28	163	**309**	0	0	0	0	0	0	3	**4**
Taos	18	24	49	122	84	70	409	**777**	0	0	0	0	0	0	1	**2**
Torrance	0	0	0	1	0	0	2	**4**	0	0	0	0	0	0	0	**0**
Union	0	0	0	0	0	0	0	**0**	0	0	1	3	2	2	18	**26**
Valencia	90	121	241	603	413	346	2,018	**3,833**	0	0	0	1	1	1	6	**9**

of the 721 voting precincts. For the purposes of our calculations, deposition density was estimated at the approximate time of peak fallout arrival measured from the time of detonation (5:29 AM Mountain Time). Because the time interval from detonation to deposition is needed to properly account for radioactive decay during the transit of debris from the detonation site to the deposition site, fallout "time-of-arrival" (TOA, h) was a necessary parameter. In this study, the TOA was estimated by interpolation of TOA data reported by Quinn (1987) for the Trinity detonation. See Bouville et al. (2020) for further discussion on estimation of TOA and exposure-rate at TOA.

Voting precincts were always relatively small areas and, of course, dependent on population number and area. In each precinct, we assumed that estimated deposition density and TOA were relatively uniform and representative of the exposure conditions to the entire resident population of the precinct.

It is important to recognize that, similar to other dose reconstructions of fallout exposures in Nevada and Utah, Marshall Islands, and Kazakhstan (Ng et al. 1990; Lloyd et al. 1990; Simon et al. 1990, 2002, 2006, 2010; NCI 1997; Bouville et al. 2002, 2010; US DHHS 2005; Gordeev et al. 2006a and b; Beck et al. 2006, 2010), the local deposition density was derived from measurements (or interpolation of local measurements) of exposure-rate or gamma spectrometry radionuclide concentrations in soil and radioactivity measurements on gummed film (Bouville and Beck 2000) rather than from the use of atmospheric dispersion codes and models. There appears to be occasional confusion among the public (TBDC 2017, p. 34) that atmospheric dispersion models, which are known to be quite uncertain for complex radiation releases (e.g., nuclear detonations), were the primary source of information on fallout deposition in this and other fallout-related dose reconstruction studies. While atmospheric dispersion model predictions are sometimes compared against ground measurements as the basis for improving our understanding of dispersion processes (Cederwall and Peterson 1990; Moroz et al. 2010), such models were only used for estimating ground deposition in the Trinity study at locations beyond the Quinn fallout deposition pattern. In this study, ground deposition of fallout at all precincts in the Quinn pattern was estimated from interpolated values of actual ground-level exposure-rate measurements (Quinn 1987; also see Fig. 3 of Beck et al. 2020) taken within 21 d of the Trinity detonation. Beyond the Quinn pattern, near the border of New Mexico and Colorado, the fallout pattern was supplemented with computer model calculations by Cederwall and Peterson (1990). At locations to the east, west, and south of the Quinn pattern, the absence of significant fallout was confirmed by measurements from x-ray film badges (Hoffman 1945) discussed further in a later section titled VALIDATION. As described in Bouville et al. (2020), the exposure rate at location L normalized to 12 h post-detonation [i.e., $\dot{X}(12, L)$] as reported by Quinn (1987), is modified to account for the actual TOA at each location of interest and the degree of fractionation of the fallout [see Appendix of Beck et al. (2020) for further information].

From each of the 45,000+ deposition density estimates in this work (721 precincts × 63 radionuclides), N_{50}, i.e., the fraction of fallout particles less than 50 μm in diameter, was estimated (see Bouville et al. 2020 for a discussion of models) as an intermediate step to determine the contamination of plants with radioactive particulates that are retained on the leaf surfaces, a phenomenon that leads to food-chain contamination. N_{50} was found to range from a minimum of 0.062 at locations very close to the detonation site where particles were predominantly much larger than 50 μm and poorly retained on plant surfaces to unity at locations where the fallout deposition occurred at times greater than about 14 h after the detonation and the particles were smaller than 50 μm.

Ground deposition and N_{50} estimates for the 63 radionuclides were used as the basis for estimating contamination of both pasture plants eaten by grazing animals and human-edible plant foods [e.g., fruits and berries, fruit vegetables (such as tomatoes, peppers, squash, melons, etc.), and leafy vegetables (such as spinach, greens, lettuce, etc.)]. Time integrated concentrations (Bq d kg^{-1}) of all radionuclides were calculated for all categories of pasture grass and human-edible plants at all relevant locations by considering biomass yield, weathering half-time, and other related variables (Bouville et al. 2020).

Intakes of radionuclides by animals in the food chain were calculated for each plant-based food using conventional data on animal nutritional requirements appropriate to the mid-1940s. Intakes of radionuclides directly by humans were calculated for each plant and animal-based food as well as from drinking water and from inhalation at the time of fallout (termed "in-cloud" inhalation) and from long-term inhalation of resuspended contaminated soil. Models of radionuclide intake by animals or humans are similar for all sources of internal contamination in that each calculation requires the time-integrated concentration in the source material and the rate of intake of that source material, a parameter that typically varies by ethnicity and age for humans. Radionuclide intakes of plant-based foods were calculated for all combinations of ethnicity/age/precinct as the product of the time-integrated concentration (Bq^{-d} kg^{-1}) in the food product and the intake-rate (kg d^{-1}) of the food (Bouville et al. 2020). Intakes of radionuclides from animal products (cows' milk, cow cheese, beef, mutton, pork) were calculated as the products of time-integrated concentrations in the food product, based on contamination of pasture grass coupled with feed-milk or feed-meat radionuclide-specific transfer coefficients, and daily intakes rates by man, in a similar fashion to calculations for plant foods. Intakes of radionuclides from potable drinking water sources, primarily cistern water, potentially contaminated by rainfall events during the fallout cloud passage time and from water derived from rivers, were calculated at the precinct level (Bouville et al. 2020). Well water was assumed not to be contaminated, and human consumption of water from open irrigation ditches, known as *acequias*, was assumed to have been too rare to account for on a population-average basis.

Inhalation of radionuclides in air was accounted for (1) during the period when fallout was being deposited (i.e., "in cloud" intake) and (2) during the entire first year from the resuspension of contaminated soil particles. The calculation for the intake of radionuclides by inhalation during the period of fallout deposition accounts for radioactive decay as well as for the approximate differences in particle size with distance downwind, the latter factor being important to determine whether the particles are small enough to reach the deep lung after inhalation. "In cloud" inhalation only takes place after the onset of deposition for a time roughly equal to (or slightly less) than TOA, while inhalation from resuspension continues during the entire year.

In contrast to "in cloud" inhalation, the potential for the intake of soil by resuspension is known to be an ongoing phenomenon, though physical weathering of fallout particles and their downward migration into the soil column results in a significant decrease in the availability of activity for resuspension with the passage of time after deposition. Due to the downward migration of radionuclides in the soil column, and because only surface soil is available for resuspension, resuspension models (Maxwell and Anspaugh 2011) predict the magnitude of the activity to be resuspended in the second year after deposition to be less than 1% of the activity available for resuspension in the first year. Moreover, the fraction available for inhalation continues to decrease significantly in successive years. This phenomenon provides the primary rationale for limiting the calculation of dose from resuspension to the first year. See Bouville et al. (2020) for further detail about inhalation models.

Another important pathway of exposure is by mothers' milk and is only relevant, of course, for nursing infants. In this work, the radionuclide mixture and the possible degree of contamination of mothers' breast milk was determined according to precinct location by considering the local ground deposition density of each radionuclide, the intake of radionuclides according to the diet of adults of the ethnic group under consideration, as well as from water and inhalation. All intakes used radionuclide-specific transfer factors estimating contamination of breast milk from reports of the International Commission on Radiological Protection (ICRP). While the time-period of breastfeeding can vary by ethnic group and by family (Potischman et al. 2020), we assumed that, on average, breastfeeding continued for 12 mo, and the intake rate of mothers' milk for nursing infants was 0.8 L d^{-1}.

Estimates of intakes of radionuclides by ingestion and inhalation were converted to organ dose using dose coefficients (mGy Bq^{-1}) derived from publications of the ICRP, as described in Bouville et al. (2020), with assignments of solubility class for lung and the gastrointestinal tract appropriate for regional fallout from nuclear testing (Ibrahim et al. 2010).

FINDINGS AND DISCUSSION

In this section, we present graphical analyses illustrating (1) the relative magnitude of each exposure pathway by ethnicity and age, (2) the relative magnitude of estimated doses for each of the five organs of interest by ethnicity, and (3) a ranking of counties in terms of population-weighted dose (accounting for the ethnic and age distribution of the county). In general, the analyses presented are intended to illustrate differences in doses to the populations of New Mexico as well as the range and heterogeneity of dose within each population group. We also present in a series of tables the relative importance of individual fallout radionuclides to the total dose at three locations of increasing TOA.

A discussion of our estimates of uncertainty is provided to illustrate a lower and upper credible range on our best estimates of doses. Best estimates of doses were determined directly from application of dose estimation formulae using diet input data, presented in companion papers (Bouville et al. 2020; Potischman et al. 2020). The derivation of uncertainty, discussed elsewhere in this paper, could alternatively be used to estimate the mean value from the resulting uncertainty distribution. For maximum transparency, however, our reported dose estimates are derived directly from the application of the dose estimation formulae and are closer to median rather than mean values of the uncertainty distributions. The Appendix of this report presents tables of best estimates of county population-weighted average organ doses by ethnicity and age as a record for further research and archival purposes.

External doses: magnitudes and spatial pattern

External doses to support the risk projection were estimated to the whole-body as well as the five organs of interest by county, ethnicity, and age. While the air kerma from deposited fallout is applied to all persons in each precinct, the dose to each ethnic population in a precinct was modified to account for the shielding from common home construction materials and the reported time spent outdoors per day in summer months (Potischman et al. 2020; Bouville et al. 2020).

The maximum assigned exposure rate at 12 h post-detonation [i.e., $\dot{X}(12)$] of 481 mR h^{-1} was for a single precinct in southern Torrance county, directly downwind of the Trinity detonation site.[7] Sites directly on the periphery of the fallout pattern were estimated to be at least 2,000-fold smaller than the maximum, and locations well outside the pattern were estimated to be up to 10,000-fold smaller. Relatively high $\dot{X}(12)$ contours from Trinity intersected numerous precincts in several counties, but because of the narrowness of the high exposure-rate contours (see Fig. 1 of Bouville et al. 2020), most of those counties had lower area-averaged $\dot{X}(12)$ values when each of the precinct's areas with unique exposure rates, expressed as a fraction of the total county area, were used as weighting factors. Counties and precincts outside of the Quinn deposition pattern were conservatively assigned $\dot{X}(12)$ values of 0.05 mR h^{-1} and TOA values from 12 to 36 h depending on the location of the county. The spatial pattern of $\dot{X}(12)$ strongly reflects the movement of the Trinity fallout cloud to the northeast from the detonation site as reported by Quinn (1987).

The time-integrated air kerma can be derived from $\dot{X}(12)$ and TOA as shown elsewhere (Simon et al. 1995; Bouville et al. 2020). Using such calculations, the spatial pattern of the 1-y integral (outdoor) air kerma at locations across New Mexico can be derived. See the top panel of Fig. 1, which directly reflects the fallout deposition or $\dot{X}(12)$ pattern. As described earlier, $\dot{X}(12)$ was interpolated between the isopleths at the locations of the centroid of each voting precinct. Once interpolated, we assumed that exposure-rate value to be relatively uniform across the precinct, consistent with our assumption that the populations were uniformly distributed in each precinct. The top panel of Fig. 1 shows the precinct locations used to derive the interpolation map in the lower panel.

The outdoor 1-y integral air kerma (Fig. 1 lower panel) can be seen to be significantly elevated only in the localized region directly northeast of the Trinity detonation site and reached values up to 200-300 mGy (1-y integral air kerma) over relatively small and sparsely populated areas. Outdoor air kerma is an intermediate step to estimating external dose received by persons living in the region since the air kerma need only to be modified by the time spent outdoors per day, a function of ethnicity and age, and the shielding provided by the type of residential or workplace construction and by the body. One-year integral external doses, after accounting for home shielding and time spent outdoors, varied among the 721 precincts from about 0.006 mGy to about 100 mGy for Whites, about 0.006 to 50 mGy for Native Americans, and 0.004 to about 100 mGy for Hispanics and African Americans (all doses rounded to two significant digits or less).

The dose derived from external irradiation, in this circumstance, is approximately equal (ICRP 2010) for all organs of the body since the energy of externally-received gamma rays from fallout is sufficient to completely penetrate the body. The variation of external doses with age was only about 30% (ICRP 2010) with younger children receiving modestly greater external doses because of smaller body sizes. External doses varied to a small degree between ethnic groups because of modest differences in time spent outdoors and differences in home occupancy and building shielding factors.

Comparison of doses by exposure pathway

Here we illustrate the importance of individual exposure pathways to the total organ dose for adults. Data for all data sets cannot be presented, nor is it necessary to do so since the relationships between dose from individual exposure pathways and food types for adults are reasonably similar to the relationships for other age groups, except for 0-1 y of age, where only consumption of mothers' milk is assumed. This discussion focuses only on the relative importance of individual pathways and food types to thyroid dose since it is the organ that received, by far, the largest doses. Other organs would show a different ranking for the importance of food types.

The ingestion doses within each ethnic group from each food type, external dose, inhalation, and resuspension, averaged over the entire population of New Mexico, can be compared in order to judge the importance of different routes of exposure within the ethnic group. However, the heterogeneity of doses among the precincts and counties results in different comparisons depending on whether mean doses or median doses are compared. To minimize the effect of substantial skewness in dose distributions, we compare median doses from each route of exposure.

Among adults, comparing the median dose for each food type (other than cows' milk) to the median dose from cows' milk illustrates the relative importance of each pathway for each ethnic group as follows. Numbers in parentheses are the median dose relative to cows' milk:

Whites - Cows' milk (1.0) : Water (0.49) : Leafy vegetables (0.40) : External Dose (0.095) : Fruit Vegetables : (0.070) : Inhalation (0.061). All other routes of intake were less than 5% of the dose from cows' milk;

Hispanics - Cows' milk (1.0) : Water (0.49) : Leafy vegetables (0.40) : External Dose (0.088) : Fruit Vegetables : (0.070) : Inhalation (0.061). All other routes of intake were less than 5% of the dose from cows' milk;

Native Americans - Cows' milk (1.0) : Leafy vegetables (0.50) : Fruits and Berries (0.35) : Water (0.28) : External

[7]Traditional units are being used here to maintain consistency with the historical data.

(0.11) : Fruit Vegetables (0.087) : Inhalation (0.059). All other routes of intake were less than 5% of the dose from cows' milk; and

African Americans - Cows' milk (1.0) : Water (0.24) : Leafy vegetables (0.24) : Fruits and Berries (0.059) : External (0.056). All other routes of intake were less than 5% of the dose from cows' milk.

In some instances, the dose from drinking water was moderately high relative to cows' milk. However, that occurred only for the subset of persons resident at locations where river water had been contaminated by the temporal coincidence of rainfall and the passage of the fallout cloud. Because rainfall is episodic and infrequent in the desert environment, such a coincidence was, in general, not common. Models to estimate this are discussed more in Bouville et al. (2020).

Inhalation ("in-cloud") dose and, to a much lower degree, resuspension dose, were extremely small contributions to thyroid dose, almost always much less than 5% of the dose from cows' milk. More detail on the range of doses from inhalation and resuspension are presented in Fig. 2a–d. Very small contributions to total dose were also contributed by animal meat products (beef, mutton, pork), primarily because of the additional limiting steps of transfer of radionuclide activity at successive steps in the food chain and because consumption of animal meat in 1945 was a luxury and consumption rates were reported to be low (Potischman et al. 2020). The dose contributions from all food types and exposure pathways including inhalation and resuspension are provided in the panels of Fig. 2.

Comparison of doses to organs of the body

The total organ dose, i.e., the sum of external plus internal doses, can be similar for some organs and substantially different for others, the differences primarily reflecting differences in the internal dose component. Differences in internal dose arise because of the differing chemical and biokinetic characteristics of the radionuclides ingested in foods and water and inhaled in air. In general, the thyroid gland received the highest internal dose, regardless of ethnicity or age. The larger doses resulted because of the predisposition of the thyroid gland to accumulate iodine; an attribute unique to the thyroid. Other organs for which dose was computed were, in general, smaller in magnitude than the doses for the thyroid gland.

Fig. 3 presents a comparison of total organ doses to adults by ethnicity for the purposes of comparing organ dose without the complication introduced by mixing persons of different ages. Only very minor differences were apparent between ethnic groups in the ratio of thyroid dose to dose to other organs (colon, lung, RBM, and stomach).

Among adults, comparing the median dose to each organ (other than thyroid) to the median dose to the thyroid illustrates the relative ranking of organs in terms of the dose received. Numbers in parentheses are the median dose relative to that received by the thyroid gland:

Whites - Thyroid (1.0) : Colon (0.34) : Lung (0.083) : Stomach (0.067) : RBM (0.065)

Hispanics - Thyroid (1.0) : Colon (0.34) : Lung (0.077) : Stomach (0.069): RBM (0.065)

Native Americans - Thyroid (1.0) : Colon (0.37) : Lung (0.071) : Stomach (0.066): RBM (0.059)

African Americans - Thyroid (1.0) : Colon (0.36) : Lung (0.079) : Stomach (0.051) : RBM (0.051).

As can be seen here and in Fig. 3, the doses to the lung, stomach, and red bone marrow were similar in magnitude. The moderately large relative dose to the colon arises

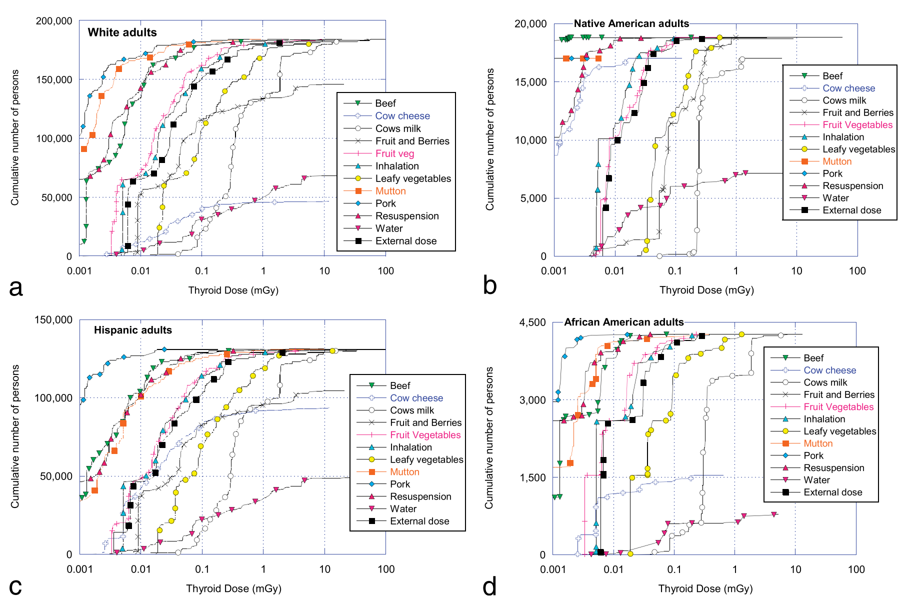

Fig. 2. Comparison of pathway and food type contributions to thyroid dose of adults by ethnicity: Whites (panel A), Native Americans (panel B), Hispanics (panel C), African Americans (panel D).

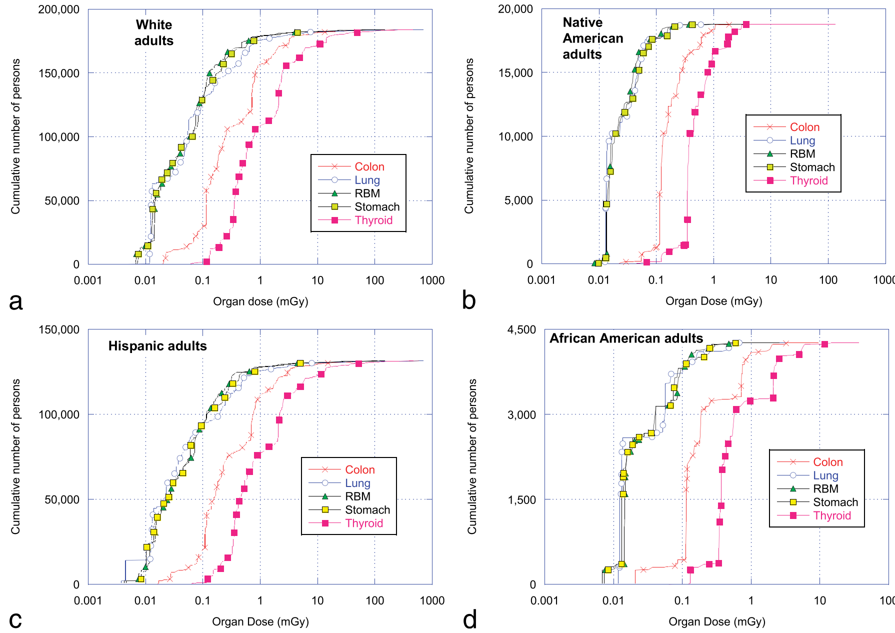

Fig. 3. Comparison of total organ doses to adults by ethnicity: Whites (panel A), Native Americans (panel B), Hispanics (panel C), African Americans (panel D). Total organ dose is a sum over all exposure sources shown in Fig. 2. Note different y-axis scaling for each panel.

because the chemical and physical form of the radionuclides following their vaporization and condensation as fallout particles is in the form of relatively insoluble particles (Ibrahim et al. 2010). The colon is exposed during the final steps of digestion of food material and its transfer to solid waste in the lower part of the intestinal tract.

The absolute values of doses to each organ received by the different ethnic groups are illustrated in more detail in Fig. 3 and can be attributed mainly to specific dietary differences. In general, higher doses, especially to the thyroid gland, would result from consumption of foods with greater radioactivity content, e.g., fresh milk products.

Comparison of doses by age at time of exposure

The effect of age alone (i.e., age in 1945 at time of exposure) on the dose received by the thyroid gland is illustrated in Fig. 4 for the ethnic groups. In the case of the dose to the thyroid gland, the average dose in each age group relative to the average adult dose, regardless of ethnicity, is governed by the internal dose from consumption of food products that contain substantial radioiodine and, to a lesser degree, by external dose. Differences in internal doses by age are primarily due to age-dependence in dose conversion factors and differences in dietary intake.

Here, we present a comparison of thyroid dose by age, relative to the adult dose, averaged over the ethnicities: In-utero (~0.8) : 0–1 y (~2.0) : 1–2 y (4.5) : 3–7 y (3.5) : 8–12 y (2.5) : 13–17 y (~2.0) : Adult (1.0).

Ranking of radionuclides to total dose

Individual radionuclides contribute different fractions to the total body and organ dose depending on several factors. For external dose, the important factors are the TOA at the location of interest, the length of the time period over which dose is integrated, and, to a much smaller degree, the R/V ratio at that location. For internal dose, the above factors are important as well as the relative magnitude of different components of the diet.

The rankings provided in this section give an indication of the approximate relative importance of each radionuclide, though the exact rank position of each nuclide among a group of 20 or more should not be considered as precise in all circumstances. The ranking is, of course, based on calculations and depends on assumed parameter values in those calculations, e.g., TOA, transfer coefficients to individual food products, and other variables.

In Tables 2 and 3, we present analyses that illustrate our findings on the relative importance of individual radionuclides to the 1-y integral external and internal doses at three different precincts covering a range of fallout TOAs: 3.1 h (Socorro County), 10.5 h (Bernalillo County), and 36.3 h (Colfax County). See Fig. 1 of Bouville for county locations. The TOA is important because of the considerable decay of the short-lived radionuclides during fallout transit. Two of the precinct locations, the closest being in Socorro County and the furthest being in Colfax County, were rural/mountain locations, while the intermediate location in Bernalillo County was an urban/plains location. The environmental differences result in modest differences in availability of foods and diet and, hence, the relative amounts of intake of different radionuclides, but more importantly, the change in TOA among the locations demonstrates a change in the importance of radionuclides according to their half-life.

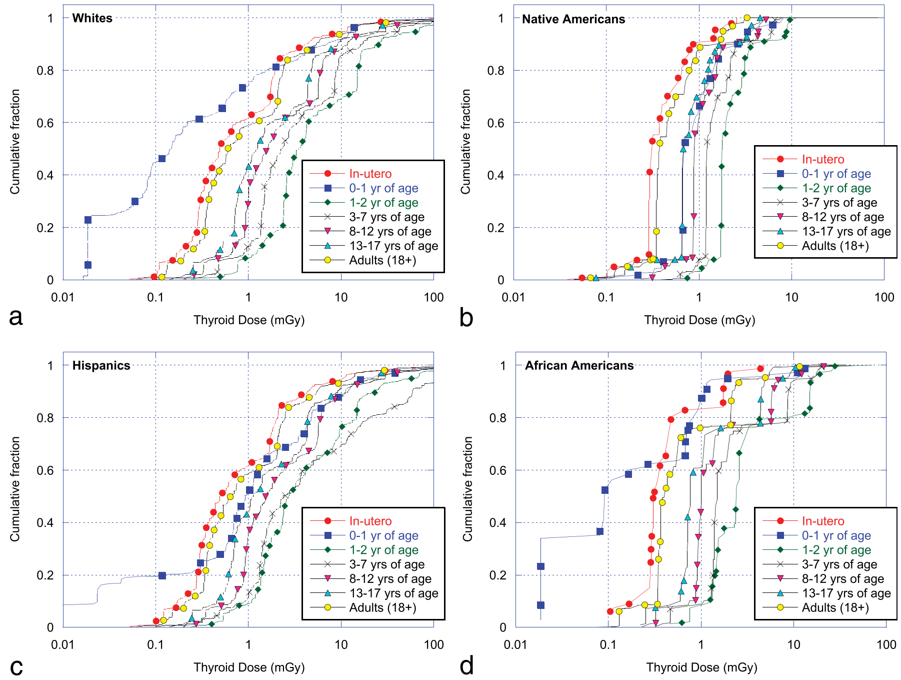

Fig. 4. Comparison of total organ doses to adults by age and ethnicity: Whites (panel A), Native Americans (panel B), Hispanics (panel C), African Americans (panel D). Thyroid dose is a sum over all exposure sources shown in Fig. 2. Note that age groups are not equal sizes.

The 22 radionuclides presented in Table 2 contribute, collectively, 95% or more of the 1-y integral external dose at all three locations. More than 50% of the external dose, regardless of location, is contributed by ^{239}Np, ^{140}La, ^{95}Nb, and ^{132}I.

Similarly, Table 3a–e presents analyses that illustrate the relative importance of individual radionuclides to the internal dose (ingestion and inhalation + resuspension separately) of the five organs studied. Analyses not shown indicate little difference in the relative ranking of radionuclides by age or ethnicity at the same location. For that reason, we restrict the presentation on the relative importance of individual radionuclides to adult Whites and Hispanics. We present the ranking at the same three locations discussed above for external dose. For all organs, 90% or more of the ingestion dose, as well as the inhalation plus resuspension dose, was contributed by 20 of the 63 radionuclides for which doses were estimated (Table 3a–e), though the relative radionuclide contributions depended on the organ, exposure pathway, and TOA of the location where the exposure was assumed to have been received. Large contributors to colon, lung, red bone marrow, and stomach dose, both by ingestion and inhalation (including resuspension), were ^{239}Np, ^{97}Zr, ^{237}U, ^{89}Sr, ^{140}Ba, ^{132}Te, and ^{140}La. As expected, the thyroid gland received nearly its entire dose from ^{131}I and ^{133}I with smaller contributions from ^{132}Te, ^{135}I, and ^{131m}Te.

The importance of two radionuclides, ^{237}U and ^{239}Np, is worthy of mention as neither is a fission-product. In the case of the Trinity device, part of the design was a heavy uranium tamper/reflector around the plutonium core, which produced a significant amount of ^{237}U and ^{239}Np during the detonation as a result of neutron capture by ^{238}U (Beck et al. 2020). The deposition density of ^{237}U and ^{239}Np, each normalized to exposure rate at 12 h (i.e., μCi per m^2 per mR per h at H+12), was reported by Hicks (1985) along with the estimates of normalized deposition factors for all other fission and activation products produced in the Trinity detonation (see Bouville 2020, this issue, for more detail). The site-specific deposition densities for ^{237}U and ^{239}Np, as for all radionuclides in this study, were estimated at each location by the product of the reported normalized deposition factor for the specific radionuclide (Hicks 1985) and the exposure rate at the location.

Comparison of county average doses

A comparison of the population-weighted average dose by county provides a relative ranking of the county-average exposures received in each of the 31 counties of New Mexico that existed in 1945. The relative position of each county in the overall ranking is dependent both on the best estimate of dose to each ethnicity and age group in the county but also on the relative numbers of persons of each ethnicity and age who were present in the county at the time of exposure as estimated from the census. Because the diets and lifestyles of each ethnic group are different, the presence or absence of an ethnic group affects the total population average dose. Counties do not have equal doses for all ethnic groups as ethnic-specific dose varies by precinct, and the county-average dose depends on which

Table 2. Radionuclides at three locations that contribute at least 95% of the first-year external dose: ranking by their fractional contribution to dose.

	Precinct 581, Socorro County TOA = 3.1 h			Precinct 13, Bernalillo County TOA = 10.5 h			Precinct 75, Colfax County TOA = 36.3 h		
Rank	Radionuclide	Fraction of annual dose	Cumulative fraction	Radio-nuclide	Fraction of annual dose	Cumu-lative fraction	Radionuclide	Fraction of annual dose	Cumulative fraction
1	Np-239	0.160	0.16	I-132	0.194	0.19	La-140	0.240	0.24
2	La-140	0.128	0.29	La-140	0.189	0.38	I-132	0.207	0.45
3	Nb-95	0.117	0.41	Np-239	0.099	0.48	Nb-95	0.100	0.55
4	I-132	0.102	0.51	Nb-95	0.079	0.56	Np-239	0.098	0.64
5	I-135	0.057	0.56	I-133	0.061	0.62	Zr-95	0.048	0.69
6	Z-r95	0.057	0.62	I-135	0.054	0.68	Cs-137	0.044	0.74
7	Zr-97/ Nb-97m	0.049	0.67	Zr-95	0.038	0.71	Ru-103/ Rh-103m	0.041	0.78
8	La-142	0.045	0.71	Cs-137	0.033	0.75	I-131	0.036	0.81
9	I-133	0.037	0.75	Ru-103/ Rh-103m	0.031	0.78	I-133	0.030	0.84
10	Sr-92	0.027	0.78	I-131	0.030	0.81	Ru-106	0.023	0.87
11	U-237	0.022	0.80	Zr-97/ Nb-97m	0.025	0.83	Te-132	0.019	0.89
12	Ru-105	0.022	0.82	Te-132	0.018	0.85	U-237	0.018	0.90
13	Sr-91	0.019	0.84	Sr-91	0.017	0.87	Ba-140	0.017	0.92
14	Ce-143	0.016	0.86	Ru-106	0.017	0.88	Zr-97/ Nb-97m	0.012	0.93
15	Ru-103/ Rh-103m	0.016	0.87	U-237	0.015	0.90	Mo-99	0.009	0.94
16	I-131	0.014	0.89	Ru-105	0.014	0.91	Te-131m	0.008	0.95
17	Mo-99	0.014	0.90	Ba-140	0.014	0.93	Ce-143	0.007	0.96
18	Cs-137	0.010	0.91	Te-131m	0.011	0.94	Co-60	0.006	0.96
19	Sb-129	0.010	0.92	Ce-143	0.010	0.95	Ce-141	0.006	0.97
20	Te-132	0.009	0.93	Mo-99	0.009	0.96	Sb-127	0.006	0.98
21	Ba-140	0.009	0.94	Sb-129	0.006	0.96	Rh-105	0.005	0.98
22	Ru-106	0.008	0.95	Sb-127	0.005	0.97	I-135	0.005	0.99

Table 3a. Radionuclides at three locations that contribute at least 90% of the first-year internal dose to colon (Whites/Hispanics): ranking by their fractional contribution to dose.

	INGESTION								
	Pct. 581, TOA= 3.1 h, Rural/Mountains Data set B (see Bouville et al., this issue, this issue)			Pct. 13, TOA= 10.5 h, Urban/Plains Data Set D (see Bouville et al., this issue, this issue)			Pct. 75, TOA= 36.3 h, Rural/Mountains Data set B (see Bouville et al., this issue)		
RANK	Radio-nuclide	Fraction of total dose	Cumulative fraction of total dose	Radio-nuclide	Fraction of total dose	Cumulative fraction of total dose	Radio-nuclide	Fraction of total dose	Cumulative fraction of total dose
1	Np-239	0.29	0.29	U-237	0.55	0.55	Np-239	0.14	0.14
2	Te-132	0.07	0.37	Sr-89	0.18	0.73	Ba-140	0.14	0.28
3	Zr-97	0.07	0.44	Te-132	0.08	0.81	Te-132	0.13	0.41
4	Ba-140	0.07	0.51	Mo-99	0.06	0.87	La-140	0.10	0.50
5	U-237	0.06	0.57	Np-239	0.03	0.90	U-237	0.09	0.60
6	La-140	0.06	0.64	I-131	0.01	0.92	Ru-106	0.08	0.67
7	Ce-143	0.04	0.67	I-133	0.01	0.93	Ce-144/Pr-144	0.04	0.71
8	Y-92	0.04	0.71	Ba-140	0.01	0.94	Sr-89	0.03	0.74
9	Mo-99	0.03	0.74	La-140	0.01	0.95	Mo-99	0.03	0.78
10	Y-93	0.03	0.77	Ru-106	0.01	0.96	Ru-103/Rh-103m	0.03	0.81
11	Ru-106	0.03	0.80	Nd-147	0.01	0.97	Ce-143	0.03	0.83
12	Ce-144/Pr-144	0.02	0.83	Ru-103/Rh-103m	0.00	0.98	Zr-97	0.03	0.86
13	Sr-89	0.02	0.84	Zr-97	0.00	0.98	I-131	0.02	0.89
14	I-133	0.02	0.86	Ce-144/Pr-144	0.00	0.98	Pr-143	0.02	0.90
15	Nd-147	0.01	0.87	Pr-143	0.00	0.98	Nd-147	0.02	0.92
16	Ru-103/Rh-103m	0.01	0.89	Ce-143	0.00	0.99	I-133	0.01	0.93
17	Sr-91	0.01	0.90	Pm-149	0.00	0.99	Rh-105	0.01	0.94
18	Pm-149	0.01	0.91	Rh-105	0.00	0.99	Pm-149	0.01	0.96
19	I-131	0.01	0.92	Sb-127	0.00	0.99	Sb-127	0.01	0.97
20	Rh-105	0.01	0.93	Cs-137	0.00	0.99	Zr-95	0.01	0.97

	Inhalation + Resuspension								
	Pct. 581, TOA = 3.1 h, Rural/Mountains Data set B (see Bouville et al. 2020)			Pct. 13, TOA = 10.5 h, Urban/Plains Data Set D (see Bouville et al. 2020)			Pct. 75, TOA = 36.3 h, Rural/Mountains Data set B (see Bouville et al. 2020)		
Rank	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose
1	Np-239	0.26	0.26	Np-239	0.28	0.28	Np-239	0.39	0.39
2	Zr-97	0.14	0.41	Zr-97	0.13	0.41	Te-132	0.13	0.52
3	Y-93	0.10	0.50	Te-132	0.09	0.50	Zr-97	0.08	0.61
4	Sr-92	0.07	0.58	Y-93	0.07	0.57	Ba-140	0.06	0.66
5	La-141	0.05	0.62	Sr-91	0.05	0.62	Mo-99	0.05	0.72
6	Ce-143	0.04	0.66	Ce-143	0.04	0.66	Ce-143	0.05	0.76
7	Mo-99	0.04	0.70	Mo-99	0.04	0.70	U-237	0.04	0.80
8	Y-92	0.04	0.74	Ba-140	0.04	0.74	Rh-105	0.03	0.83
9	Sr-91	0.03	0.78	Y-92	0.03	0.77	Y-93	0.02	0.86

Continued next page

Table 3a. *(Continued)*

	Inhalation + Resuspension								
	Pct. 581, TOA = 3.1 h, Rural/Mountains Data set B (see Bouville et al. 2020)			Pct. 13, TOA = 10.5 h, Urban/Plains Data Set D (see Bouville et al. 2020)			Pct. 75, TOA = 36.3 h, Rural/Mountains Data set B (see Bouville et al. 2020)		
Rank	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose
10	Pr-145	0.03	0.81	Ru-105	0.02	0.79	Sr-91	0.02	0.87
11	Te-132	0.03	0.84	Rh-105	0.02	0.82	La-140	0.02	0.89
12	U-237	0.03	0.87	U-237	0.02	0.84	Ru-106	0.01	0.90
13	Ru-105	0.02	0.89	La-141	0.02	0.86	Pm-149	0.01	0.91
14	Ba-140	0.02	0.91	Pr-145	0.02	0.88	Sr-89	0.01	0.92
15	La-142	0.01	0.92	Sr-92	0.01	0.89	Te-131m	0.01	0.93
16	U-240	0.01	0.93	Sb-129	0.01	0.90	Sb-127	0.01	0.94
17	Sb-129	0.01	0.94	Pm-149	0.01	0.91	Ru-103/Rh-103m	0.01	0.95
18	Pm-149	0.01	0.94	Te-131m	0.01	0.92	Pr-143	0.01	0.95
19	Pm-151	0.01	0.95	U-240	0.01	0.93	Ce-144/Pr-144	0.01	0.96
20	Ce-144/Pr-144	0.01	0.96	Ru106	0.01	0.94	Nd-147	0.01	0.97

precincts each ethnic group resided in the county and the number of persons of that ethnic group present there.

The four panels of Fig. 5 graphically present the ranking of the 31 counties in terms of population-weighted total thyroid dose to adults for each of the four ethnicities. Dose distributions for Hispanic and White populations were similar. For most counties, average doses to Native Americans were lower than for other ethnic groups except for Torrance County. As can be seen, population age-weighted doses for each group ranged from small fractions of a mGy up to about 50–60 mGy for all ethnic groups but Native Americans. In Torrance County, the average dose for Native Americans was estimated to be about 80 mGy, though the census population data indicates there were only four Native American adults present in Torrance County and, therefore, that average may not be representative and should be considered with caution.

The four counties (Torrance, Guadalupe, Lincoln, and San Miguel) had the greatest thyroid doses primarily because of the greater depositions of fallout in each. While the Trinity test took place in Socorro county, the fallout pattern of Quinn (1987) illustrates that the deposition occurred to the northeast of the detonation site, primarily in other counties, resulting in average doses to Socorro county that were not extraordinarily large. Average doses to Native Americans reflected the counties and precincts that Native Americans resided in, which, for the most part, were not within the fallout pattern to any significant degree. Torrance County, relatively close to the Trinity detonation site, was an exception in that Native Americans lived in three precincts, including one in which the largest thyroid doses were received.

As an outcome of this analysis, we were able to estimate the population-weighted dose to residents of four counties suggested by TBDC (2017) to be at high radiation risk, and by inference, to have received higher radiation doses: Socorro, Lincoln, Otero, and Sierra. It should be noted that TBDC (2017) identified the health risk based on the findings from a health survey; however, health risk in the Tularosa Basin Downwinders Consortium (TBDC) report was not defined in conventional scientific terms as cases per 100,000 persons at risk but rather on the basis of the absolute number of reported cases—without reference to the size of the underlying population at risk. As the data on measurements of fallout exposure-rates (Quinn 1987) show a pattern of deposition that moved in a northwesterly direction from the Trinity test site in western Socorro county, it is reasonable to assume that the counties of Otero and Sierra would have received very low to negligible exposure and that the counties of Socorro, Lincoln, Torrance, Guadalupe, and San Miguel would likely have received the highest exposures. The data in Table 4 confirms that assumption. The few high dose precincts in Socorro (where Trinity was conducted) and Lincoln result in the relatively

Table 3b. Radionuclides at three locations that contribute at least 90% of the first-year internal dose to lung (Whites/Hispanics): ranking by their fractional contribution to dose.

	Ingestion								
	Pct. 581, TOA = 3.1 h, Rural/Mountains Data set B (see Bouville et al. 2020)			Pct. 13, TOA = 10.5 h, Urban/Plains Data Set D (see Bouville et al. 2020)			Pct. 75, TOA = 36.3 h, Rural/Mountains Data set B (see Bouville et al. 2020)		
Rank	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose
1	Np-239	0.29	0.29	Sr-89	0.32	0.32	Cs-137	0.33	0.33
2	Te-132	0.07	0.37	Mo-99	0.21	0.54	Te-132	0.21	0.54
3	Zr-97	0.07	0.44	Te-132	0.18	0.71	I-131	0.10	0.64
4	Ba-140	0.07	0.51	Cs-137	0.11	0.82	Mo-99	0.09	0.73
5	U-237	0.06	0.57	I-131	0.08	0.90	Ba-140	0.09	0.82
6	La-140	0.06	0.64	U-237	0.03	0.93	Sr-89	0.05	0.86
7	Ce-143	0.04	0.67	I-133	0.03	0.97	Ru-106	0.03	0.90
8	Y-92	0.04	0.71	Ba-140	0.01	0.98	La-140	0.03	0.92
9	Mo-99	0.03	0.74	Ru-106	0.01	0.98	I-133	0.02	0.94
10	Y-93	0.03	0.77	Sr-90	0.00	0.99	Ru-103/Rh-103m	0.01	0.96
11	Ru-106	0.03	0.80	La-140	0.00	0.99	Zr-95	0.01	0.97
12	Ce-144/Pr-144	0.02	0.83	Ru-103/Rh-103m	0.00	0.99	Np-239	0.00	0.97
13	Sr-89	0.02	0.84	Te-131m	0.00	0.99	Te-131m	0.00	0.98
14	I-133	0.02	0.86	Np-239	0.00	1.00	U-237	0.00	0.98
15	Nd-147	0.01	0.87	Zr-95	0.00	1.00	Sb-127	0.00	0.99
16	Ru-103/Rh-103m	0.01	0.89	Sb-127	0.00	1.00	Zr-97	0.00	0.99
17	Sr-91	0.01	0.90	I-135	0.00	1.00	Rh-105	0.00	0.99
18	Pm-149	0.01	0.91	Zr-97	0.00	1.00	Nb-95	0.00	0.99
19	I-131	0.01	0.92	Sr-91	0.00	1.00	Sr-91	0.00	0.99
20	Rh-105	0.01	0.93	Nd-147	0.00	1.00	Ce-143	0.00	0.99

	Inhalation + Resuspension								
	Pct. 581, TOA = 3.1 h, Rural/Mountains Data set B (see Bouville et al. 2020)			Pct. 13, TOA = 10.5 h, Urban/Plains Data Set D (see Bouville et al. 2020)			Pct. 75, TOA = 36.3 h, Rural/Mountains Data set B (see Bouville et al. 2020)		
Rank	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose
1	Np-239	0.39	0.39	Np-239	0.35	0.35	Np-239	0.39	0.39
2	U-237	0.08	0.47	Ba-140	0.09	0.44	Ba-140	0.11	0.49
3	Zr-97	0.05	0.52	Te-132	0.07	0.51	U-237	0.08	0.57
4	Ba-140	0.05	0.57	U-237	0.07	0.57	Te-132	0.07	0.64
5	Ce-144/Pr-144	0.04	0.62	Ru-106	0.06	0.63	Ru-106	0.07	0.71
6	Ce-143	0.04	0.65	Zr-97	0.04	0.67	Ce-144/Pr-144	0.04	0.74
7	Mo-99	0.03	0.69	Ce-144/Pr-144	0.03	0.70	Mo-99	0.03	0.77
8	Ru-106	0.03	0.71	Ce-143	0.03	0.73	Ru-103/Rh-103m	0.03	0.80
9	Y-93	0.03	0.74	Mo-99	0.03	0.76	Rh-105	0.03	0.83

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Table 3b. *(Continued)*

	Inhalation + Resuspension								
	Pct. 581, TOA = 3.1 h, Rural/Mountains Data set B (see Bouville et al. 2020)			Pct. 13, TOA = 10.5 h, Urban/Plains Data Set D (see Bouville et al. 2020)			Pct. 75, TOA = 36.3 h, Rural/Mountains Data set B (see Bouville et al. 2020)		
Rank	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose
10	Te-132	0.03	0.77	Ru-103/Rh-103m	0.02	0.78	Ce-143	0.02	0.85
11	Sr-92	0.03	0.79	Rh-105	0.02	0.81	Sr-89	0.02	0.88
12	La-141	0.03	0.82	Sr-89	0.02	0.83	Zr-97	0.02	0.90
13	Sr-91	0.02	0.83	Sr-91	0.02	0.85	Ce-141	0.02	0.92
14	Zr-95	0.02	0.85	Y-93	0.02	0.87	Zr-95	0.01	0.93
15	Ru-105	0.02	0.87	Ru-105	0.02	0.88	Nd-147	0.01	0.94
16	Y-92	0.02	0.88	Zr-95	0.01	0.90	Pr-143	0.01	0.95
17	Pr-145	0.01	0.90	Nd-147	0.01	0.91	Sb-127	0.01	0.96
18	Nd-147	0.01	0.91	Ce-141	0.01	0.92	Pm-149	0.01	0.97
19	La-142	0.01	0.92	La-141	0.01	0.93	Sr-91	0.01	0.97
20	Ru-103/Rh-103m	0.01	0.93	Y-92	0.01	0.94	La-140	0.00	0.98

high ranks of those two counties (Fig. 5) for Whites and Hispanics. According to the census, few Native Americans or African Americans, however, lived in high-fallout deposition precincts in Lincoln county, resulting in the very low position of Lincoln county for those ethnic groups. Organs other than thyroid would have received even lower doses. In contrast, the counties of Otero and Sierra received very little fallout deposition and almost no radiation exposure at all, giving them near zero estimated doses.

One further point about the location-specific dose estimates is important. It has been reported that there were a few dozens of ranches and farms within 64.4 km of the Trinity detonation site (LAHDRA 2009). In this analysis, we have not attempted to estimate doses received by persons living at specific ranch locations because (1) average doses were estimated for all precincts, so in theory, their doses have been estimated—at least approximately; (2) those people were presumably included in the census and, therefore, included in the risk projection; and finally, (3) any misclassification of dose for the persons living at these ranches and farms (because of their contamination) would not appreciably affect the risk projection for New Mexico because of the few numbers of people residing at each ranch or farm.

Validation

Validation in dose reconstruction is the process of using measurements of radiation dose, or measurements of quantities as close to dose as possible, to confirm model-based estimates of dose. Internal dose cannot be directly measured and, while it can be derived from bioassay measurements today, no such measurements were known to have been conducted among the public following Trinity. Measurements to validate external doses are less fraught with technical problems and thus are useful for purposes of validation or confirmation. In the case of the Trinity test in 1945, in addition to the post-shot monitoring data used by Quinn et al. (1987), there were film-badge data collected by the Los Alamos Scientific Laboratory (LASL) that can be used to examine the validity of our estimated external doses. That data is also useful to examine the validity of the published geographic footprint of the Quinn (1987)-based fallout pattern.

Hoffman (1945), in a summary of radiation monitor's field notes, provided data on environmental exposure in Roentgens (R) derived from blackening of x-ray film-badges. The badges had been sent to numerous towns and communities across New Mexico before 16 July 1945 to be returned in the days afterward. Exposure was determined by densitometer readings of films and using calibration films exposed to a known radiation source. Little information is available on how the film-badges were instructed to be deployed, though presumably, they were hung outdoors in

Table 3c. Radionuclides at three locations that contribute at least 90% of the first-year internal dose to active (red) bone marrow (Whites/Hispanics): ranking by their fractional contribution to dose.

	Ingestion								
	Pct. 581, TOA = 3.1 h, Rural/Mountains Data set B (see Bouville et al. 2020)			Pct. 13, TOA = 10.5 h, Urban/Plains Data Set D (see Bouville et al. 2020)			Pct. 75, TOA = 36.3 h, Rural/Mountains Data set B (see Bouville et al. 2020)		
Rank	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose
1	Sr-89	0.23	0.23	Sr-89	0.78	0.78	Sr-89	0.29	0.29
2	Ba-140	0.21	0.44	Mo-99	0.05	0.83	Ba-140	0.24	0.53
3	Te-132	0.13	0.56	U-237	0.05	0.87	Te-132	0.13	0.66
4	Mo-99	0.08	0.64	Te-132	0.04	0.91	Cs-137	0.08	0.74
5	Np-239	0.05	0.69	Sr-90	0.04	0.95	Mo-99	0.05	0.79
6	La-140	0.05	0.75	Ba-140	0.01	0.97	La-140	0.05	0.84
7	Cs-137	0.04	0.79	Cs-137	0.01	0.98	I-131	0.03	0.87
8	Zr-97	0.03	0.82	I-131	0.01	0.99	Ru-103/Rh-103m	0.02	0.89
9	Zr-95	0.02	0.84	I-133	0.00	0.99	Sr-90	0.02	0.91
10	I-131	0.02	0.86	La-140	0.00	0.99	Zr-95	0.02	0.92
11	Sr-91	0.02	0.88	Np-239	0.00	0.99	Np-239	0.01	0.94
12	I-133	0.02	0.90	Ru-103/Rh-103m	0.00	1.00	U-237	0.01	0.95
13	U-237	0.02	0.91	Zr-95	0.00	1.00	Ru-106	0.01	0.96
14	Ru-103/Rh-103m	0.01	0.93	Ru-106	0.00	1.00	I-133	0.01	0.97
15	Sr-90	0.01	0.94	Te-131m	0.00	1.00	Sb-127	0.01	0.98
16	I-135	0.01	0.95	Sb-127	0.00	1.00	Zr-97	0.01	0.98
17	Ce-143	0.01	0.95	Nd-147	0.00	1.00	Te-131m	0.00	0.99
18	Te-131m	0.01	0.96	Zr-97	0.00	1.00	Ce-143	0.00	0.99
19	Ru-106	0.01	0.97	Sr-91	0.00	1.00	Ce-144/Pr-144	0.00	0.99
20	Sb-127	0.01	0.97	Ce-143	0.00	1.00	Sr-91	0.00	0.99

	Inhalation + Resuspension								
	Pct. 581, TOA = 3.1 h, Rural/Mountains Data set B (see Bouville et al. 2020)			Pct. 13, TOA = 10.5 h, Urban/Plains Data Set D (see Bouville et al. 2020)			Pct. 75, TOA = 36.3 h, Rural/Mountains Data set B (see Bouville et al. 2020)		
Rank	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose
1	Np-239	0.38	0.38	Np-239	0.31	0.31	Np-239	0.36	0.36
2	Zr-97	0.09	0.46	Te-132	0.17	0.48	Te-132	0.21	0.57
3	Te-132	0.08	0.54	Ba-140	0.11	0.59	Ba-140	0.14	0.71
4	Ba-140	0.07	0.61	I-135	0.06	0.64	Zr-95	0.04	0.75
5	Zr-95	0.05	0.66	Zr-97	0.06	0.70	Ru-103/Rh-103m	0.04	0.79
6	I-135	0.05	0.71	I-133	0.05	0.75	Zr-97	0.03	0.82
7	La-142	0.04	0.75	Zr-95	0.03	0.79	I-133	0.03	0.85
8	Sr-92	0.03	0.79	Sr-91	0.03	0.82	La-140	0.02	0.86

Continued next page

Table 3c. *(Continued)*

	Inhalation + Resuspension								
	Pct. 581, TOA = 3.1 h, Rural/Mountains Data set B (see Bouville et al. 2020)			Pct. 13, TOA = 10.5 h, Urban/Plains Data Set D (see Bouville et al. 2020)			Pct. 75, TOA = 36.3 h, Rural/Mountains Data set B (see Bouville et al. 2020)		
Rank	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose
9	Sr-91	0.03	0.81	Ru-103/Rh-103m	0.03	0.85	I-131	0.01	0.88
10	I-133	0.02	0.84	Ru-105	0.02	0.87	U-237	0.01	0.89
11	Ru-105	0.02	0.86	Te-131m	0.01	0.88	Mo-99	0.01	0.91
12	Ru-103/Rh-103m	0.02	0.88	Mo-99	0.01	0.89	Te-131m	0.01	0.92
13	Mo-99	0.02	0.89	U-237	0.01	0.90	Ru-106	0.01	0.93
14	U-237	0.02	0.91	I-131	0.01	0.92	I-132	0.01	0.94
15	Ce-143	0.01	0.92	Ce-143	0.01	0.93	Ce-143	0.01	0.95
16	Sb-129	0.01	0.93	Sb-129	0.01	0.93	Sr-91	0.01	0.96
17	Ce-144/Pr-144	0.01	0.94	Ru-106	0.01	0.94	Rh-105	0.01	0.96
18	Te-131m	0.01	0.95	I-132	0.01	0.95	Ce-144/Pr-144	0.01	0.97
19	Y-92	0.01	0.95	Rh-105	0.01	0.96	I-135	0.01	0.98
20	I-131	0.00	0.96	Ce-144/Pr-144	0.01	0.96	Sb-127	0.00	0.98

reasonably open locations. Badges were returned to LASL by mail in the period from 17–23 July. More than 118 badges were deployed widely across the state. The exact number is difficult to determine because some were reported as lost. In this analysis, we used data on 118.

Hoffman (1945) reports that approximately 82% (n = 97) of the 118 badges gave readings of "background" dose. Though "background" was not well defined, it can be presumed that those badges gave no evidence of exposure from Trinity fallout. The precise background value was not reported, though it can be assumed to be less than 0.1 R[8] over the time-period when the badges were deployed, as some locations reported measurements of 0.1 R. About 8% (n = 9) were very low, just above background; i.e., 0.10 to 0.13 R. Another 7% (n = 8) were also quite low, i.e., within 3 times background or 0.23–0.34 R. A single badge (sent to Pedernal, a present-day uninhabited town in Torrance County) gave a reading within 7 times background (0.68 R), i.e., a medium exposure level. Finally, 3% (n = 3) of the badges deployed directly northeast of the detonation site had readings significantly greater than all others, from 3.3 to 8.2 R. A review of the estimated exposures from our dose estimation calculations indicated that about 5.8% of the 721 precincts across the state received an accumulated exposure in the six days following Trinity of 3.3 R or greater, similar in magnitude to the 3% fraction of badges that reported exposures greater than 3.3 R.

The geographic locations of the film-badges, colored by their approximate exposure, are presented in Fig. 6 along with the H+12 exposure isopleths derived from Quinn (1987). The large number of "background" measurements, widely distributed throughout the state, confirms that only very low exposures were likely received by people resident outside of the presumed fallout pattern. Moreover, there were no readings of significance south of the detonation site, and the only high readings were in the very center of the isopleths where the H+12 exposure rate was thought to be several thousand times greater than the exposure rates on the periphery of the pattern. These findings provide a moderately high degree of confidence in the fallout pattern used as the basis for this dose reconstruction, and therefore, we conclude that the pattern boundaries appear quite reasonable.

Uncertainty

Clearly the estimation of exposures received more than 70 y ago is fraught with uncertainties. In this work, contemporary interviews on diet and lifestyle data, benchmarked against historical reports and compendia on nutrition and dietary habits, allowed estimates of doses to be made that are the best possible today. Variability of dietary data collected from the small groups interviewed, while recorded and

[8] 0.1 R = 100 mR ≅ 87.7 mrad to air = 0.88 mGy to air.

Table 3d. Radionuclides at three locations that contribute at least 90% of the first-year internal dose to stomach (Whites/Hispanics): ranking by their fractional contribution to dose.

	Ingestion								
	Pct. 581, TOA = 3.1 h, Rural/Mountains Data set B (see Bouville et al. 2020)			Pct. 13, TOA = 10.5 h, Urban/Plains Data Set D (see Bouville et al. 2020)			Pct. 75, TOA = 36.3 h, Rural/Mountains Data set B (see Bouville et al. 2020)		
Rank	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose
1	Y-92	0.19	0.19	U-237	0.42	0.42	La-140	0.12	0.12
2	Np-239	0.17	0.36	Sr-89	0.18	0.59	Np-239	0.12	0.24
3	Zr-97	0.06	0.42	Mo-99	0.11	0.71	Te-132	0.11	0.35
4	La-140	0.05	0.47	Te-132	0.08	0.79	Ba-140	0.07	0.42
5	Y-93	0.05	0.52	I-133	0.07	0.85	U-237	0.06	0.49
6	I-133	0.05	0.57	I-131	0.04	0.89	Mo-99	0.06	0.55
7	Te-132	0.04	0.61	Np-239	0.03	0.92	I-131	0.06	0.61
8	Mo-99	0.04	0.65	Cs-137	0.01	0.93	Cs-137	0.05	0.66
9	U-237	0.03	0.68	La-140	0.01	0.94	I-133	0.05	0.71
10	La-141	0.03	0.71	Ba-140	0.01	0.95	Ru-106	0.05	0.76
11	I-135	0.03	0.74	Ru-106	0.01	0.96	Zr-97	0.03	0.79
12	Sr-91	0.03	0.76	Y-92	0.01	0.96	Sr-89	0.03	0.82
13	Ba-140	0.03	0.79	Nd-147	0.01	0.97	Ce-143	0.03	0.85
14	Ce-143	0.03	0.81	Zr-97	0.00	0.97	Ru-103/Rh-103m	0.03	0.87
15	Pr-145	0.02	0.83	Ru-103/Rh-103m	0.00	0.98	Ce-144/Pr-144	0.01	0.89
16	I-131	0.02	0.85	Ce-143	0.00	0.98	Rh-105	0.01	0.90
17	Ru-105	0.02	0.86	Y-93	0.00	0.98	Pr-143	0.01	0.91
18	Ru-106	0.01	0.88	Pm-149	0.00	0.98	Nd-147	0.01	0.92
19	Cs-137	0.01	0.89	Rh-105	0.00	0.98	Y-93	0.01	0.93
20	Sr-89	0.01	0.90	Pr-143	0.00	0.99	Pm-149	0.01	0.94

	Inhalation + Resuspension								
	Pct. 581, TOA = 3.1 h, Rural/Mountains Data set B (see Bouville et al. 2020)			Pct. 13, TOA = 10.5 h, Urban/Plains Data Set D (see Bouville et al. 2020)			Pct. 75, TOA = 36.3 h, Rural/Mountains Data set B (see Bouville et al. 2020)		
Rank	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose
1	La-142	0.12	0.12	Np-239	0.12	0.12	Np-239	0.28	0.28
2	La-141	0.11	0.23	Y-92	0.10	0.22	Te-132	0.12	0.39
3	Y-92	0.11	0.34	Zr-97	0.08	0.30	Zr-97	0.09	0.48
4	Np-239	0.09	0.42	Y-93	0.08	0.38	Ba-140	0.08	0.56
5	Y-93	0.08	0.50	La-141	0.07	0.45	I-133	0.05	0.60
6	Zr-97	0.07	0.57	Sr-91	0.07	0.52	Y-93	0.04	0.64
7	Sr-92	0.07	0.64	Ru-105	0.06	0.57	Mo-99	0.04	0.68
8	Pr-145	0.05	0.69	Te-132	0.05	0.62	Ce-143	0.04	0.72
9	Ba-139	0.04	0.73	I-135	0.05	0.67	Sr-91	0.03	0.75

Continued next page

Table 3d. *(Continued)*

	Inhalation + Resuspension								
	Pct. 581, TOA = 3.1 h, Rural/Mountains Data set B (see Bouville et al. 2020)			Pct. 13, TOA = 10.5 h, Urban/Plains Data Set D (see Bouville et al. 2020)			Pct. 75, TOA = 36.3 h, Rural/Mountains Data set B (see Bouville et al. 2020)		
Rank	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose
10	Ru-105	0.04	0.77	I-133	0.04	0.72	Rh-105	0.03	0.78
11	Sr-91	0.03	0.80	Pr-145	0.03	0.75	I-132	0.03	0.80
12	I-135	0.02	0.82	Ba-140	0.03	0.78	U-237	0.02	0.83
13	Nd-149	0.02	0.84	Sb-129	0.02	0.80	Ru-103/ Rh-103m	0.02	0.85
14	Ce-143	0.02	0.85	Ce-143	0.02	0.82	La-140	0.02	0.87
15	Sb-129	0.01	0.87	Sr-92	0.02	0.84	Zr-95	0.02	0.88
16	Rb-88	0.01	0.88	Mo-99	0.02	0.86	I-135	0.01	0.89
17	Te-132	0.01	0.89	Rh-105	0.01	0.87	Te-131m	0.01	0.90
18	Mo-99	0.01	0.91	Rb-88	0.01	0.88	Ru-106	0.01	0.91
19	I-133	0.01	0.92	Te-129	0.01	0.89	Ag-112	0.01	0.92
20	Ba-140	0.01	0.93	I-132	0.01	0.90	Pm-149	0.01	0.93

considered, does not in itself adequately capture the uncertainty on the mean data value, the reasons being the limitations of the sample of persons in terms of number of persons and quality of memory recall. Hence, an uncertainty analysis based only on statistical distributions of variability was not reasonable. In this work, we conducted an uncertainty analysis using Monte Carlo methods using data-supported but judgement-based probability distributions that quantify our degree-of-belief in the mean values of the parameters used.

Using the aforementioned strategy, we derived uncertainty factors that can be either applied to county-specific best estimate doses (i.e., those provided in the Appendix) or, as in this study, used to propagate uncertainty into the risk projection (Cahoon et al. 2020). Under conventional uncertainty analysis paradigms, variances or geometric standard deviations (GSDs) of log-normally distributed input parameters for dose models are used to derive "uncertainty distributions" that could be used to derive statistical confidence levels. In this work, however, we use the term "uncertainty factors" as we want to make the important distinction that these estimates are not parameters of precise statistical distributions because of the large degree of subjectivity involved in their derivation.

Because the total number of dose calculations we made for the 721 precincts, 63 radionuclides, 13 exposure pathways, 6 data sets, 7 age groups, and 5 organs was large (~124 million), we determined it was not feasible to conduct Monte Carlo simulations for every combination of parameters. For that reason, we conducted the uncertainty analysis with a simplified strategy that we believe represented an adequate cross-section of the combinations of exposure condition such that the findings could be generalized.

TOA, which is an important parameter in the calculation of deposition densities of fallout radionuclides, varied across New Mexico from about 1 h to about 40 h. Because of its importance, we chose precincts at three locations in the Quinn pattern (*L1, L2,* and *L3*) that we determined were representative of ranges of TOAs (*L1* for close-in locations with a TOA of about 3 h or less; *L2* for mid-distance locations with a TOA from 3 h to about 10.5 h, and *L3* for a far-field locations with a TOA of about from 10.5 to about 36 h), plus two locations outside the Quinn fallout pattern where we had estimated the $\dot{X}(12)$ to be 0.05 mR h^{-1} (*L4* was for TOA of 10–25 h and $\dot{X}(12)$ = 0.05 mR h^{-1} and *L5* was for TOA of 25–40 h).

At the locations chosen for simulation, we modeled the uncertainty of the external dose relative to the central best estimate by assigning probability density functions (PDFs) presented in Bouville et al. (2020) for the external dose model parameters normalized to the best estimate. Similarly, we modeled the uncertainty of the internal dose by assigning PDFs (also from Bouville et al. 2020) to those radionuclides that accounted for at least 80% of the internal dose

Table 3e. Radionuclides at three locations that contribute at least 90% of the first-year internal dose to thyroid (Whites/Hispanics): ranking by their fractional contribution to dose.

	Ingestion								
	Pct. 581, TOA = 3.1 h, Rural/Mountains Data set B (see Bouville et al. 2020)			Pct. 13, TOA = 10.5 h, Urban/Plains Data Set D (see Bouville et al. 2020)			Pct. 75, TOA = 36.3 h, Rural/Mountains Data set B (see Bouville et al. 2020)		
Rank	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose
1	I-131	0.71	0.71	I-131	0.80	0.80	I-131	0.86	0.86
2	I-133	0.20	0.90	I-133	0.14	0.94	I-133	0.08	0.93
3	Te-132	0.07	0.97	Te-132	0.06	1.00	Te-132	0.06	1.00
4	I-135	0.02	0.99	Te-131m	0.00	1.00	Te-131m	0.00	1.00
5	Te-131m	0.00	1.00	Sr-89	0.00	1.00	I-135	0.00	1.00
6	Cs-137	0.00	1.00	I-135	0.00	1.00	Cs-137	0.00	1.00
7	Te1-33m	0.00	1.00	Mo-99	0.00	1.00	Mo-99	0.00	1.00
8	Mo-99	0.00	1.00	Cs-137	0.00	1.00	Ba-140	0.00	1.00
9	Ba-140	0.00	1.00	U-237	0.00	1.00	Sr-89	0.00	1.00
10	Tc-99m	0.00	1.00	Ba-140	0.00	1.00	Ru-106	0.00	1.00
11	I-132	0.00	1.00	Ru-106	0.00	1.00	I-132	0.00	1.00
12	Sr-89	0.00	1.00	Sr-90	0.00	1.00	Tc-99m	0.00	1.00
13	Ru-106	0.00	1.00	I-132	0.00	1.00	Ru-103/Rh-103m	0.00	1.00
14	Sr-91	0.00	1.00	Ru-103/Rh-103m	0.00	1.00	Zr-95	0.00	1.00
15	Zr-95	0.00	1.00	Tc-99m	0.00	1.00	La-140	0.00	1.00
16	Ru-103/Rh-103m	0.00	1.00	Zr-95	0.00	1.00	Sb-127	0.00	1.00
17	La-140	0.00	1.00	Sb-127	0.00	1.00	U-237	0.00	1.00
18	Zr-97	0.00	1.00	La-140	0.00	1.00	Rh-105	0.00	1.00
19	Sb-127	0.00	1.00	Sr-91	0.00	1.00	Sr-91	0.00	1.00
20	Sr-92	0.00	1.00	Rh-105	0.00	1.00	Sr-90	0.00	1.00

	Inhalation + Resuspension								
	Pct. 581, TOA = 3.1 h, Rural/Mountains Data set B (see Bouville et al. 2020)			Pct. 13, TOA = 10.5 h, Urban/Plains Data Set D (see Bouville et al. 2020)			Pct. 75, TOA = 36.3 h, Rural/Mountains Data set B (see Bouville et al. 2020)		
Rank	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose
1	I-133	0.46	0.46	I-133	0.50	0.50	I-131	0.55	0.55
2	I-131	0.26	0.72	I-131	0.32	0.82	I-133	0.37	0.92
3	I-135	0.22	0.94	I-135	0.14	0.96	Te-132	0.04	0.96
4	Te-133m	0.02	0.96	Te-132	0.03	0.99	I-135	0.02	0.98
5	Te-132	0.02	0.99	I-132	0.01	0.99	I-132	0.01	0.99
6	I-132	0.01	0.99	Te-131m	0.00	1.00	Te-131m	0.00	1.00
7	Te-131m	0.00	1.00	Ba-140	0.00	1.00	Ba-140	0.00	1.00
8	Np-239	0.00	1.00	Np-239	0.00	1.00	Np-239	0.00	1.00
9	Ba-140	0.00	1.00	Zr-97	0.00	1.00	Zr-95	0.00	1.00

Continued next page

Table 3e. *(Continued)*

	Inhalation + Resuspension								
	Pct. 581, TOA = 3.1 h, Rural/Mountains Data set B (see Bouville et al. 2020)			Pct. 13, TOA = 10.5 h, Urban/Plains Data Set D (see Bouville et al. 2020)			Pct. 75, TOA = 36.3 h, Rural/Mountains Data set B (see Bouville et al. 2020)		
Rank	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose	Radionuclide	Fraction of total dose	Cumulative fraction of total dose
10	Zr-97	0.00	1.00	Zr-95	0.00	1.00	Zr-97	0.00	1.00
11	Zr-95	0.00	1.00	Sr-91	0.00	1.00	La-140	0.00	1.00
12	La-142	0.00	1.00	Ru-105	0.00	1.00	Ru-106	0.00	1.00
13	Sr-92	0.00	1.00	Te-133m	0.00	1.00	U-237	0.00	1.00
14	Sr-91	0.00	1.00	Ru-106	0.00	1.00	Mo-99	0.00	1.00
15	Ru-105	0.00	1.00	Mo-99	0.00	1.00	Ce-143	0.00	1.00
16	U-237	0.00	1.00	U-237	0.00	1.00	Sr-91	0.00	1.00
17	Mo-99	0.00	1.00	Sb-129	0.00	1.00	Rh-105	0.00	1.00
18	Ce-143	0.00	1.00	Ce-143	0.00	1.00	Cs-137	0.00	1.00
19	Sb-129	0.00	1.00	Rh-105	0.00	1.00	Sb-127	0.00	1.00
20	Ru-106	0.00	1.00	Sr-92	0.00	1.00	Ce-141	0.00	1.00

(sometimes as much as 96%). Similar to the calculations for external dose, we modeled the uncertainty of the internal dose by assigning PDFs to the internal dose model parameters normalized to the best estimate. As described here, we conducted Monte Carlo simulations of doses for five pathways: external dose, ingestion dose from milk, ingestion dose from leafy vegetables, and doses from inhalation and resuspension. This analysis was limited to adults and extrapolated to other ages.

Our initial simulations confirmed that because the inhalation and resuspension doses are so small compared to the external and ingestion doses, their uncertainty contributes very little to the overall dose uncertainty. For that reason, those pathways were not simulated further. The overall uncertainty was determined primarily by the most important contributors to the organ dose: external irradiation and ingestion of milk and leafy vegetables.

Each Monte Carlo simulation for external and internal dose, run for 50,000 iterations (separately), produced a data set for each organ and location that closely fit a log-normal distribution. From each simulated dose data set, we derived a geometric standard deviation (GSD) by fitting a log-normal type distribution and calculating the GSD from the median, mean, and variance using standard statistical formulae. From the external and internal dose GSD values, the GSD of the total dose (external + internal) distribution was derived and the square of the GSD was assigned the term of "uncertainty factor." The lower credible dose was found by the best estimate of dose at each county divided by the uncertainty factor (i.e., best estimate of dose/GSD^2), while the upper end credible dose was found by the best estimate of dose multiplied by the uncertainty factor (best estimate of dose $\times$ GSD^2). Based on well-known statistical properties for log-normal distributions, the range from the lower credible dose to the upper credible dose would encompass 95% of the simulated values (i.e., from the 2.5% to 97.5%).

Table 4 presents the uncertainty factors derived for external doses and internal doses at the precinct locations that we generalized to other locations with similar TOAs. That is, the uncertainty factors were assigned to all locations with the same attributes of TOA as in the simulations: (1) TOA of 1–10 h, (2) TOA of 10–25 h, (3) TOA of 25–40 h, (4), TOA of 10–25 h and $\dot{X}(12) = 0.05$ mR h^{-1}, and (5) TOA of 25–40 h and $\dot{X}(12) = 0.05$ mR h^{-1}.

The derived uncertainty factors, presented in Table 4, are in the range from 2.5 to 3.0 for all external dose estimates at all precinct locations. Uncertainty factors for internal dose varied by organ and with TOA, with the largest uncertainty factors being for lung and thyroid at close-in locations and for stomach and thyroid at distant locations (see Table 4 for all values). As an example, the uncertainty factors for thyroid dose were estimated to be the largest

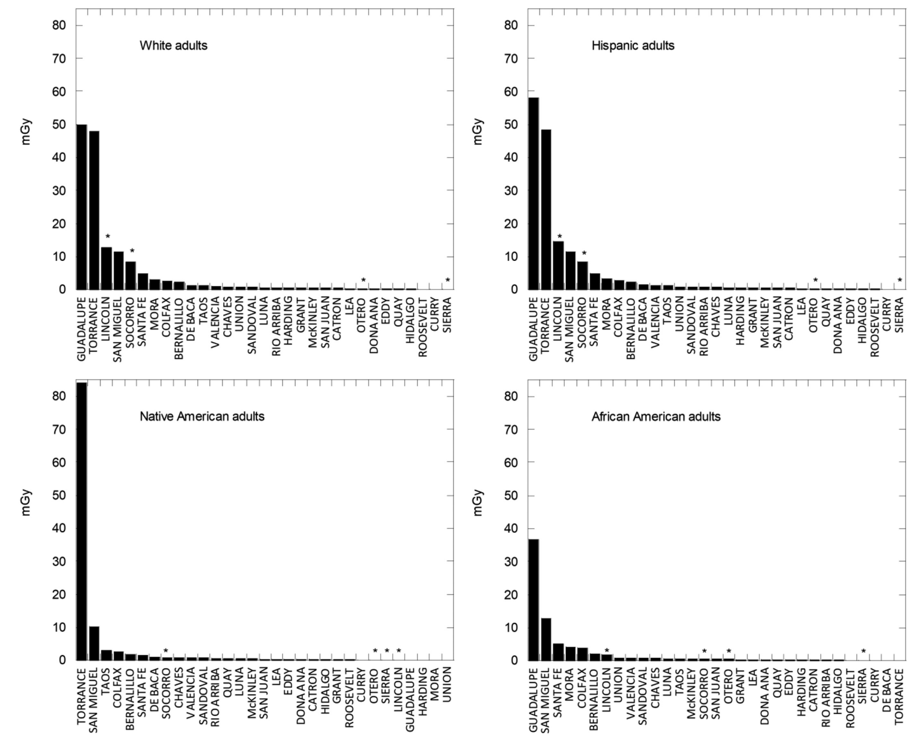

Fig. 5. Ordering (left to right) of counties by magnitude of population-weighted average doses to the thryoid gland of adults. Top panels (left to right): Whites, Hispanic. Bottom panels (left to right): Native Americans, African Americans. For discussion on Native Amerian doses in Torrance County, see section on "Comparison of county average doses." Four counties with asterisks (*) are those identified as "high risk" (and presumably, "high dose" counties) by TBDC (2017).

(~12.5) for the precincts closest to the detonation site (TOA of <10 h), the smallest (~8.3) for precincts at TOA from 10 to 25 h, and intermediate (~10.6) for precincts with TOA>25 h. Uncertainties well outside the pattern were similar to the estimated values inside the pattern because the uncertainty was dominated by factors other than the exposure rate and TOA. The uncertainty factors for the combined external and internal doses varied depending on the magnitude of the external and internal doses relative to one another. Fig. 7 illustrates cumulative distributions of lower credible doses, best estimates of dose, and upper credible doses for adults at each of the 721 precincts, derived by the strategy described.

The modestly larger uncertainty for the thyroid gland compared to other organs is a mathematical outcome of two conditions. First, the milk pathway model has a larger number of uncertain parameters, e.g., feed-to-milk transfer coefficients (Bouville et al. 2020). Second, the thyroid dose is nearly 100% contributed by only two or three radionuclides (see Table 3e), whereas doses to other organs have significant partial dose contributions by up to 20 radionuclides. In the Monte Carlo simulation, the uncertainty distributions for each radionuclide must be summed in proportion to their contribution to the total dose. A larger number of components in the sum results in a narrower distribution of the sum distribution.

Context on the magnitude of estimated doses

While the findings of cancer risks in the analysis of Cahoon et al. (2020) are the most important metric of health impact from this study, it is useful to have an understanding of the magnitude of exposures received in New Mexico from Trinity and other sources of nuclear testing fallout as well as from natural sources. For this analysis, we provide individual county estimates of air kerma (integral over one year) and ^{137}Cs deposition density (Bq m^{-2}) from Trinity, Nevada Test Site (NTS), and global fallout. Air kerma is used to normalize the comparison without the introduction of building shielding and age-dependent dose factors. The findings are presented in Table 5 (including NTS and global fallout data derived from US DHHS 2005).

As can be seen in Table 5, the 1-y integral air kerma (the primary determinant of external dose to man) from Trinity was very heterogeneous across New Mexico, with county average values differing by almost 1,300-fold, from 0.018 to 23 mGy with a coefficient of variation (CV = standard deviation/mean) of 2.8, implying that the distribution was highly positively skewed with a standard deviation equal to 2.8 times the mean value. In contrast, the CV was much smaller for NTS fallout, about 0.5, and even more homogeneous for global weapons testing fallout with a CV of 0.3. The magnitudes of the average value of air kerma among the counties for Trinity, NTS, and global fallout were

Table 4. Derived uncertainty factors (GSD^2) for external and internal dose for five representative locations (L1 = TOA of 3.1 h, L2 = TOA of 10.5 h, L3 = TOA of 36.3 h, L4 = TOA>10 h, and $\dot{X}(12)$ of 0.05 (i.e., "outside the fallout pattern") and L5 = TOA of 25–40 h and $\dot{X}(12)$ of 0.05 (i.e., "outside the fallout pattern").

Location	TOA and $\dot{X}(12)$	Uncertainty factors from simulation
External Dose		
L1	TOA=1–10 h	3.0
L2 & L3	TOA>10 h	2.5
L4 & L5 (outside fallout pattern)	$\dot{X}(12)$=0.05 and TOA>10 h	2.8
Internal Dose		
COLON		
L1	TOA=1–10 h	8.9
L2	TOA=10–25 h	4.8
L3	TOA=25–40 h	6.9
L4	TOA=10–25 h	4.8
L5	TOA=25–40 h	6.9
LUNG		
L1	TOA=1–10 h	10.7
L2	TOA=10–25 h	3.3
L3	TOA=25–40 h	4.7
L4	TOA=10–25 h	3.3
L5	TOA=25–40 h	4.7
RBM		
L1	TOA=1–10 h	8.9
L2	TOA=10–25 h	5.9
L3	TOA=25–40 h	7.2
L4	TOA=10–25 h	5.9
L5	TOA=25–40 h	7.2
STOMACH		
L1	TOA=1–10 h	9.6
L2	TOA=10–25 h	4.8
L3	TOA=25–40 h	7.8
L4	TOA=10–25 h	4.8
L5	TOA=25–40 h	7.8
THYROID		
L1	TOA=1–10 h	12.5
L2	TOA=10–25 h	8.3
L3	TOA=25–40 h	10.6
L4	TOA=10–25 h	8.3
L5	TOA=25–40 h	10.6

quite similar with mean values over the counties of 1.6, 2.5, and 1.1 mGy. However, because of the wide variation for Trinity fallout, the median of the county values for Trinity fallout was only 0.071 mGy compared to 2.7 and 1.1 mGy for NTS and global fallout. As expected from a visual inspection of the Trinity fallout pattern, dose to air (kerma) from fallout was very heterogeneous, with a much smaller median value and a greater maximum value than from fallout from NTS or global fallout. The variations of ^{137}Cs ground deposition density from Trinity, NTS, and global fallout were similar to the variations of air kerma. The CVs for Trinity, NTS, and global fallout were 2.7, 0.52, and 0.30, respectively.

The general finding from this analysis is that the statewide-average air kerma over the 31 counties from Trinity, NTS, and global fallout were similar (1.6, 2.5, 1.1 mGy, respectively), though because the heterogeneity was much greater for Trinity, there were counties with much lower and higher values than the mean value, a situation which did not occur to any significant extent for NTS and global fallout. The statewide median values of air kerma for NTS and global fallout were 10 to 20 times greater than the median for Trinity. While the heterogeneity of ^{137}Cs deposition density estimates, as assessed by CVs, was similar to that of air kerma, the relationships between mean values as well as median values for Trinity, NTS, and global fallout were different than for air kerma (see Table 5). For example, the statewide mean ^{137}Cs deposition density for NTS and global fallout were about 3-fold and 25-fold greater, respectively, than the statewide mean value for Trinity fallout, and the statewide median ^{137}Cs deposition density for NTS and global fallout was about 28-fold and 244-fold, respectively, greater than the statewide median value for Trinity fallout. The different relationships for ^{137}Cs deposition density and air kerma are not surprising given that ^{137}Cs does not provide a large contribution to the integral air kerma, particularly in the first few months when air kerma is greatest.

In summary, Trinity, as might be expected, resulted in a very heterogeneous deposition pattern across New Mexico where, in some locations, the air kerma exceeded the maximum values from NTS and global fallout even though it was similar on a statewide average basis. In contrast, global fallout deposition of ^{137}Cs was much more homogeneous across the state and was much greater at most individual locations, as well as for a statewide average, than from either NTS or Trinity fallout.

It is also interesting to compare the thyroid doses resulting from the three sources of fallout, because the doses to the thyroid are greater than the doses to any other organ. For that comparison, it is important to realize that the birth cohorts exposed to Trinity fallout and the peak years of NTS and global fallout were not the same. Most residents of New Mexico who were in childhood at the time of Trinity were adults at the time of NTS or global atmospheric weapons testing. Because of the strong age-dependency of the doses to the thyroid, the comparison of the thyroid doses is easiest for the persons who were exposed as adults at the time of Trinity and of NTS and global testing. Taking as examples three counties that were exposed to high (Guadalupe), moderate (San Miguel), and small amounts (Bernalillo) of Trinity fallout, one can see that the estimated adult thyroid dose to the residents of Guadalupe county (about 50 mGy) was substantially greater than the thyroid doses from NTS fallout (30 mGy) and from global fallout

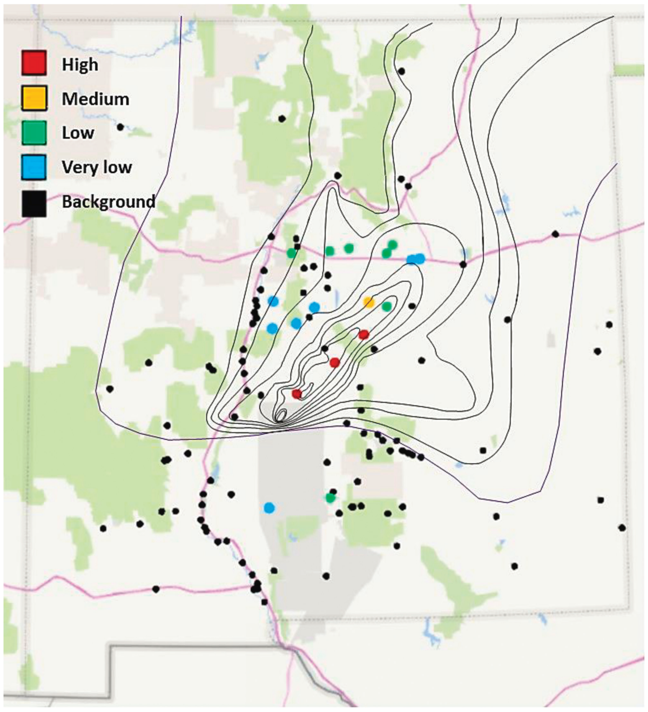

Fig. 6. Results of exposure measurements from Los Alamos Scientific Laboratory (Hoffman 1945) using x-ray film badges deployed in communities across the state before the Trinity detonation.

(9 mGy). In San Miguel county, the thyroid dose from Trinity (10 mGy) was smaller than the dose from NTS fallout (30 mGy) and approximately equal to the dose from global fallout (10 mGy). In Bernalillo county, the thyroid dose from Trinity (2 mGy) was smaller than both the dose from NTS fallout (10 mGy) and the dose from global fallout (3 mGy). Taking the entire state of New Mexico into consideration, the largest component of the dose to the thyroid gland was from fallout from NTS tests, though for nine counties, thyroid doses were dominated by exposure to fallout from Trinity.

While comparison of Trinity exposures with NTS and global fallout are useful, it is also informative to compare Trinity exposures with other sources of radiation. Here we restrict our comparison to natural background radiation because both Trinity and background radiation can be assumed to be an involuntary exposure.

New Mexico, with an average elevation of 5,700 ft, is the fourth highest state[9] on average and hence has a higher cosmic-ray exposure rate than most other states. As well, it has significant mineral deposits, typical of the Rocky Mountains, which leads to increased natural radiation exposure from the terrestrial environment, including both gamma radiation and radon. According to Brookins (1992), the terrestrial background and cosmic ray components of natural radiation received by Albuquerque residents (as a representation of New Mexico residents) are about 0.6 and 0.8 mSv per year, respectively, corresponding to about 1.4 mGy in terms of annual whole-body dose.

As a comparison, the statewide average air kerma for Trinity was about 1.4 mGy, similar in magnitude to the gamma-ray component of natural background radiation, though it varied considerably by county from 0.018 to 23

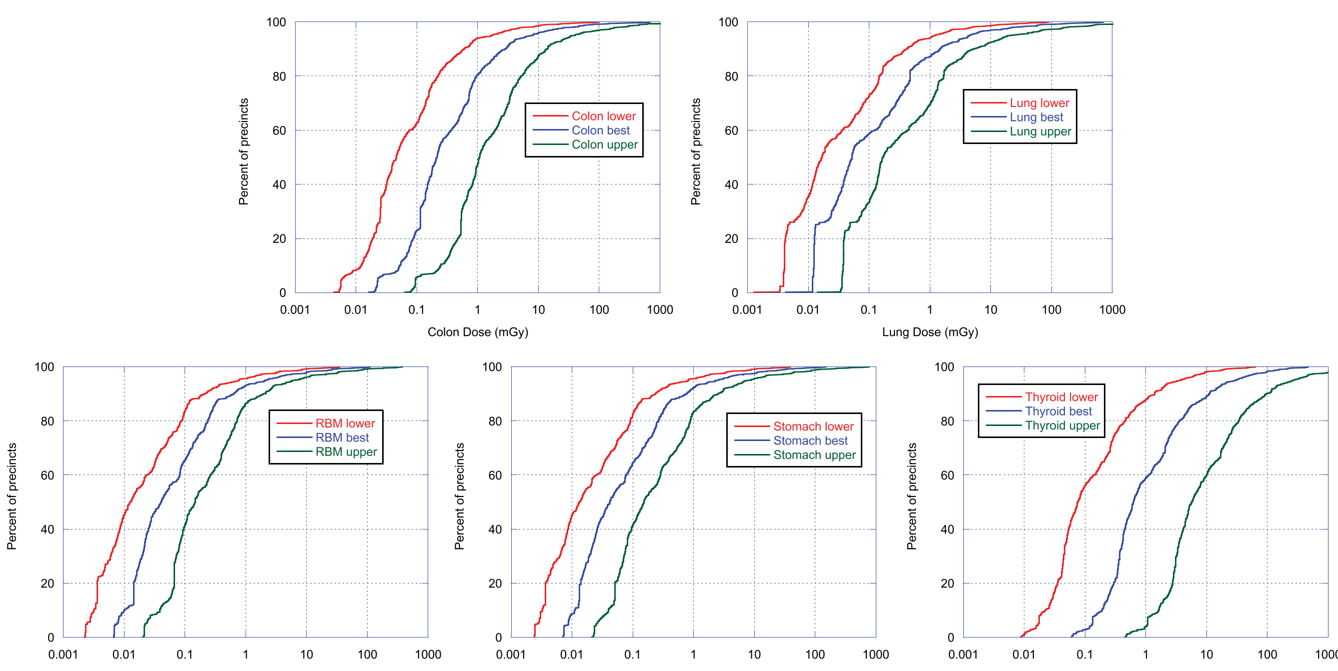

Fig. 7. Cumulative distributions of lower credible doses, best estimates of dose, and upper credible doses for adults at each of the 721 precincts.

[9]http://www.netstate.com/states/geography/mapcom/nm_mapscom.htm.

Table 5. Comparison of estimated integral air kerma in 1945 (mGy) and ^{137}Cs deposition density (Bq m^{-2}) by counties in New Mexico from three sources of nuclear testing fallout (TRINITY, Nevada Test Site, and global fallout). NTS and global fallout data taken from US DHHS (2005). TRINITY values are population weighted values derived from precinct estimates. All values rounded to two significant digits.

County	Integral air kerma (mGy) Trinity (1945)	Integral air kerma (mGy) NTS (1951–1963)	Integral air kerma (mGy) Global fallout (1953–2000)	^{137}Cs (Bq m^{-2}) Trinity (1945)	^{137}Cs (Bq m^{-2}) NTS (1951–1963)	^{137}Cs (Bq m^{-2}) Global fallout (1953–2000)
Bernalillo	0.14	4.0	1.4	12	380	2,800
Catron	0.039	1.7	0.91	3.3	150	1,800
Chaves	0.12	2.9	0.95	12	270	1,900
Colfax	0.61	2.8	1.6	73	260	3,400
Curry	0.022	2.4	1.3	2.4	230	2,800
De Baca	0.25	2.5	0.99	23	240	2,000
Dona Ana	0.019	0.66	0.65	2.0	55	1,200
Eddy	0.019	1.2	0.95	2.0	110	1,899
Grant	0.019	0.76	1.1	2.0	63	2,100
Guadalupe	10	3.0	1.0	810	280	2,000
Harding	0.065	2.6	1.5	7.1	250	3,300
Hidalgo	0.019	0.68	0.84	2.0	56	1,600
Lea	0.019	1.1	1.1	2.0	100	2,200
Lincoln	7.9	2.8	1.1	170	270	2,200
Luna	0.019	0.71	0.74	2.0	59	1,300
McKinley	0.023	5.6	1.0	2.3	530	2,100
Mora	0.60	2.8	1.6	64	260	3,500
Otero	0.019	0.76	1.1	2.0	67	2,200
Quay	0.056	2.7	1.6	5.5	250	3,300
Rio Arriba	0.089	2.8	1.3	9.9	260	2,600
Roosevelt	0.022	2.3	1.1	2.4	220	2,400
Sandoval	0.090	4.9	1.2	8.6	460	2,500
San Juan	0.018	3.5	0.76	2.2	330	1,500
San Miguel	1.2	2.9	1.4	110	270	3,000
Santa Fe	0.37	4.1	1.2	36	380	2,500
Sierra	0.022	1.1	0.86	2.0	93	1,600
Socorro	5.2	2.0	0.74	72	190	1,500
Taos	0.23	2.5	1.3	26	240	2,600
Torrance	23	4.0	0.97	880	380	1,900
Union	0.071	2.7	1.6	8.7	250	3,500
Valencia	0.12	4.4	0.59	10	410	1,200
Minimum =	0.018	0.66	0.59	2.0	55	1,200
Maximum =	23	5.6	1.6	880	530	3,500
Mean =	1.6	2.5	1.1	76	240	2,300
Median =	0.071	2.7	1.1	8.6	250	2,200
Coefficient of Variation =	2.8	0.51	0.27	2.7	0.52	0.30

mGy. This comparison suggests that the whole-body dose to Trinity fallout as an external source of radiation, on *average* for the whole state (~1.4 mGy), was about equal to the annual whole-body dose from the external component of natural background radiation. It can also be viewed that Trinity fallout resulted in an incremental increase (28% to 47%) in the average total dose (Trinity + natural background) of New Mexico residents alive at that time. The main differences for Trinity fallout, however, compared to natural radiation exposure were the much greater internal doses to the thyroid because of the importance of radioiodine in fallout, whereas radioiodine does not contribute to the internal dose from natural background.

Tabular values for archival purpose

Appendix Tables 1 through 4 and their sub-tables provide numerical values of population-weighted best estimates of organ doses by ethnicity and age for use in other studies and for archival purposes. For example, Appendix Table A1a–e provides doses for White ethnicity to colon, lung, active (red) bone marrow, stomach, and thyroid, respectively. Tables A2a–e, A3a–e, and A4a–e provide the doses to the same organs for Native Americans, Hispanics, and African Americans, respectively. The weighted value for each county considers the fraction of the county's total population in each of its precincts and the radiation doses estimated for each precinct.

It is important to recognize that the deposition and the dose estimates provided in the Appendix for counties well outside the central part of the fallout pattern appear to be relatively homogeneous across the county. Therefore, individual precincts in those counties would likely have doses quite close to the population weighted value. In contrast, counties near the central part of the fallout pattern, e.g., Socorro, Torrance, Lincoln, and Guadalupe, likely had precincts that had doses substantially lower as well as greater than the weighted average values.

CONCLUSION

For the first time, organ doses received by representative persons in four ethnic groups, all age groups, and all counties of New Mexico have been estimated as a result of exposure to radioactive fallout from the 1945 Trinity nuclear test. A high degree of spatial heterogeneity of dose was estimated for New Mexico due to characteristics of the published Trinity fallout pattern. That pattern was a result of a wind dispersion to the northeast and was based primarily on actual field measurements of exposure rate across central New Mexico in the first few weeks after Trinity. We used the data on exposure rate and fallout TOA to derive ground deposition densities of the 63 most important radionuclides in fallout. We found the Trinity fallout pattern exposure rates, the major available resource for estimating doses, to have overall good reliability based on comparisons with historical film badges deployed across New Mexico before the Trinity test. Fortunately, despite that radiation measurement instrumentation was not well developed in the mid-1940s, some aspects of the Trinity test, such as the presumed fallout pattern (Quinn 1987; Hoffman 1945), appear to be relatively well documented.

The crucial data needed for dose reconstruction were descriptions of diet and lifestyle from the mid-1940s for different ethnic groups, derived for this study from contemporary focus groups and interviews. While those data have clear and obvious uncertainties due to limitations of memory recall, they were derived from persons alive and living in New Mexico at the time of Trinity and for that reason are viewed as relevant for the purposes of the dose reconstruction.

We used the fallout pattern, the data on diet and lifestyle, and a large suite of exposure models to estimate doses for external exposure and internal exposure resulting from consumption of 11 different food types including mothers' breast milk, drinking water, in-cloud inhalation, and resuspension over the first year following Trinity.

Radiation doses were found, expectedly, to differ significantly by location, age, and organ, and to a lesser degree by ethnicity. Doses received from Trinity by external irradiation were not large except in very limited areas immediately downwind of the detonation site where they ranged up to 100 mGy. Organ doses, except to the thyroid gland and for a relatively small fraction of the public, were also not large. For the thyroid gland, young age groups, e.g., 1–2 y of age, received the largest doses, though few would be considered high compared to annual doses from natural radiation and even less so compared to lifetime natural radiation. About 20% of that age cohort might have received doses greater than 10 mGy extending up to (for a very few persons) a few hundred mGy. Other organs and age groups would have been less.

Uncertainties were evaluated and uncertainty factors (as previously defined) ranged from 2.5 to 3.0 for external dose and for internal dose from 3.3 to 10.7 for the lung (depending on location) and 8.3 to 12.5 for thyroid (also depending on location). Our analysis suggests that the "credibility range" of dose estimated from the best parameter estimates should capture the true average dose in each precinct and county. Moreover, this analysis suggests that doses to individuals at either the very low or high end seem relatively unlikely since the mass of the uncertainty distributions is small at the extremes. For the most part, White and Hispanic populations received the highest exposures, while Native Americans, except for the few in Torrance County, received smaller doses than did other ethnic groups. The reason for the generally smaller doses to Native Americans pueblos was due to their locations being outside the high contamination area of the fallout pattern. However, according to the US Census, there were Native Americans in New Mexico not resident in pueblos. For Native Americans living in other towns in New Mexico and not in the pueblos, their doses would be expected to be similar in magnitude to the other ethnic groups living in those same towns.

Despite that there was no public notice before the test and no evacuations and a low detonation height, our findings indicate that only small geographic areas immediately downwind received exposures of significance as judged by their magnitude relative to naturally occurring background radiation. All locations other than the center line of the pattern were found to have likely received doses from Trinity at least 1,000-fold lower than those in the maximum exposed locations.

These findings constitute the only comprehensive dose estimates for Trinity known to exist. Doses reconstructed in this study for representative persons of White, Hispanic, Native American, and African American ethnicity are being used to project the excess cancer risk over their natural baseline rate of occurrence (Cahoon et al. 2020).

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APPENDIX

Table 1A[1]. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for Whites/colon from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	8.2E-02	1.3E-01	4.3E+00	2.2E+00	1.8E+00	1.2E+00	7.7E-01
Catron	1.7E-02	9.6E-02	1.2E-01	7.7E-02	7.7E-02	7.1E-02	6.7E-02
Chaves	4.6E-02	6.3E-02	8.6E-01	5.0E-01	4.3E-01	3.0E-01	2.1E-01
Colfax	2.3E-01	4.1E-01	1.3E+00	9.4E-01	8.8E-01	7.2E-01	6.6E-01
Curry	9.0E-03	2.4E-02	7.6E-02	5.3E-02	4.9E-02	3.8E-02	3.0E-02
De Baca	9.8E-02	1.4E-01	6.9E-01	5.1E-01	4.7E-01	3.5E-01	2.8E-01
Dona Ana	1.1E-02	2.1E-02	6.5E-01	3.4E-01	2.7E-01	1.9E-01	1.2E-01
Eddy	1.1E-02	1.1E-02	6.5E-01	3.4E-01	2.7E-01	1.8E-01	1.1E-01
Grant	1.6E-02	9.1E-02	1.2E+00	8.0E-01	6.4E-01	3.6E-01	1.9E-01
Guadalupe	4.0E+00	5.6E+00	2.7E+01	2.0E+01	1.8E+01	1.4E+01	1.1E+01
Harding	2.7E-02	1.5E-01	2.6E-01	1.8E-01	1.7E-01	1.4E-01	1.2E-01
Hidalgo	8.6E-03	7.7E-02	9.6E-02	6.1E-02	6.2E-02	5.4E-02	4.9E-02
Lea	1.1E-02	1.1E-02	6.5E-01	3.4E-01	2.7E-01	1.9E-01	1.2E-01
Lincoln	2.9E+00	7.3E+00	1.1E+01	8.1E+00	8.3E+00	6.8E+00	5.6E+00
Luna	1.7E-02	1.1E-02	1.3E+00	6.6E-01	5.3E-01	3.6E-01	2.2E-01
McKinley	1.5E-02	8.1E-02	8.6E-01	4.5E-01	3.7E-01	2.6E-01	1.7E-01
Mora	2.4E-01	1.1E+00	1.7E+00	1.2E+00	1.2E+00	1.0E+00	9.6E-01
Otero	1.2E-02	6.5E-02	6.2E-01	3.3E-01	2.8E-01	1.9E-01	1.2E-01
Quay	2.2E-02	5.0E-02	1.7E-01	1.2E-01	1.1E-01	8.6E-02	7.1E-02
Rio Arriba	4.0E-02	2.1E-01	7.3E-01	4.7E-01	4.1E-01	2.8E-01	2.1E-01
Roosevelt	8.6E-03	1.4E-02	7.0E-02	5.0E-02	4.6E-02	3.4E-02	2.7E-02
Sandoval	4.4E-02	2.6E-01	7.7E-01	4.9E-01	4.3E-01	3.1E-01	2.3E-01
San Juan	1.2E-02	1.1E-02	8.1E-01	4.2E-01	3.4E-01	2.3E-01	1.4E-01
San Miguel	5.1E-01	2.9E+00	4.9E+00	3.2E+00	3.1E+00	2.7E+00	2.4E+00
Santa Fe	2.0E-01	1.5E+00	5.1E+00	3.2E+00	2.7E+00	2.0E+00	1.7E+00
Sierra	9.1E-03	1.4E-02	5.7E-02	4.0E-02	3.8E-02	3.2E-02	2.9E-02
Socorro	2.4E+00	2.5E+01	1.7E+01	1.0E+01	1.1E+01	1.1E+01	1.1E+01
Taos	9.5E-02	5.4E-01	9.5E-01	6.5E-01	5.9E-01	4.7E-01	4.1E-01
Torrance	8.8E+00	3.8E+01	3.8E+01	2.5E+01	2.6E+01	2.4E+01	2.3E+01
Union	2.8E-02	8.9E-02	2.3E-01	1.6E-01	1.5E-01	1.2E-01	1.0E-01
Valencia	6.3E-02	2.7E-01	1.2E+00	6.9E-01	6.1E-01	4.6E-01	3.4E-01

[1]E-notation used here to conserve space.

Table 1B. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for Whites/lung from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	7.9E-02	7.4E-02	1.1E-01	9.2E-02	1.0E-01	9.5E-02	7.4E-02
Catron	1.7E-02	2.5E-02	2.8E-02	2.6E-02	3.0E-02	2.8E-02	2.3E-02
Chaves	4.4E-02	6.4E-02	7.6E-02	7.3E-02	9.2E-02	8.8E-02	7.1E-02
Colfax	2.2E-01	3.8E-01	4.5E-01	4.2E-01	5.2E-01	5.1E-01	4.2E-01
Curry	8.3E-03	1.3E-02	1.5E-02	1.5E-02	1.8E-02	1.7E-02	1.4E-02
De Baca	8.9E-02	1.3E-01	1.5E-01	1.5E-01	1.8E-01	1.7E-01	1.3E-01
Dona Ana	1.1E-02	1.1E-02	1.6E-02	1.4E-02	1.7E-02	1.6E-02	1.2E-02
Eddy	1.1E-02	1.1E-02	1.6E-02	1.4E-02	1.7E-02	1.6E-02	1.2E-02
Grant	1.5E-02	1.2E-02	2.0E-02	1.7E-02	1.8E-02	1.6E-02	1.3E-02
Guadalupe	3.6E+00	5.5E+00	6.1E+00	6.0E+00	7.5E+00	7.1E+00	5.6E+00
Harding	2.5E-02	3.9E-02	4.4E-02	4.3E-02	5.5E-02	5.2E-02	4.2E-02
Hidalgo	7.4E-03	1.1E-02	1.3E-02	1.2E-02	1.6E-02	1.5E-02	1.2E-02
Lea	1.1E-02	1.1E-02	1.6E-02	1.4E-02	1.7E-02	1.6E-02	1.2E-02
Lincoln	2.7E+00	4.1E+00	4.4E+00	4.4E+00	5.3E+00	5.0E+00	3.9E+00
Luna	1.7E-02	1.1E-02	2.0E-02	1.6E-02	1.8E-02	1.7E-02	1.3E-02
McKinley	1.4E-02	1.2E-02	1.8E-02	1.6E-02	1.8E-02	1.7E-02	1.3E-02
Mora	2.2E-01	3.4E-01	3.9E-01	3.7E-01	4.4E-01	4.3E-01	3.6E-01
Otero	1.1E-02	1.1E-02	1.6E-02	1.4E-02	1.7E-02	1.6E-02	1.2E-02
Quay	2.0E-02	3.1E-02	3.5E-02	3.4E-02	4.3E-02	4.0E-02	3.2E-02
Rio Arriba	3.7E-02	5.6E-02	6.7E-02	6.1E-02	7.3E-02	7.0E-02	5.9E-02
Roosevelt	8.0E-03	1.3E-02	1.5E-02	1.4E-02	1.8E-02	1.7E-02	1.4E-02
Sandoval	3.9E-02	5.4E-02	6.4E-02	5.7E-02	6.6E-02	6.3E-02	5.4E-02
San Juan	1.2E-02	1.1E-02	1.8E-02	1.5E-02	1.9E-02	1.7E-02	1.4E-02
San Miguel	4.5E-01	7.2E-01	8.5E-01	7.8E-01	9.3E-01	8.7E-01	7.1E-01
Santa Fe	1.4E-01	5.8E-01	6.2E-01	4.3E-01	4.5E-01	4.1E-01	3.5E-01
Sierra	8.4E-03	1.4E-02	2.3E-02	1.8E-02	2.0E-02	2.0E-02	1.8E-02
Socorro	2.4E+00	2.5E+01	1.6E+01	9.6E+00	1.1E+01	1.1E+01	1.1E+01
Taos	9.4E-02	4.7E-01	8.2E-01	5.9E-01	5.7E-01	4.8E-01	4.1E-01
Torrance	8.7E+00	3.6E+01	3.5E+01	2.5E+01	2.7E+01	2.7E+01	2.5E+01
Union	3.5E-02	4.8E-02	6.7E-02	6.4E-02	7.9E-02	7.8E-02	6.9E-02
Valencia	5.4E-02	7.6E-02	1.1E-01	9.7E-02	1.1E-01	9.4E-02	7.2E-02

Table 1C. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for Whites/RBM from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	8.8E-01	6.5E-02	3.2E-01	1.9E-01	2.1E-01	2.1E-01	9.9E-02
Catron	3.4E-02	3.4E-02	2.8E-02	2.4E-02	2.6E-02	2.5E-02	1.9E-02
Chaves	1.8E-01	4.9E-02	9.3E-02	7.1E-02	8.0E-02	7.7E-02	5.0E-02
Colfax	3.3E-01	2.8E-01	3.2E-01	2.8E-01	2.8E-01	2.7E-01	2.2E-01
Curry	1.5E-02	1.1E-02	1.2E-02	1.1E-02	1.2E-02	1.1E-02	8.1E-03
De Baca	1.4E-01	1.1E-01	1.2E-01	1.2E-01	1.3E-01	1.2E-01	9.0E-02
Dona Ana	1.3E-01	9.0E-03	4.7E-02	2.7E-02	3.1E-02	3.1E-02	1.4E-02
Eddy	1.3E-01	8.1E-03	4.8E-02	2.7E-02	3.1E-02	3.1E-02	1.4E-02
Grant	2.8E-01	2.6E-02	1.1E-01	6.9E-02	7.8E-02	6.8E-02	2.3E-02
Guadalupe	5.6E+00	4.3E+00	5.0E+00	4.7E+00	5.2E+00	4.8E+00	3.6E+00
Harding	4.7E-02	3.7E-02	3.5E-02	3.2E-02	3.6E-02	3.4E-02	2.5E-02
Hidalgo	1.6E-02	1.3E-02	1.1E-02	9.5E-03	1.1E-02	1.1E-02	7.6E-03
Lea	1.3E-01	8.1E-03	4.8E-02	2.7E-02	3.1E-02	3.1E-02	1.5E-02
Lincoln	3.2E+00	3.5E+00	3.6E+00	3.5E+00	3.8E+00	3.5E+00	2.7E+00
Luna	3.7E-01	8.1E-03	1.2E-01	5.9E-02	6.8E-02	7.2E-02	2.8E-02
McKinley	1.7E-01	1.4E-02	6.0E-02	3.4E-02	3.9E-02	4.0E-02	1.8E-02
Mora	3.8E-01	3.2E-01	3.1E-01	2.7E-01	2.8E-01	2.7E-01	2.2E-01
Otero	1.2E-01	1.3E-02	4.5E-02	2.6E-02	3.0E-02	3.0E-02	1.4E-02
Quay	3.3E-02	2.6E-02	2.8E-02	2.7E-02	2.9E-02	2.7E-02	2.0E-02
Rio Arriba	1.4E-01	5.7E-02	7.9E-02	6.0E-02	6.3E-02	5.9E-02	3.9E-02
Roosevelt	1.4E-02	9.7E-03	1.2E-02	1.1E-02	1.2E-02	1.1E-02	8.2E-03
Sandoval	1.5E-01	6.0E-02	8.2E-02	6.2E-02	6.5E-02	6.2E-02	4.1E-02
San Juan	1.7E-01	8.1E-03	5.8E-02	3.2E-02	3.6E-02	3.7E-02	1.6E-02
San Miguel	8.9E-01	6.7E-01	6.5E-01	5.8E-01	6.4E-01	6.2E-01	4.6E-01
Santa Fe	4.2E-01	2.2E-01	2.4E-01	1.9E-01	2.0E-01	2.0E-01	1.4E-01
Sierra	1.3E-02	9.9E-03	1.1E-02	1.0E-02	1.1E-02	1.0E-02	8.1E-03
Socorro	2.4E+00	3.0E+00	2.7E+00	2.3E+00	2.3E+00	2.2E+00	1.9E+00
Taos	2.0E-01	1.4E-01	1.5E-01	1.2E-01	1.2E-01	1.1E-01	9.1E-02
Torrance	1.0E+01	1.1E+01	1.2E+01	9.9E+00	9.3E+00	8.8E+00	8.1E+00
Union	7.5E-02	5.7E-02	6.7E-02	5.8E-02	5.8E-02	5.6E-02	5.0E-02
Valencia	2.4E-01	7.0E-02	1.1E-01	8.5E-02	9.6E-02	9.3E-02	5.8E-02

Table 1D. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for Whites/stomach from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	8.1E-02	6.8E-02	3.0E-01	1.8E-01	1.6E-01	1.3E-01	9.2E-02
Catron	2.5E-02	4.2E-02	4.0E-02	3.3E-02	3.4E-02	3.1E-02	2.6E-02
Chaves	4.6E-02	5.0E-02	9.6E-02	7.5E-02	7.5E-02	6.6E-02	5.0E-02
Colfax	2.3E-01	2.8E-01	3.5E-01	3.0E-01	2.9E-01	2.7E-01	2.4E-01
Curry	8.8E-03	1.1E-02	1.4E-02	1.3E-02	1.3E-02	1.2E-02	8.9E-03
De Baca	9.8E-02	1.1E-01	1.6E-01	1.4E-01	1.4E-01	1.3E-01	1.0E-01
Dona Ana	1.1E-02	9.1E-03	4.4E-02	2.6E-02	2.3E-02	1.9E-02	1.3E-02
Eddy	1.1E-02	8.3E-03	4.4E-02	2.6E-02	2.3E-02	1.9E-02	1.3E-02
Grant	1.5E-02	1.5E-02	7.3E-02	4.9E-02	3.9E-02	2.8E-02	1.7E-02
Guadalupe	4.0E+00	4.5E+00	6.3E+00	5.6E+00	5.9E+00	5.2E+00	4.1E+00
Harding	2.7E-02	3.7E-02	4.4E-02	3.7E-02	3.9E-02	3.6E-02	2.9E-02
Hidalgo	8.4E-03	1.3E-02	1.4E-02	1.1E-02	1.2E-02	1.1E-02	9.2E-03
Lea	1.1E-02	8.3E-03	4.5E-02	2.6E-02	2.3E-02	1.9E-02	1.3E-02
Lincoln	2.9E+00	3.9E+00	4.2E+00	3.9E+00	4.2E+00	3.7E+00	2.9E+00
Luna	1.7E-02	8.3E-03	7.6E-02	4.2E-02	3.5E-02	2.9E-02	1.9E-02
McKinley	1.5E-02	1.5E-02	5.8E-02	3.4E-02	3.0E-02	2.6E-02	1.8E-02
Mora	2.3E-01	3.2E-01	3.6E-01	3.0E-01	3.0E-01	2.8E-01	2.5E-01
Otero	1.2E-02	1.3E-02	4.3E-02	2.6E-02	2.3E-02	1.9E-02	1.4E-02
Quay	2.2E-02	2.6E-02	3.4E-02	3.1E-02	3.2E-02	2.9E-02	2.3E-02
Rio Arriba	3.9E-02	5.4E-02	8.3E-02	6.3E-02	5.8E-02	5.1E-02	4.3E-02
Roosevelt	8.5E-03	1.0E-02	1.4E-02	1.2E-02	1.3E-02	1.1E-02	8.9E-03
Sandoval	4.3E-02	6.1E-02	8.9E-02	6.6E-02	6.2E-02	5.5E-02	4.7E-02
San Juan	1.2E-02	8.2E-03	5.3E-02	3.1E-02	2.6E-02	2.2E-02	1.5E-02
San Miguel	5.0E-01	7.1E-01	8.3E-01	6.9E-01	7.2E-01	6.6E-01	5.4E-01
Santa Fe	1.9E-01	2.3E-01	4.8E-01	3.3E-01	2.8E-01	2.5E-01	2.1E-01
Sierra	8.9E-03	1.0E-02	1.4E-02	1.2E-02	1.2E-02	1.1E-02	9.2E-03
Socorro	2.4E+00	4.5E+00	3.7E+00	2.8E+00	2.8E+00	2.8E+00	2.6E+00
Taos	9.4E-02	1.4E-01	1.6E-01	1.3E-01	1.2E-01	1.1E-01	1.0E-01
Torrance	8.9E+00	1.3E+01	1.4E+01	1.1E+01	1.0E+01	9.7E+00	9.1E+00
Union	6.2E-02	7.4E-02	9.6E-02	7.9E-02	7.4E-02	6.9E-02	6.8E-02
Valencia	6.2E-02	7.7E-02	1.3E-01	9.8E-02	9.7E-02	8.6E-02	6.7E-02

Table 1E. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for Whites/thyroid from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	1.9E+00	4.0E-01	1.5E+01	8.9E+00	6.0E+00	4.6E+00	2.2E+00
Catron	3.2E-01	8.4E-01	1.6E+00	1.1E+00	8.2E-01	6.8E-01	3.8E-01
Chaves	5.3E-01	1.1E-01	3.6E+00	2.2E+00	1.6E+00	1.2E+00	6.5E-01
Colfax	2.2E+00	2.6E+00	1.3E+01	9.4E+00	6.6E+00	4.9E+00	2.7E+00
Curry	1.3E-01	4.8E-02	8.3E-01	5.2E-01	3.6E-01	2.9E-01	1.5E-01
De Baca	1.1E+00	2.3E-01	6.9E+00	4.4E+00	3.1E+00	2.4E+00	1.3E+00
Dona Ana	2.9E-01	4.8E-02	2.4E+00	1.4E+00	9.4E-01	7.2E-01	3.5E-01
Eddy	2.9E-01	1.8E-02	2.4E+00	1.4E+00	9.4E-01	7.2E-01	3.5E-01
Grant	4.1E-01	6.4E-01	3.8E+00	2.8E+00	1.9E+00	1.2E+00	5.0E-01
Guadalupe	4.2E+01	8.5E+00	2.5E+02	1.6E+02	1.2E+02	9.1E+01	5.0E+01
Harding	4.1E-01	3.1E-01	2.4E+00	1.5E+00	1.1E+00	8.8E-01	5.0E-01
Hidalgo	1.4E-01	1.7E-01	7.5E-01	4.7E-01	3.5E-01	3.0E-01	1.8E-01
Lea	3.1E-01	1.8E-02	2.6E+00	1.5E+00	1.0E+00	7.7E-01	3.7E-01
Lincoln	1.1E+01	7.1E+00	5.5E+01	3.6E+01	2.7E+01	2.2E+01	1.3E+01
Luna	4.9E-01	1.8E-02	4.2E+00	2.4E+00	1.6E+00	1.3E+00	6.0E-01
McKinley	3.9E-01	1.8E-01	3.0E+00	1.7E+00	1.2E+00	9.4E-01	4.7E-01
Mora	2.6E+00	4.7E+00	1.2E+01	8.7E+00	6.4E+00	5.1E+00	3.1E+00
Otero	3.0E-01	2.0E-01	2.3E+00	1.4E+00	9.4E-01	7.2E-01	3.6E-01
Quay	2.5E-01	9.7E-02	1.5E+00	9.9E-01	7.0E-01	5.6E-01	3.1E-01
Rio Arriba	5.0E-01	1.0E+00	3.0E+00	2.2E+00	1.5E+00	1.1E+00	6.0E-01
Roosevelt	1.3E-01	2.5E-02	8.9E-01	5.5E-01	3.9E-01	3.0E-01	1.6E-01
Sandoval	5.2E-01	1.2E+00	2.8E+00	2.0E+00	1.4E+00	1.1E+00	6.1E-01
San Juan	3.5E-01	2.5E-02	3.0E+00	1.8E+00	1.2E+00	9.0E-01	4.3E-01
San Miguel	8.8E+00	7.2E+00	5.6E+01	3.5E+01	2.5E+01	2.0E+01	1.1E+01
Santa Fe	3.7E+00	1.1E+01	2.0E+01	1.4E+01	9.7E+00	7.8E+00	4.8E+00
Sierra	8.5E-02	6.7E-02	4.4E-01	3.1E-01	2.2E-01	1.7E-01	1.0E-01
Socorro	7.6E+00	2.5E+01	2.1E+01	1.4E+01	1.2E+01	1.2E+01	8.4E+00
Taos	9.3E-01	2.6E+00	4.6E+00	3.6E+00	2.6E+00	1.9E+00	1.1E+00
Torrance	4.2E+01	1.0E+02	2.1E+02	1.7E+02	1.2E+02	8.4E+01	4.8E+01
Union	5.3E-01	9.1E-01	2.9E+00	2.2E+00	1.5E+00	1.1E+00	6.5E-01
Valencia	9.1E-01	6.1E-01	5.7E+00	3.5E+00	2.5E+00	2.0E+00	1.1E+00

Table 2A. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for Hispanics/Colon from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	7.6E-02	1.6E-01	3.5E+00	2.2E+00	1.8E+00	1.1E+00	7.6E-01
Catron	1.8E-02	9.9E-02	1.2E-01	8.1E-02	8.1E-02	7.5E-02	7.0E-02
Chaves	3.5E-02	4.3E-02	7.9E-01	5.0E-01	4.3E-01	2.9E-01	2.0E-01
Colfax	2.4E-01	4.6E-01	1.4E+00	1.0E+00	9.6E-01	7.9E-01	7.3E-01
Curry	8.3E-03	2.5E-02	8.2E-02	5.7E-02	5.3E-02	4.0E-02	3.1E-02
De Baca	1.1E-01	1.8E-01	7.9E-01	5.8E-01	5.4E-01	4.2E-01	3.5E-01
Dona Ana	1.1E-02	2.7E-02	5.0E-01	3.2E-01	2.7E-01	1.7E-01	1.2E-01
Eddy	1.0E-02	1.8E-02	4.8E-01	3.2E-01	2.6E-01	1.7E-01	1.1E-01
Grant	1.6E-02	1.1E-01	9.8E-01	7.8E-01	6.2E-01	3.3E-01	1.9E-01
Guadalupe	4.5E+00	7.4E+00	3.1E+01	2.2E+01	2.1E+01	1.6E+01	1.4E+01
Harding	3.0E-02	1.6E-01	2.9E-01	2.0E-01	1.9E-01	1.6E-01	1.4E-01
Hidalgo	9.5E-03	8.2E-02	1.0E-01	6.7E-02	6.8E-02	6.0E-02	5.3E-02
Lea	1.1E-02	1.8E-02	4.9E-01	3.2E-01	2.6E-01	1.7E-01	1.1E-01
Lincoln	3.2E+00	7.9E+00	1.2E+01	8.8E+00	8.6E+00	7.2E+00	6.3E+00
Luna	1.7E-02	4.6E-02	7.0E-01	6.1E-01	4.9E-01	2.9E-01	2.2E-01
McKinley	1.6E-02	1.0E-01	5.0E-01	4.1E-01	3.5E-01	2.2E-01	1.7E-01
Mora	2.5E-01	1.1E+00	1.9E+00	1.3E+00	1.3E+00	1.1E+00	1.0E+00
Otero	1.2E-02	7.9E-02	3.9E-01	3.1E-01	2.6E-01	1.6E-01	1.2E-01
Quay	2.5E-02	6.1E-02	1.9E-01	1.4E-01	1.3E-01	1.0E-01	8.6E-02
Rio Arriba	4.2E-02	2.2E-01	6.3E-01	4.7E-01	4.1E-01	2.8E-01	2.2E-01
Roosevelt	9.7E-03	1.9E-02	7.7E-02	5.7E-02	5.3E-02	4.0E-02	3.3E-02
Sandoval	4.6E-02	2.7E-01	6.6E-01	4.8E-01	4.3E-01	3.0E-01	2.4E-01
San Juan	1.3E-02	3.1E-02	4.5E-01	3.9E-01	3.2E-01	1.9E-01	1.4E-01
San Miguel	4.7E-01	2.9E+00	5.1E+00	3.4E+00	3.3E+00	2.8E+00	2.4E+00
Santa Fe	2.4E-01	1.5E+00	5.2E+00	3.2E+00	2.8E+00	2.1E+00	1.7E+00
Sierra	9.8E-03	1.6E-02	6.3E-02	4.4E-02	4.3E-02	3.6E-02	3.2E-02
Socorro	2.4E+00	2.5E+01	1.8E+01	1.0E+01	1.1E+01	1.1E+01	1.1E+01
Taos	9.6E-02	5.5E-01	9.3E-01	6.5E-01	6.0E-01	4.7E-01	4.1E-01
Torrance	8.8E+00	3.8E+01	3.8E+01	2.5E+01	2.6E+01	2.4E+01	2.3E+01
Union	3.0E-02	1.0E-01	2.5E-01	1.8E-01	1.7E-01	1.4E-01	1.2E-01
Valencia	7.0E-02	3.2E-01	9.2E-01	7.0E-01	6.2E-01	4.5E-01	3.7E-01

Table 2B. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for Hispanics/Lung from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	7.2E-02	6.0E-02	1.1E-01	9.3E-02	9.4E-02	7.6E-02	5.2E-02
Catron	1.8E-02	2.6E-02	3.1E-02	2.7E-02	2.9E-02	2.7E-02	2.4E-02
Chaves	3.3E-02	3.7E-02	7.7E-02	6.9E-02	7.1E-02	5.4E-02	3.1E-02
Colfax	2.3E-01	3.9E-01	4.7E-01	4.2E-01	5.1E-01	5.0E-01	4.3E-01
Curry	7.5E-03	1.1E-02	1.6E-02	1.4E-02	1.5E-02	1.3E-02	9.1E-03
De Baca	9.9E-02	1.4E-01	1.7E-01	1.5E-01	1.7E-01	1.6E-01	1.4E-01
Dona Ana	1.0E-02	8.9E-03	1.6E-02	1.4E-02	1.4E-02	1.2E-02	8.3E-03
Eddy	1.0E-02	9.0E-03	1.6E-02	1.4E-02	1.4E-02	1.2E-02	8.5E-03
Grant	1.5E-02	1.3E-02	1.9E-02	1.7E-02	1.8E-02	1.6E-02	1.3E-02
Guadalupe	4.0E+00	5.9E+00	7.0E+00	6.2E+00	7.0E+00	6.7E+00	5.9E+00
Harding	2.7E-02	4.2E-02	5.0E-02	4.4E-02	5.1E-02	5.0E-02	4.4E-02
Hidalgo	8.1E-03	1.2E-02	1.4E-02	1.3E-02	1.5E-02	1.4E-02	1.2E-02
Lea	1.0E-02	8.9E-03	1.6E-02	1.4E-02	1.4E-02	1.2E-02	8.5E-03
Lincoln	3.0E+00	4.4E+00	5.1E+00	4.5E+00	4.9E+00	4.7E+00	4.2E+00
Luna	1.8E-02	1.3E-02	1.8E-02	1.6E-02	1.7E-02	1.6E-02	1.4E-02
McKinley	1.5E-02	1.4E-02	1.8E-02	1.6E-02	1.7E-02	1.6E-02	1.4E-02
Mora	2.3E-01	3.5E-01	4.2E-01	3.7E-01	4.3E-01	4.2E-01	3.7E-01
Otero	1.2E-02	1.2E-02	1.6E-02	1.4E-02	1.6E-02	1.5E-02	1.3E-02
Quay	2.2E-02	3.4E-02	4.0E-02	3.5E-02	4.0E-02	3.9E-02	3.4E-02
Rio Arriba	3.8E-02	5.7E-02	6.9E-02	6.2E-02	7.1E-02	6.9E-02	6.0E-02
Roosevelt	8.9E-03	1.4E-02	1.7E-02	1.5E-02	1.7E-02	1.7E-02	1.5E-02
Sandoval	4.0E-02	5.5E-02	6.6E-02	5.8E-02	6.4E-02	6.2E-02	5.4E-02
San Juan	1.3E-02	1.3E-02	1.7E-02	1.5E-02	1.8E-02	1.7E-02	1.4E-02
San Miguel	4.0E-01	6.1E-01	9.2E-01	7.8E-01	8.2E-01	7.0E-01	5.1E-01
Santa Fe	1.8E-01	6.4E-01	6.8E-01	4.9E-01	5.2E-01	4.7E-01	3.9E-01
Sierra	8.9E-03	1.4E-02	2.4E-02	1.9E-02	2.0E-02	2.0E-02	1.9E-02
Socorro	2.4E+00	2.5E+01	1.7E+01	9.6E+00	1.1E+01	1.1E+01	1.1E+01
Taos	9.5E-02	4.7E-01	8.2E-01	5.9E-01	5.7E-01	4.8E-01	4.1E-01
Torrance	8.7E+00	3.6E+01	3.5E+01	2.5E+01	2.7E+01	2.7E+01	2.5E+01
Union	3.7E-02	5.0E-02	7.2E-02	6.4E-02	7.5E-02	7.5E-02	6.9E-02
Valencia	5.9E-02	8.2E-02	1.2E-01	9.9E-02	1.0E-01	8.9E-02	7.6E-02

Table 2C. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for Hispanics/RBM from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	8.6E-01	9.3E-02	2.8E-01	1.9E-01	2.1E-01	2.0E-01	9.0E-02
Catron	3.6E-02	3.6E-02	3.1E-02	2.6E-02	2.5E-02	2.4E-02	2.1E-02
Chaves	1.7E-01	3.8E-02	1.1E-01	8.4E-02	8.8E-02	7.4E-02	3.6E-02
Colfax	3.6E-01	2.9E-01	3.4E-01	2.8E-01	2.7E-01	2.6E-01	2.3E-01
Curry	1.5E-02	1.0E-02	1.5E-02	1.3E-02	1.3E-02	1.1E-02	7.0E-03
De Baca	1.6E-01	1.3E-01	1.5E-01	1.3E-01	1.2E-01	1.2E-01	1.0E-01
Dona Ana	1.3E-01	1.5E-02	4.0E-02	2.8E-02	3.0E-02	2.9E-02	1.3E-02
Eddy	1.3E-01	1.5E-02	3.9E-02	2.7E-02	3.0E-02	2.8E-02	1.3E-02
Grant	2.8E-01	4.2E-02	8.7E-02	6.7E-02	7.6E-02	6.2E-02	2.3E-02
Guadalupe	6.4E+00	5.0E+00	6.0E+00	5.0E+00	4.8E+00	4.6E+00	4.0E+00
Harding	5.3E-02	4.2E-02	4.1E-02	3.4E-02	3.4E-02	3.4E-02	2.7E-02
Hidalgo	1.8E-02	1.5E-02	1.2E-02	1.0E-02	1.0E-02	1.0E-02	8.3E-03
Lea	1.3E-01	1.5E-02	4.0E-02	2.8E-02	3.0E-02	2.9E-02	1.3E-02
Lincoln	3.6E+00	3.9E+00	4.3E+00	3.6E+00	3.4E+00	3.2E+00	3.0E+00
Luna	3.6E-01	4.6E-02	6.5E-02	5.4E-02	6.2E-02	5.8E-02	2.8E-02
McKinley	1.7E-01	3.2E-02	3.9E-02	3.2E-02	3.5E-02	3.3E-02	1.9E-02
Mora	4.0E-01	3.4E-01	3.4E-01	2.8E-01	2.7E-01	2.7E-01	2.3E-01
Otero	1.2E-01	2.4E-02	3.1E-02	2.5E-02	2.8E-02	2.6E-02	1.4E-02
Quay	3.8E-02	2.9E-02	3.4E-02	2.8E-02	2.7E-02	2.7E-02	2.2E-02
Rio Arriba	1.4E-01	6.3E-02	7.5E-02	6.0E-02	6.1E-02	5.7E-02	4.0E-02
Roosevelt	1.6E-02	1.1E-02	1.4E-02	1.1E-02	1.1E-02	1.1E-02	9.0E-03
Sandoval	1.5E-01	6.8E-02	7.7E-02	6.2E-02	6.3E-02	5.9E-02	4.2E-02
San Juan	1.6E-01	2.5E-02	3.6E-02	3.0E-02	3.3E-02	3.1E-02	1.7E-02
San Miguel	8.8E-01	6.3E-01	7.9E-01	6.6E-01	6.7E-01	6.0E-01	3.9E-01
Santa Fe	4.5E-01	2.8E-01	3.0E-01	2.4E-01	2.6E-01	2.6E-01	1.7E-01
Sierra	1.4E-02	1.1E-02	1.3E-02	1.1E-02	1.0E-02	9.9E-03	8.7E-03
Socorro	2.5E+00	3.1E+00	2.8E+00	2.3E+00	2.2E+00	2.1E+00	2.0E+00
Taos	2.0E-01	1.4E-01	1.5E-01	1.2E-01	1.2E-01	1.1E-01	9.1E-02
Torrance	1.0E+01	1.1E+01	1.2E+01	9.9E+00	9.2E+00	8.8E+00	8.1E+00
Union	7.9E-02	6.0E-02	7.1E-02	5.8E-02	5.5E-02	5.5E-02	5.0E-02
Valencia	2.4E-01	9.5E-02	1.0E-01	8.6E-02	8.8E-02	8.5E-02	6.3E-02

Table 2D. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for Hispanics/Stomach from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	7.5E-02	6.5E-02	2.7E-01	1.9E-01	1.6E-01	1.3E-01	8.3E-02
Catron	2.7E-02	4.4E-02	4.5E-02	3.5E-02	3.3E-02	3.1E-02	2.8E-02
Chaves	3.4E-02	3.5E-02	1.1E-01	8.7E-02	8.2E-02	6.3E-02	3.7E-02
Colfax	2.4E-01	3.0E-01	3.8E-01	3.1E-01	2.9E-01	2.7E-01	2.5E-01
Curry	8.1E-03	1.0E-02	1.7E-02	1.4E-02	1.4E-02	1.1E-02	7.8E-03
De Baca	1.1E-01	1.3E-01	1.9E-01	1.5E-01	1.4E-01	1.3E-01	1.1E-01
Dona Ana	1.0E-02	9.2E-03	3.8E-02	2.7E-02	2.3E-02	1.8E-02	1.2E-02
Eddy	1.0E-02	8.6E-03	3.7E-02	2.7E-02	2.3E-02	1.8E-02	1.2E-02
Grant	1.5E-02	1.7E-02	6.0E-02	4.7E-02	3.8E-02	2.6E-02	1.7E-02
Guadalupe	4.5E+00	5.2E+00	7.5E+00	6.0E+00	5.6E+00	5.1E+00	4.6E+00
Harding	3.0E-02	4.2E-02	5.0E-02	4.0E-02	3.7E-02	3.5E-02	3.2E-02
Hidalgo	9.2E-03	1.5E-02	1.6E-02	1.2E-02	1.1E-02	1.1E-02	1.0E-02
Lea	1.0E-02	8.6E-03	3.8E-02	2.7E-02	2.3E-02	1.8E-02	1.2E-02
Lincoln	3.3E+00	4.3E+00	5.0E+00	4.1E+00	3.8E+00	3.5E+00	3.3E+00
Luna	1.7E-02	1.4E-02	4.6E-02	3.9E-02	3.2E-02	2.4E-02	1.9E-02
McKinley	1.6E-02	1.9E-02	4.0E-02	3.3E-02	2.8E-02	2.3E-02	1.9E-02
Mora	2.5E-01	3.4E-01	4.0E-01	3.1E-01	2.9E-01	2.8E-01	2.6E-01
Otero	1.2E-02	1.5E-02	3.1E-02	2.5E-02	2.2E-02	1.8E-02	1.4E-02
Quay	2.4E-02	3.0E-02	4.1E-02	3.3E-02	3.0E-02	2.8E-02	2.5E-02
Rio Arriba	4.1E-02	5.7E-02	8.0E-02	6.3E-02	5.7E-02	5.0E-02	4.4E-02
Roosevelt	9.5E-03	1.2E-02	1.6E-02	1.3E-02	1.2E-02	1.1E-02	1.0E-02
Sandoval	4.5E-02	6.4E-02	8.6E-02	6.7E-02	6.0E-02	5.4E-02	4.8E-02
San Juan	1.3E-02	1.2E-02	3.4E-02	2.9E-02	2.4E-02	1.9E-02	1.5E-02
San Miguel	4.6E-01	6.6E-01	9.7E-01	7.7E-01	7.5E-01	6.5E-01	4.8E-01
Santa Fe	2.2E-01	2.9E-01	5.4E-01	3.8E-01	3.5E-01	3.1E-01	2.5E-01
Sierra	9.6E-03	1.1E-02	1.5E-02	1.2E-02	1.1E-02	1.1E-02	9.9E-03
Socorro	2.5E+00	4.6E+00	3.8E+00	2.9E+00	2.8E+00	2.8E+00	2.6E+00
Taos	9.5E-02	1.4E-01	1.6E-01	1.3E-01	1.2E-01	1.1E-01	1.0E-01
Torrance	8.9E+00	1.3E+01	1.4E+01	1.1E+01	1.0E+01	9.7E+00	9.2E+00
Union	6.2E-02	7.2E-02	9.7E-02	7.9E-02	7.2E-02	6.8E-02	6.7E-02
Valencia	6.9E-02	8.9E-02	1.3E-01	1.0E-01	9.3E-02	8.3E-02	7.3E-02

Table 2E. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for Hispanics/Thyroid from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	1.9E+00	2.3E+00	1.2E+01	8.7E+00	5.8E+00	4.3E+00	2.2E+00
Catron	3.6E-01	1.2E+00	1.4E+00	1.2E+00	8.5E-01	6.8E-01	4.2E-01
Chaves	5.1E-01	3.6E-01	3.2E+00	2.2E+00	1.5E+00	1.2E+00	6.2E-01
Colfax	2.4E+00	5.7E+00	1.1E+01	9.6E+00	6.8E+00	4.9E+00	2.9E+00
Curry	1.4E-01	2.3E-01	7.1E-01	5.2E-01	3.7E-01	2.8E-01	1.6E-01
De Baca	1.3E+00	2.9E+00	5.3E+00	4.6E+00	3.3E+00	2.5E+00	1.5E+00
Dona Ana	2.9E-01	4.2E-01	1.8E+00	1.3E+00	9.1E-01	6.6E-01	3.5E-01
Eddy	2.9E-01	4.0E-01	1.8E+00	1.3E+00	9.1E-01	6.6E-01	3.5E-01
Grant	4.0E-01	1.2E+00	3.0E+00	2.7E+00	1.8E+00	1.1E+00	4.9E-01
Guadalupe	4.8E+01	1.1E+02	2.0E+02	1.7E+02	1.2E+02	9.4E+01	5.8E+01
Harding	4.5E-01	1.3E+00	1.8E+00	1.5E+00	1.1E+00	8.8E-01	5.6E-01
Hidalgo	1.6E-01	5.2E-01	5.9E-01	4.9E-01	3.6E-01	3.0E-01	1.9E-01
Lea	3.1E-01	4.3E-01	1.9E+00	1.4E+00	9.7E-01	7.0E-01	3.7E-01
Lincoln	1.3E+01	2.9E+01	4.5E+01	3.9E+01	2.9E+01	2.2E+01	1.5E+01
Luna	4.9E-01	1.3E+00	2.3E+00	2.2E+00	1.5E+00	1.0E+00	6.0E-01
McKinley	4.0E-01	1.1E+00	1.7E+00	1.6E+00	1.1E+00	8.0E-01	4.8E-01
Mora	2.8E+00	8.0E+00	1.1E+01	9.0E+00	6.7E+00	5.3E+00	3.4E+00
Otero	3.0E-01	8.2E-01	1.4E+00	1.3E+00	9.1E-01	6.3E-01	3.7E-01
Quay	2.9E-01	7.3E-01	1.2E+00	1.0E+00	7.5E-01	5.8E-01	3.6E-01
Rio Arriba	5.2E-01	1.5E+00	2.6E+00	2.2E+00	1.6E+00	1.1E+00	6.2E-01
Roosevelt	1.4E-01	3.6E-01	6.3E-01	5.7E-01	4.0E-01	2.9E-01	1.8E-01
Sandoval	5.4E-01	1.6E+00	2.4E+00	2.0E+00	1.4E+00	1.1E+00	6.4E-01
San Juan	3.5E-01	8.4E-01	1.7E+00	1.6E+00	1.1E+00	7.4E-01	4.3E-01
San Miguel	9.0E+00	1.6E+01	4.8E+01	3.5E+01	2.5E+01	2.0E+01	1.2E+01
Santa Fe	3.8E+00	1.1E+01	2.0E+01	1.4E+01	9.7E+00	7.9E+00	4.8E+00
Sierra	9.5E-02	2.1E-01	3.8E-01	3.2E-01	2.3E-01	1.8E-01	1.1E-01
Socorro	7.7E+00	2.6E+01	2.0E+01	1.4E+01	1.2E+01	1.2E+01	8.5E+00
Taos	9.5E-01	3.0E+00	4.5E+00	3.6E+00	2.6E+00	1.9E+00	1.1E+00
Torrance	4.2E+01	1.1E+02	2.0E+02	1.7E+02	1.2E+02	8.4E+01	4.8E+01
Union	5.7E-01	1.4E+00	2.6E+00	2.2E+00	1.6E+00	1.2E+00	6.9E-01
Valencia	9.9E-01	2.7E+00	4.0E+00	3.5E+00	2.5E+00	1.9E+00	1.2E+00

Table 3A. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for Native Americans/Colon from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	7.6E-02	1.4E-01	2.6E+00	1.6E+00	1.4E+00	9.1E-01	6.3E-01
Catron	1.9E-02	2.7E-02	1.3E-01	8.8E-02	7.6E-02	6.4E-02	6.1E-02
Chaves	5.3E-02	8.8E-02	7.7E-01	5.0E-01	4.4E-01	3.2E-01	2.8E-01
Colfax	3.4E-01	5.4E-01	2.0E+00	1.3E+00	1.2E+00	9.9E-01	9.6E-01
Curry	9.2E-03	1.6E-02	9.1E-02	6.3E-02	5.4E-02	4.3E-02	4.1E-02
De Baca	6.9E-02	1.0E-01	6.1E-01	4.2E-01	3.6E-01	3.0E-01	2.8E-01
Dona Ana	1.2E-02	2.4E-02	4.0E-01	2.5E-01	2.2E-01	1.4E-01	1.0E-01
Eddy	1.2E-02	2.4E-02	4.0E-01	2.5E-01	2.2E-01	1.4E-01	1.0E-01
Grant	1.4E-02	9.4E-02	3.9E-01	2.6E-01	1.9E-01	1.1E-01	8.6E-02
Guadalupe	–	–	–	–	–	–	–
Harding	–	–	–	–	–	–	–
Hidalgo	1.1E-02	9.8E-02	1.5E-01	9.2E-02	8.7E-02	7.9E-02	7.6E-02
Lea	1.2E-02	2.4E-02	4.0E-01	2.5E-01	2.2E-01	1.4E-01	1.0E-01
Lincoln	4.8E-02	1.2E+00	1.6E+00	1.1E+00	1.4E+00	8.3E-01	5.9E-01
Luna	1.6E-02	3.6E-02	7.4E-01	4.5E-01	3.9E-01	2.5E-01	1.7E-01
McKinley	1.7E-02	4.3E-02	5.2E-01	3.2E-01	2.8E-01	1.9E-01	1.4E-01
Mora	–	–	–	–	–	–	–
Otero	1.3E-02	8.4E-02	2.6E-01	1.8E-01	1.3E-01	7.3E-02	6.4E-02
Quay	3.3E-02	4.9E-02	3.0E-01	2.1E-01	1.8E-01	1.5E-01	1.4E-01
Rio Arriba	3.9E-02	6.5E-02	6.1E-01	4.0E-01	3.3E-01	2.3E-01	1.9E-01
Roosevelt	9.5E-03	1.6E-02	9.5E-02	6.5E-02	5.6E-02	4.5E-02	4.3E-02
Sandoval	4.7E-02	9.3E-02	7.5E-01	4.8E-01	4.2E-01	3.1E-01	2.5E-01
San Juan	1.2E-02	2.6E-02	4.8E-01	3.0E-01	2.6E-01	1.7E-01	1.2E-01
San Miguel	4.3E-01	3.0E+00	4.7E+00	3.0E+00	2.9E+00	3.0E+00	2.9E+00
Santa Fe	1.4E-01	9.4E-01	1.2E+00	7.5E-01	7.2E-01	6.7E-01	6.3E-01
Sierra	1.4E-02	3.7E-02	8.9E-02	5.7E-02	5.3E-02	4.7E-02	4.6E-02
Socorro	1.9E-01	7.5E-01	1.4E+00	9.8E-01	1.1E+00	8.3E-01	7.0E-01
Taos	1.4E-01	1.3E+00	2.2E+00	1.4E+00	1.3E+00	1.1E+00	1.0E+00
Torrance	3.0E+01	5.0E+01	8.7E+01	6.3E+01	6.1E+01	5.2E+01	4.8E+01
Union	–	–	–	–	–	–	–
Valencia	5.5E-02	1.1E-01	8.0E-01	5.2E-01	4.5E-01	3.3E-01	2.7E-01

Table 3B. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for Native Americans/Lung from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	6.4E-02	6.3E-02	8.1E-02	7.1E-02	7.8E-02	7.2E-02	6.2E-02
Catron	1.7E-02	2.4E-02	2.8E-02	2.6E-02	2.9E-02	2.8E-02	2.4E-02
Chaves	4.7E-02	6.5E-02	7.5E-02	6.9E-02	8.2E-02	8.0E-02	6.8E-02
Colfax	3.2E-01	5.1E-01	5.6E-01	5.3E-01	6.3E-01	6.1E-01	5.2E-01
Curry	8.1E-03	1.2E-02	1.4E-02	1.3E-02	1.5E-02	1.5E-02	1.3E-02
De Baca	5.5E-02	7.6E-02	8.5E-02	7.9E-02	9.1E-02	8.7E-02	7.5E-02
Dona Ana	1.1E-02	1.2E-02	1.6E-02	1.4E-02	1.6E-02	1.6E-02	1.3E-02
Eddy	1.1E-02	1.2E-02	1.6E-02	1.4E-02	1.6E-02	1.6E-02	1.3E-02
Grant	1.2E-02	1.6E-02	1.8E-02	1.7E-02	1.9E-02	1.8E-02	1.5E-02
Guadalupe	–	–	–	–	–	–	–
Harding	–	–	–	–	–	–	–
Hidalgo	9.1E-03	1.3E-02	1.4E-02	1.3E-02	1.6E-02	1.5E-02	1.3E-02
Lea	1.1E-02	1.2E-02	1.6E-02	1.4E-02	1.6E-02	1.6E-02	1.3E-02
Lincoln	1.1E-02	1.6E-02	1.8E-02	1.7E-02	1.9E-02	1.8E-02	1.6E-02
Luna	1.5E-02	1.3E-02	1.8E-02	1.5E-02	1.7E-02	1.6E-02	1.4E-02
McKinley	1.5E-02	1.6E-02	2.0E-02	1.8E-02	2.0E-02	1.9E-02	1.6E-02
Mora	–	–	–	–	–	–	–
Otero	1.1E-02	1.6E-02	1.8E-02	1.6E-02	1.9E-02	1.8E-02	1.5E-02
Quay	2.7E-02	3.8E-02	4.3E-02	4.0E-02	4.7E-02	4.5E-02	3.9E-02
Rio Arriba	3.5E-02	5.0E-02	5.7E-02	5.3E-02	6.3E-02	6.0E-02	5.2E-02
Roosevelt	8.2E-03	1.2E-02	1.4E-02	1.3E-02	1.5E-02	1.5E-02	1.3E-02
Sandoval	3.9E-02	5.0E-02	5.7E-02	5.2E-02	6.0E-02	5.7E-02	4.9E-02
San Juan	1.2E-02	1.3E-02	1.7E-02	1.5E-02	1.8E-02	1.7E-02	1.4E-02
San Miguel	3.4E-01	4.7E-01	5.1E-01	4.7E-01	5.6E-01	6.0E-01	5.1E-01
Santa Fe	1.2E-01	1.8E-01	1.9E-01	1.7E-01	2.0E-01	2.1E-01	1.8E-01
Sierra	1.2E-02	1.6E-02	1.8E-02	1.6E-02	1.8E-02	1.8E-02	1.5E-02
Socorro	1.5E-01	2.1E-01	2.2E-01	2.0E-01	2.2E-01	2.1E-01	1.8E-01
Taos	1.2E-01	1.7E-01	1.8E-01	1.7E-01	2.1E-01	2.0E-01	1.7E-01
Torrance	2.8E+01	4.2E+01	4.4E+01	4.1E+01	4.6E+01	4.4E+01	3.8E+01
Union	–	–	–	–	–	–	–
Valencia	4.3E-02	5.5E-02	6.1E-02	5.6E-02	6.3E-02	6.0E-02	5.2E-02

Table 3C. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for Native Americans/RBM from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	6.0E-01	1.1E-01	1.9E-01	1.3E-01	1.5E-01	1.5E-01	7.8E-02
Catron	2.8E-02	2.2E-02	2.5E-02	2.2E-02	2.3E-02	2.2E-02	1.8E-02
Chaves	1.6E-01	6.2E-02	8.1E-02	6.5E-02	7.0E-02	6.9E-02	5.0E-02
Colfax	4.5E-01	4.1E-01	4.4E-01	3.9E-01	3.9E-01	3.8E-01	3.2E-01
Curry	1.5E-02	9.9E-03	1.1E-02	1.0E-02	1.0E-02	1.0E-02	8.2E-03
De Baca	9.7E-02	6.6E-02	7.6E-02	6.6E-02	6.8E-02	6.6E-02	5.5E-02
Dona Ana	9.4E-02	1.8E-02	3.1E-02	2.1E-02	2.5E-02	2.4E-02	1.3E-02
Eddy	9.3E-02	1.8E-02	3.1E-02	2.1E-02	2.5E-02	2.4E-02	1.3E-02
Grant	7.3E-02	2.4E-02	3.9E-02	2.8E-02	2.8E-02	2.2E-02	1.4E-02
Guadalupe	–	–	–	–	–	–	–
Harding	–	–	–	–	–	–	–
Hidalgo	2.2E-02	1.7E-02	1.3E-02	1.1E-02	1.1E-02	1.2E-02	9.2E-03
Lea	9.4E-02	1.8E-02	3.1E-02	2.1E-02	2.5E-02	2.4E-02	1.3E-02
Lincoln	1.4E-02	1.4E-02	2.3E-02	2.0E-02	1.7E-02	1.3E-02	1.1E-02
Luna	2.4E-01	3.4E-02	6.6E-02	4.0E-02	5.0E-02	5.0E-02	2.2E-02
McKinley	1.2E-01	2.4E-02	4.0E-02	2.7E-02	3.2E-02	3.1E-02	1.7E-02
Mora	–	–	–	–	–	–	–
Otero	3.3E-02	1.9E-02	2.5E-02	2.0E-02	1.9E-02	1.6E-02	1.2E-02
Quay	4.8E-02	3.3E-02	3.7E-02	3.3E-02	3.4E-02	3.3E-02	2.7E-02
Rio Arriba	1.2E-01	4.7E-02	6.5E-02	5.2E-02	5.4E-02	5.1E-02	3.7E-02
Roosevelt	1.6E-02	1.0E-02	1.2E-02	1.0E-02	1.0E-02	1.0E-02	8.3E-03
Sandoval	1.5E-01	5.4E-02	7.2E-02	5.6E-02	6.1E-02	5.9E-02	4.1E-02
San Juan	1.1E-01	2.0E-02	3.6E-02	2.4E-02	2.8E-02	2.8E-02	1.4E-02
San Miguel	7.5E-01	5.7E-01	4.8E-01	4.1E-01	4.4E-01	5.1E-01	4.0E-01
Santa Fe	2.3E-01	2.1E-01	1.8E-01	1.5E-01	1.6E-01	1.7E-01	1.4E-01
Sierra	1.8E-02	1.6E-02	1.6E-02	1.4E-02	1.4E-02	1.4E-02	1.2E-02
Socorro	1.9E-01	1.9E-01	2.0E-01	1.8E-01	1.8E-01	1.7E-01	1.5E-01
Taos	3.7E-01	2.2E-01	1.9E-01	1.5E-01	1.6E-01	1.7E-01	1.2E-01
Torrance	3.2E+01	3.7E+01	3.7E+01	3.4E+01	3.4E+01	3.2E+01	2.8E+01
Union	–	–	–	–	–	–	–
Valencia	1.6E-01	6.0E-02	7.8E-02	6.2E-02	6.6E-02	6.4E-02	4.6E-02

Table 3D. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for Native Americans/Stomach from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	7.5E-02	6.6E-02	2.1E-01	1.4E-01	1.3E-01	1.1E-01	8.2E-02
Catron	2.6E-02	2.3E-02	4.3E-02	3.4E-02	3.1E-02	2.9E-02	2.6E-02
Chaves	5.2E-02	5.6E-02	9.6E-02	7.5E-02	7.1E-02	6.4E-02	5.6E-02
Colfax	3.4E-01	4.1E-01	4.9E-01	4.2E-01	4.1E-01	3.8E-01	3.5E-01
Curry	9.0E-03	1.0E-02	1.5E-02	1.2E-02	1.1E-02	1.1E-02	9.5E-03
De Baca	6.7E-02	6.9E-02	1.1E-01	8.6E-02	8.1E-02	7.5E-02	6.9E-02
Dona Ana	1.2E-02	1.1E-02	3.2E-02	2.2E-02	2.0E-02	1.7E-02	1.3E-02
Eddy	1.2E-02	1.1E-02	3.2E-02	2.2E-02	2.0E-02	1.7E-02	1.3E-02
Grant	1.3E-02	1.9E-02	3.3E-02	2.4E-02	2.1E-02	1.7E-02	1.4E-02
Guadalupe	–	–	–	–	–	–	–
Harding	–	–	–	–	–	–	–
Hidalgo	1.1E-02	1.7E-02	1.8E-02	1.4E-02	1.3E-02	1.3E-02	1.2E-02
Lea	1.2E-02	1.1E-02	3.2E-02	2.2E-02	2.0E-02	1.7E-02	1.3E-02
Lincoln	1.2E-02	1.4E-02	2.4E-02	2.0E-02	1.6E-02	1.3E-02	1.2E-02
Luna	1.5E-02	1.3E-02	4.8E-02	3.2E-02	2.8E-02	2.3E-02	1.7E-02
McKinley	1.6E-02	1.6E-02	4.3E-02	3.0E-02	2.7E-02	2.3E-02	1.8E-02
Mora	–	–	–	–	–	–	–
Otero	1.2E-02	1.8E-02	2.7E-02	2.1E-02	1.8E-02	1.5E-02	1.3E-02
Quay	3.2E-02	3.4E-02	5.1E-02	4.2E-02	3.9E-02	3.6E-02	3.3E-02
Rio Arriba	3.8E-02	4.2E-02	7.3E-02	5.7E-02	5.3E-02	4.7E-02	4.1E-02
Roosevelt	9.2E-03	1.0E-02	1.5E-02	1.2E-02	1.2E-02	1.1E-02	9.8E-03
Sandoval	4.5E-02	4.7E-02	8.7E-02	6.6E-02	6.1E-02	5.5E-02	4.8E-02
San Juan	1.2E-02	1.1E-02	3.6E-02	2.4E-02	2.2E-02	1.8E-02	1.4E-02
San Miguel	4.1E-01	6.1E-01	6.8E-01	5.2E-01	5.2E-01	5.7E-01	5.1E-01
Santa Fe	1.4E-01	2.1E-01	2.1E-01	1.7E-01	1.7E-01	1.7E-01	1.6E-01
Sierra	1.3E-02	1.6E-02	2.0E-02	1.6E-02	1.6E-02	1.5E-02	1.4E-02
Socorro	1.9E-01	2.1E-01	2.7E-01	2.2E-01	2.2E-01	2.0E-01	1.9E-01
Taos	1.4E-01	2.1E-01	2.4E-01	1.8E-01	1.8E-01	1.7E-01	1.5E-01
Torrance	3.0E+01	3.8E+01	4.1E+01	3.6E+01	3.6E+01	3.3E+01	3.0E+01
Union	–	–	–	–	–	–	–
Valencia	5.4E-02	5.5E-02	1.0E-01	7.7E-02	7.1E-02	6.4E-02	5.6E-02

Table 3E. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for Native Americans/Thyroid from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	1.5E+00	3.5E+00	9.2E+00	6.3E+00	4.6E+00	3.4E+00	1.8E+00
Catron	2.6E-01	4.9E-01	1.0E+00	7.5E-01	5.2E-01	4.4E-01	3.1E-01
Chaves	7.1E-01	1.6E+00	3.1E+00	2.2E+00	1.6E+00	1.3E+00	8.6E-01
Colfax	2.2E+00	4.9E+00	1.0E+01	7.8E+00	5.0E+00	3.7E+00	2.7E+00
Curry	1.4E-01	3.2E-01	6.2E-01	4.5E-01	3.2E-01	2.6E-01	1.7E-01
De Baca	8.2E-01	1.7E+00	3.2E+00	2.3E+00	1.7E+00	1.4E+00	9.8E-01
Dona Ana	2.6E-01	5.9E-01	1.5E+00	1.0E+00	7.5E-01	5.6E-01	3.1E-01
Eddy	2.6E-01	5.9E-01	1.5E+00	1.0E+00	7.5E-01	5.7E-01	3.1E-01
Grant	1.8E-01	5.7E-01	1.2E+00	9.3E-01	5.6E-01	3.5E-01	2.1E-01
Guadalupe	–	–	–	–	–	–	–
Harding	–	–	–	–	–	–	–
Hidalgo	2.0E-01	6.3E-01	7.4E-01	5.1E-01	3.9E-01	3.5E-01	2.4E-01
Lea	2.7E-01	6.2E-01	1.6E+00	1.1E+00	7.9E-01	6.0E-01	3.2E-01
Lincoln	5.6E-02	1.1E-01	6.7E-01	5.7E-01	2.6E-01	8.3E-02	6.6E-02
Luna	3.9E-01	9.7E-01	2.4E+00	1.7E+00	1.2E+00	9.2E-01	4.7E-01
McKinley	3.3E-01	7.6E-01	1.8E+00	1.3E+00	9.2E-01	7.1E-01	4.0E-01
Mora	–	–	–	–	–	–	–
Otero	1.3E-01	4.3E-01	9.2E-01	7.0E-01	4.0E-01	2.4E-01	1.6E-01
Quay	4.1E-01	8.8E-01	1.6E+00	1.2E+00	8.3E-01	7.1E-01	4.9E-01
Rio Arriba	4.8E-01	1.1E+00	2.4E+00	1.8E+00	1.2E+00	8.9E-01	5.7E-01
Roosevelt	1.4E-01	3.3E-01	6.5E-01	4.6E-01	3.4E-01	2.7E-01	1.8E-01
Sandoval	6.2E-01	1.4E+00	2.8E+00	2.0E+00	1.4E+00	1.1E+00	7.3E-01
San Juan	3.0E-01	6.9E-01	1.8E+00	1.2E+00	9.0E-01	6.7E-01	3.6E-01
San Miguel	7.0E+00	2.1E+01	3.2E+01	2.2E+01	1.7E+01	1.6E+01	1.0E+01
Santa Fe	1.2E+00	4.1E+00	4.0E+00	2.7E+00	2.0E+00	2.0E+00	1.5E+00
Sierra	1.0E-01	2.5E-01	4.1E-01	3.0E-01	2.0E-01	1.7E-01	1.2E-01
Socorro	8.1E-01	1.6E+00	2.7E+00	1.9E+00	1.4E+00	1.3E+00	9.2E-01
Taos	2.5E+00	7.9E+00	9.3E+00	6.4E+00	4.9E+00	4.4E+00	3.0E+00
Torrance	7.7E+01	1.4E+02	3.5E+02	2.7E+02	1.6E+02	1.0E+02	8.4E+01
Union	–	–	–	–	–	–	–
Valencia	7.2E-01	1.6E+00	3.4E+00	2.4E+00	1.7E+00	1.4E+00	8.5E-01

Table 4A. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for African Americans/Colon from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	2.0E-02	1.5E-01	1.5E-01	9.0E-02	9.3E-02	9.0E-02	8.7E-02
Catron	4.3E-02	5.9E-02	8.3E-01	4.8E-01	4.1E-01	2.9E-01	2.0E-01
Chaves	2.7E-01	4.9E-01	1.7E+00	1.3E+00	1.2E+00	9.4E-01	8.2E-01
Colfax	7.0E-03	1.1E-02	5.5E-02	3.9E-02	3.6E-02	2.7E-02	2.1E-02
Curry	–	–	–	–	–	–	–
De Baca	1.2E-02	4.0E-02	4.7E-01	3.3E-01	2.7E-01	1.7E-01	1.2E-01
Dona Ana	1.1E-02	1.6E-02	5.6E-01	3.3E-01	2.7E-01	1.8E-01	1.1E-01
Eddy	1.4E-02	1.1E-01	5.1E-01	4.1E-01	3.4E-01	2.0E-01	1.4E-01
Grant	2.6E+00	3.9E+00	2.0E+01	1.4E+01	1.4E+01	1.1E+01	9.6E+00
Guadalupe	2.5E-02	4.3E-02	1.9E-01	1.4E-01	1.3E-01	1.0E-01	8.4E-02
Harding	9.9E-03	9.7E-02	1.1E-01	7.3E-02	7.4E-02	6.6E-02	6.0E-02
Hidalgo	1.1E-02	1.4E-02	6.0E-01	3.3E-01	2.7E-01	1.8E-01	1.1E-01
Lea	2.9E-01	4.6E-01	1.4E+00	1.1E+00	9.7E-01	7.3E-01	6.2E-01
Lincoln	1.7E-02	4.6E-02	7.0E-01	6.1E-01	4.9E-01	2.9E-01	2.2E-01
Luna	1.6E-02	1.1E-01	5.0E-01	4.2E-01	3.5E-01	2.2E-01	1.7E-01
McKinley	3.2E-01	5.4E-01	2.5E+00	1.8E+00	1.7E+00	1.3E+00	1.1E+00
Mora	1.3E-02	8.4E-02	4.0E-01	3.3E-01	2.8E-01	1.8E-01	1.4E-01
Otero	2.7E-02	4.4E-02	1.9E-01	1.4E-01	1.3E-01	1.0E-01	8.5E-02
Quay	2.2E-02	4.1E-02	4.2E-01	3.3E-01	2.6E-01	1.4E-01	8.3E-02
Rio Arriba	8.1E-03	1.5E-02	6.4E-02	4.7E-02	4.4E-02	3.3E-02	2.7E-02
Roosevelt	4.5E-02	1.3E-01	6.7E-01	5.3E-01	4.6E-01	3.1E-01	2.4E-01
Sandoval	1.2E-02	3.0E-02	4.4E-01	3.8E-01	3.1E-01	1.9E-01	1.4E-01
San Juan	4.8E-01	4.4E+00	5.6E+00	3.5E+00	3.6E+00	3.3E+00	2.8E+00
San Miguel	2.1E-01	1.4E+00	5.8E+00	3.7E+00	3.2E+00	2.3E+00	1.7E+00
Santa Fe	1.0E-02	1.6E-02	8.1E-02	5.7E-02	5.4E-02	4.4E-02	3.7E-02
Sierra	1.4E-01	2.1E-01	4.4E-01	3.1E-01	3.1E-01	2.8E-01	2.7E-01
Socorro	5.5E-02	9.9E-02	5.4E-01	4.1E-01	3.4E-01	2.1E-01	1.6E-01
Taos	–	–	–	–	–	–	–
Torrance	3.3E-02	7.8E-02	2.7E-01	1.9E-01	1.8E-01	1.4E-01	1.2E-01
Union	4.4E-02	7.4E-02	6.4E-01	5.2E-01	4.4E-01	2.9E-01	2.2E-01
Valencia	2.0E-02	1.5E-01	1.5E-01	9.0E-02	9.3E-02	9.0E-02	8.7E-02

Table 4B. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for African Americans/Lung from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	7.6E-02	6.9E-02	1.0E-01	8.6E-02	9.9E-02	9.0E-02	7.1E-02
Catron	1.8E-02	2.7E-02	3.0E-02	2.6E-02	2.8E-02	2.7E-02	2.4E-02
Chaves	4.1E-02	5.9E-02	7.0E-02	6.8E-02	8.5E-02	8.0E-02	6.4E-02
Colfax	2.5E-01	4.3E-01	5.3E-01	4.7E-01	5.7E-01	5.5E-01	4.8E-01
Curry	6.7E-03	1.1E-02	1.2E-02	1.2E-02	1.6E-02	1.5E-02	1.2E-02
De Baca	–	–	–	–	–	–	–
Dona Ana	1.2E-02	1.2E-02	1.6E-02	1.4E-02	1.6E-02	1.5E-02	1.3E-02
Eddy	1.1E-02	1.1E-02	1.6E-02	1.4E-02	1.7E-02	1.6E-02	1.3E-02
Grant	1.3E-02	1.3E-02	1.6E-02	1.4E-02	1.6E-02	1.5E-02	1.3E-02
Guadalupe	2.2E+00	3.1E+00	3.7E+00	3.2E+00	3.5E+00	3.4E+00	3.0E+00
Harding	2.3E-02	3.7E-02	4.5E-02	4.0E-02	4.7E-02	4.5E-02	3.9E-02
Hidalgo	8.3E-03	1.2E-02	1.4E-02	1.3E-02	1.5E-02	1.4E-02	1.3E-02
Lea	1.1E-02	1.1E-02	1.6E-02	1.4E-02	1.7E-02	1.6E-02	1.3E-02
Lincoln	2.7E-01	3.9E-01	4.5E-01	4.0E-01	4.2E-01	4.1E-01	3.6E-01
Luna	1.8E-02	1.3E-02	1.8E-02	1.6E-02	1.7E-02	1.6E-02	1.4E-02
McKinley	1.5E-02	1.4E-02	1.8E-02	1.6E-02	1.7E-02	1.6E-02	1.4E-02
Mora	2.9E-01	4.7E-01	5.6E-01	5.0E-01	5.8E-01	5.7E-01	4.9E-01
Otero	1.2E-02	1.3E-02	1.6E-02	1.4E-02	1.6E-02	1.5E-02	1.3E-02
Quay	2.4E-02	3.7E-02	4.4E-02	3.9E-02	4.4E-02	4.2E-02	3.7E-02
Rio Arriba	2.2E-02	3.6E-02	4.5E-02	4.0E-02	4.8E-02	4.6E-02	4.0E-02
Roosevelt	7.5E-03	1.2E-02	1.4E-02	1.3E-02	1.5E-02	1.4E-02	1.2E-02
Sandoval	4.0E-02	5.1E-02	6.2E-02	5.5E-02	6.0E-02	5.7E-02	5.1E-02
San Juan	1.2E-02	1.2E-02	1.6E-02	1.4E-02	1.6E-02	1.5E-02	1.3E-02
San Miguel	4.0E-01	5.7E-01	6.5E-01	6.3E-01	7.7E-01	7.5E-01	5.9E-01
Santa Fe	1.4E-01	2.6E-01	4.8E-01	3.8E-01	4.0E-01	3.2E-01	2.3E-01
Sierra	8.9E-03	1.3E-02	1.5E-02	1.3E-02	1.5E-02	1.4E-02	1.3E-02
Socorro	1.4E-01	2.0E-01	3.6E-01	2.7E-01	2.9E-01	2.9E-01	2.8E-01
Taos	5.5E-02	1.0E-01	5.5E-01	4.3E-01	3.8E-01	2.6E-01	2.0E-01
Torrance	–	–	–	–	–	–	–
Union	4.0E-02	5.9E-02	7.9E-02	7.1E-02	8.5E-02	8.3E-02	7.1E-02
Valencia	3.9E-02	4.9E-02	9.3E-02	7.8E-02	7.6E-02	6.2E-02	5.0E-02

Table 4C. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for African Americans/RBM from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	8.9E-01	6.4E-02	3.1E-01	1.8E-01	2.0E-01	2.1E-01	9.7E-02
Catron	3.4E-02	3.6E-02	2.7E-02	2.2E-02	2.2E-02	2.2E-02	1.9E-02
Chaves	1.8E-01	4.6E-02	8.9E-02	6.7E-02	7.5E-02	7.2E-02	4.5E-02
Colfax	4.2E-01	3.2E-01	3.8E-01	3.2E-01	3.1E-01	3.0E-01	2.6E-01
Curry	1.1E-02	8.2E-03	9.7E-03	9.0E-03	9.9E-03	9.2E-03	6.9E-03
De Baca	–	–	–	–	–	–	–
Dona Ana	1.3E-01	1.9E-02	3.7E-02	2.6E-02	2.9E-02	2.9E-02	1.5E-02
Eddy	1.3E-01	1.2E-02	4.2E-02	2.7E-02	3.0E-02	3.0E-02	1.5E-02
Grant	1.8E-01	3.2E-02	4.7E-02	3.7E-02	4.2E-02	3.7E-02	1.8E-02
Guadalupe	3.9E+00	2.7E+00	3.3E+00	2.7E+00	2.7E+00	2.6E+00	2.2E+00
Harding	3.9E-02	2.9E-02	3.5E-02	2.9E-02	2.9E-02	2.8E-02	2.3E-02
Hidalgo	1.9E-02	1.6E-02	1.3E-02	1.0E-02	1.0E-02	1.1E-02	8.5E-03
Lea	1.3E-01	1.0E-02	4.5E-02	2.7E-02	3.0E-02	3.1E-02	1.5E-02
Lincoln	4.2E-01	3.5E-01	4.1E-01	3.5E-01	3.3E-01	3.1E-01	2.7E-01
Luna	3.6E-01	4.6E-02	6.5E-02	5.4E-02	6.2E-02	5.8E-02	2.8E-02
McKinley	1.7E-01	3.2E-02	3.9E-02	3.2E-02	3.5E-02	3.3E-02	1.9E-02
Mora	5.0E-01	3.7E-01	4.5E-01	3.7E-01	3.6E-01	3.5E-01	3.0E-01
Otero	1.4E-01	2.6E-02	3.2E-02	2.6E-02	2.9E-02	2.7E-02	1.6E-02
Quay	4.0E-02	3.1E-02	3.7E-02	3.1E-02	3.0E-02	2.9E-02	2.5E-02
Rio Arriba	7.4E-02	3.0E-02	5.2E-02	4.1E-02	4.1E-02	3.5E-02	2.3E-02
Roosevelt	1.3E-02	9.5E-03	1.1E-02	9.6E-03	9.3E-03	9.0E-03	7.6E-03
Sandoval	1.9E-01	6.1E-02	7.7E-02	6.3E-02	6.5E-02	6.2E-02	4.4E-02
San Juan	1.6E-01	2.4E-02	3.5E-02	2.9E-02	3.3E-02	3.0E-02	1.6E-02
San Miguel	9.4E-01	7.1E-01	5.9E-01	5.2E-01	6.0E-01	6.1E-01	4.2E-01
Santa Fe	4.3E-01	2.3E-01	3.6E-01	3.0E-01	3.1E-01	2.7E-01	1.3E-01
Sierra	1.5E-02	1.1E-02	1.3E-02	1.1E-02	1.1E-02	1.1E-02	9.0E-03
Socorro	1.5E-01	1.7E-01	1.9E-01	1.6E-01	1.5E-01	1.4E-01	1.3E-01
Taos	1.2E-01	7.2E-02	9.9E-02	8.1E-02	7.8E-02	7.1E-02	5.6E-02
Torrance	–	–	–	–	–	–	–
Union	8.4E-02	6.1E-02	7.5E-02	6.2E-02	6.1E-02	5.9E-02	5.0E-02
Valencia	1.9E-01	5.7E-02	7.5E-02	6.3E-02	6.4E-02	6.0E-02	4.3E-02

Table 4D. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for African Americans/Stomach from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	7.6E-02	6.0E-02	2.9E-01	1.8E-01	1.6E-01	1.3E-01	8.9E-02
Catron	2.3E-02	4.1E-02	3.6E-02	2.7E-02	2.6E-02	2.6E-02	2.4E-02
Chaves	4.2E-02	4.6E-02	9.1E-02	7.0E-02	6.9E-02	6.1E-02	4.6E-02
Colfax	2.6E-01	3.3E-01	4.3E-01	3.5E-01	3.2E-01	3.0E-01	2.8E-01
Curry	7.0E-03	8.3E-03	1.1E-02	1.0E-02	1.0E-02	9.3E-03	7.3E-03
De Baca	–	–	–	–	–	–	–
Dona Ana	1.2E-02	1.2E-02	3.5E-02	2.6E-02	2.2E-02	1.8E-02	1.4E-02
Eddy	1.1E-02	9.2E-03	4.0E-02	2.6E-02	2.3E-02	1.9E-02	1.3E-02
Grant	1.3E-02	1.7E-02	3.6E-02	2.9E-02	2.4E-02	1.9E-02	1.5E-02
Guadalupe	2.5E+00	2.8E+00	4.2E+00	3.3E+00	3.1E+00	2.9E+00	2.6E+00
Harding	2.5E-02	3.0E-02	4.1E-02	3.3E-02	3.1E-02	2.8E-02	2.6E-02
Hidalgo	9.5E-03	1.6E-02	1.6E-02	1.2E-02	1.2E-02	1.2E-02	1.0E-02
Lea	1.1E-02	8.8E-03	4.2E-02	2.6E-02	2.3E-02	1.9E-02	1.3E-02
Lincoln	3.0E-01	3.6E-01	4.8E-01	3.9E-01	3.6E-01	3.3E-01	3.0E-01
Luna	1.7E-02	1.4E-02	4.6E-02	3.9E-02	3.2E-02	2.4E-02	1.9E-02
McKinley	1.6E-02	1.9E-02	4.0E-02	3.2E-02	2.8E-02	2.3E-02	1.9E-02
Mora	3.1E-01	3.7E-01	5.2E-01	4.2E-01	3.9E-01	3.6E-01	3.3E-01
Otero	1.3E-02	1.6E-02	3.2E-02	2.6E-02	2.3E-02	1.9E-02	1.5E-02
Quay	2.7E-02	3.2E-02	4.4E-02	3.6E-02	3.3E-02	3.1E-02	2.8E-02
Rio Arriba	2.2E-02	2.7E-02	5.0E-02	4.0E-02	3.4E-02	2.8E-02	2.3E-02
Roosevelt	7.9E-03	9.6E-03	1.3E-02	1.1E-02	1.0E-02	9.2E-03	8.3E-03
Sandoval	4.5E-02	5.1E-02	8.7E-02	7.0E-02	6.3E-02	5.5E-02	4.8E-02
San Juan	1.2E-02	1.1E-02	3.3E-02	2.8E-02	2.3E-02	1.8E-02	1.4E-02
San Miguel	4.6E-01	7.6E-01	7.9E-01	6.4E-01	6.8E-01	6.6E-01	5.3E-01
Santa Fe	1.9E-01	2.4E-01	6.4E-01	4.6E-01	4.1E-01	3.3E-01	2.1E-01
Sierra	1.0E-02	1.1E-02	1.7E-02	1.4E-02	1.3E-02	1.2E-02	1.1E-02
Socorro	1.4E-01	1.7E-01	2.1E-01	1.7E-01	1.6E-01	1.5E-01	1.4E-01
Taos	5.5E-02	6.9E-02	1.0E-01	8.1E-02	7.2E-02	6.3E-02	5.7E-02
Torrance	–	–	–	–	–	–	–
Union	5.9E-02	6.9E-02	9.7E-02	7.9E-02	7.4E-02	6.8E-02	6.1E-02
Valencia	4.4E-02	4.6E-02	8.6E-02	7.0E-02	6.2E-02	5.3E-02	4.6E-02

Table 4E. Estimates of precinct population-weighted average radiation absorbed doses (mGy) by county and age group for African Americans/Thyroid from all sources of internal and external exposure to fallout radionuclides (as discussed in the text). Doses rounded to two significant digits except those less than 0.01 mGy are rounded to one digit.

	AGE GROUP (yrs)						
COUNTY	In-utero	0–1	1–2	3–7	8–12	13–17	Adult (18+)
Bernalillo	1.8E+00	5.0E-01	1.5E+01	8.8E+00	5.9E+00	4.5E+00	2.2E+00
Catron	2.6E-01	1.0E+00	1.1E+00	8.4E-01	6.2E-01	5.1E-01	3.1E-01
Chaves	5.1E-01	1.3E-01	3.4E+00	2.2E+00	1.5E+00	1.2E+00	6.1E-01
Colfax	3.2E+00	8.0E+00	1.5E+01	1.4E+01	9.6E+00	6.8E+00	4.0E+00
Curry	1.0E-01	2.7E-02	7.4E-01	4.6E-01	3.2E-01	2.5E-01	1.3E-01
De Baca	–	–	–	–	–	–	–
Dona Ana	3.0E-01	5.4E-01	1.7E+00	1.4E+00	9.2E-01	6.7E-01	3.7E-01
Eddy	2.9E-01	2.2E-01	2.1E+00	1.4E+00	9.2E-01	7.0E-01	3.5E-01
Grant	3.1E-01	9.3E-01	1.6E+00	1.5E+00	1.0E+00	6.9E-01	3.7E-01
Guadalupe	3.1E+01	7.0E+01	1.2E+02	1.0E+02	7.4E+01	5.8E+01	3.7E+01
Harding	2.8E-01	6.7E-01	1.2E+00	1.0E+00	7.3E-01	5.6E-01	3.4E-01
Hidalgo	1.7E-01	5.8E-01	6.2E-01	5.1E-01	3.8E-01	3.2E-01	2.1E-01
Lea	3.1E-01	1.4E-01	2.4E+00	1.5E+00	9.9E-01	7.6E-01	3.7E-01
Lincoln	1.6E+00	3.5E+00	6.7E+00	5.8E+00	4.2E+00	3.0E+00	1.9E+00
Luna	4.9E-01	1.3E+00	2.3E+00	2.2E+00	1.5E+00	1.0E+00	6.0E-01
McKinley	4.1E-01	1.1E+00	1.8E+00	1.6E+00	1.1E+00	8.1E-01	4.9E-01
Mora	3.4E+00	8.0E+00	1.4E+01	1.2E+01	8.6E+00	6.7E+00	4.2E+00
Otero	3.4E-01	9.2E-01	1.5E+00	1.4E+00	9.6E-01	6.9E-01	4.1E-01
Quay	2.9E-01	6.7E-01	1.2E+00	1.0E+00	7.4E-01	5.7E-01	3.5E-01
Rio Arriba	2.1E-01	4.8E-01	1.8E+00	1.5E+00	1.0E+00	5.9E-01	2.5E-01
Roosevelt	1.2E-01	3.0E-01	5.4E-01	4.9E-01	3.4E-01	2.5E-01	1.5E-01
Sandoval	5.8E-01	1.4E+00	2.5E+00	2.2E+00	1.5E+00	1.1E+00	6.9E-01
San Juan	3.5E-01	8.3E-01	1.6E+00	1.6E+00	1.1E+00	7.3E-01	4.3E-01
San Miguel	1.0E+01	1.2E+01	5.9E+01	3.7E+01	2.7E+01	2.3E+01	1.3E+01
Santa Fe	4.1E+00	1.1E+01	2.3E+01	1.6E+01	1.1E+01	8.7E+00	5.1E+00
Sierra	1.2E-01	2.6E-01	4.6E-01	3.8E-01	2.8E-01	2.2E-01	1.4E-01
Socorro	4.4E-01	8.2E-01	1.4E+00	1.2E+00	8.6E-01	7.0E-01	4.8E-01
Taos	4.3E-01	1.0E+00	3.0E+00	2.5E+00	1.7E+00	1.1E+00	5.2E-01
Torrance	–	–	–	–	–	–	–
Union	7.1E-01	1.7E+00	2.9E+00	2.6E+00	1.9E+00	1.4E+00	8.7E-01
Valencia	5.9E-01	1.3E+00	2.7E+00	2.4E+00	1.7E+00	1.2E+00	7.1E-01