The Assessment of Radiation Exposures in Native American Communities from Nuclear Weapons Testing in Nevada

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The Assessment of Radiation Exposures in Native American Communities from Nuclear Weapons Testing in Nevada

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Native Americans residing in a broad region downwind from the Nevada Test Site during the 1950s and 1960s received significant radiation exposures from nuclear weapons testing. Because of differences in diet, activities, and housing, their radiation exposures are only very imperfectly represented in the Department of Energy dose reconstructions. There are important missing pathways, including exposures to radioactive iodine from eating small game. The dose reconstruction model assumptions about cattle feeding practices across a year are unlikely to apply to the native communities as are other model assumptions about diet. Thus exposures from drinking milk and eating vegetables have not yet been properly estimated for these communities. Through consultations with members of the affected communities, these deficiencies could be corrected and the dose reconstruction extended to Native Americans. An illustration of the feasibility of extending the dose reconstruction is provided by a sample calculation to estimate radiation exposures to the thyroid from eating radio-iodine-contaminated rabbit thyroids after the Sedan test. The illustration is continued with a discussion of how the calculation results may be used to make estimates for other tests and other locations.

KEY WORDS: Native American; dose reconstruction; radiation; nuclear testing; Nevada

1. INTRODUCTION

The Nevada Test Site (NTS) was selected in 1950 as the prime U.S. continental location for nuclear weapons testing. In part it was chosen for "its climate, remoteness, the low population density in the area, and the fact that the adjoining Nellis Air Force Base Bombing and Gunnery Range . . . minimized risk to public safety while providing added security."[1] Substantial amounts of radiation were released from nuclear weapons tests and this radiation traveled long distances. Hence remoteness and low population density did not mean there were no significant exposures. Faced with public concerns and lawsuits, the Department of Energy (DOE) began in 1979 its estimates of radiation doses from nuclear weapons testing at NTS, with the Off-Site Radiation Exposure Review Project (ORERP).[2,3]

> The ultimate goal was to be able to estimate the potential dose to any person who lived in an area where fallout from the NTS was deposited, based on that person's age, occupation, and place of residence. Both external and internal doses were to be considered and the calculations were to use actual data (as opposed to assumed values) if appropriate data could be found. (3, p. 470)

This was the first of DOE's major dose reconstructions, estimates of the radiation exposures that people may have received from living downwind of nuclear production and testing.[4] As such it was a major accomplishment and had considerable influence. The models developed were used as templates for

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other dose reconstructions, such as the Hanford Environmental Dose Reconstruction Project, and provided experience in collecting and evaluating a wide variety of historical data.[2,5,6] Because it was early in the learning process there were also difficulties and deficiencies in the effort. The computational effort was very complex and is thus difficult to adapt to answering new questions. The importance of public involvement in obtaining information, in reviewing the models, in interpreting results, and in developing public confidence in the results[4] was not recognized. No concerted effort was made for identifying subpopulations with special lifestyle characteristics, despite the strong influence lifestyle, especially diet, had on exposure. Some recent efforts at dose reconstruction for native populations are described by Harris and Harper and by Simon and Graham.[7,8] Furthermore, at that time stakeholder involvement in planning and design of the study as contemplated, for instance, in the NAS report *Understanding Risk*[9] and explored to some extent in later Hanford studies,[7] was not even considered.

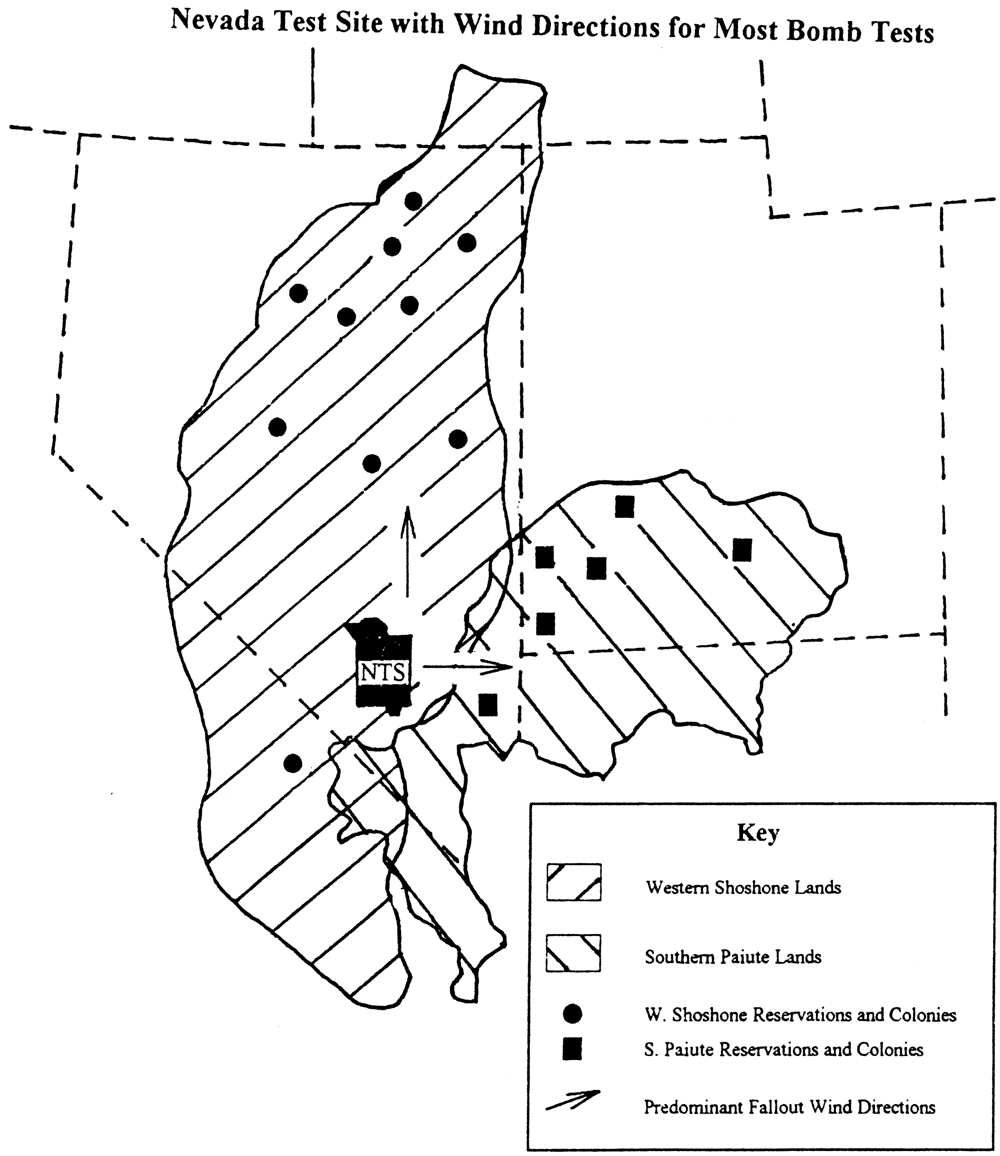

Fig. 1. Traditional lands of the Western Shoshone and Southern Paiutes. The Nevada Test Site is shown in the center; two arrows indicate the most frequent wind directions for nuclear tests, chosen to avoid transport in the direction of major southwestern cities.

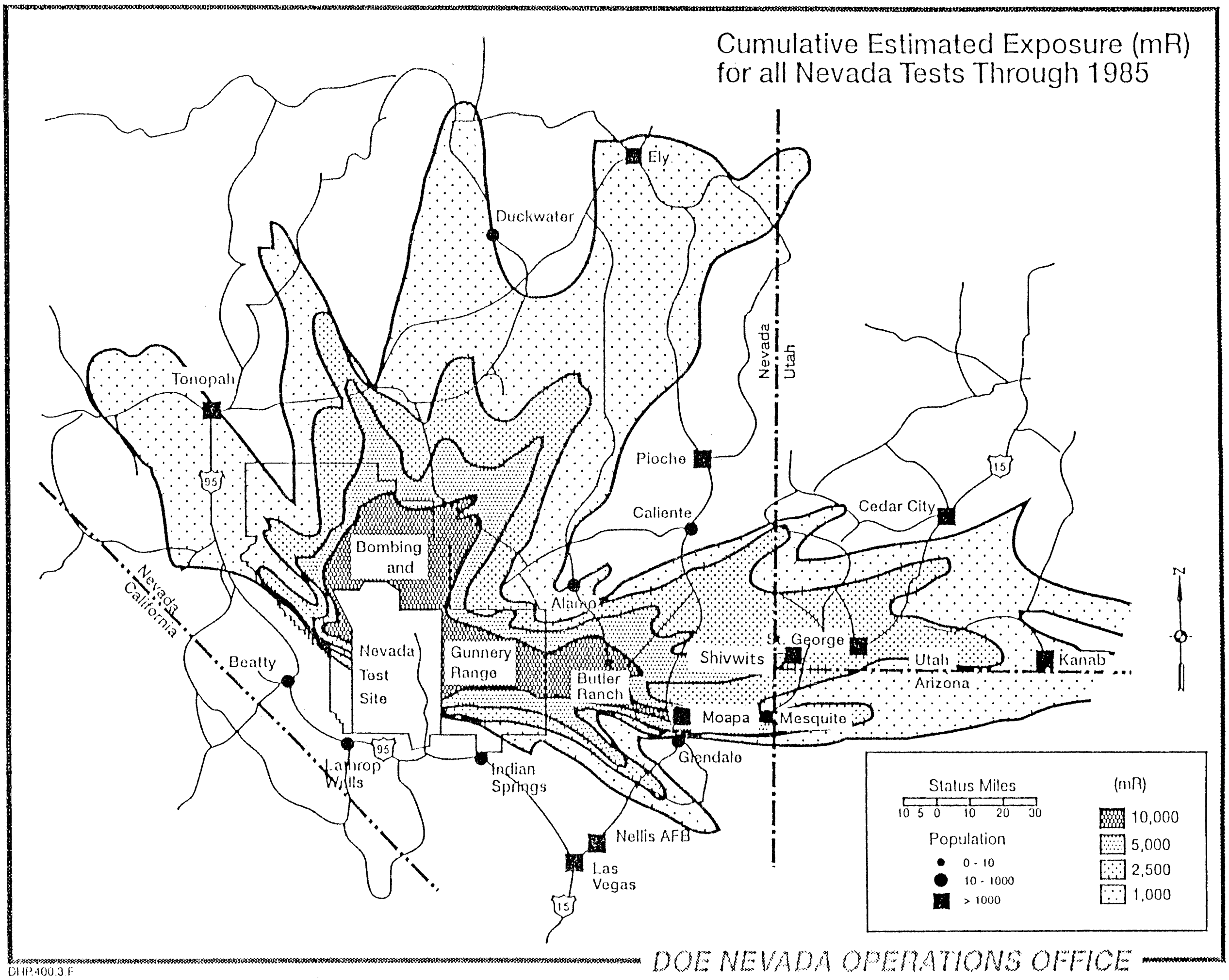

Fig. 2. Spatial distribution of the cumulative external exposures from nuclear weapons testing at the Nevada Test Site through the period of testing (1951–1972) as estimated in the ORERP. The heaviest exposures occur downwind in the directions indicated by the arrows in Fig. 1.

Among the populations with the largest exposure to nuclear testing were Western Shoshone and Southern Paiutes. Their traditional lands are shown in Fig. 1. The lands surround the Nevada Test Site and occupy the areas that were downwind for most of the tests. Isopleths for external radiation exposures from nuclear weapons testing at NTS to date are shown in Fig. 2. The two figures together suggest that radiation exposures to Western Shoshone and Southern Paiute communities may be of concern and raise the further concern of whether the ORERP dose reconstruction provides an adequate description of such exposures.

This paper explores these two concerns by attempting to answer the following questions:

1. Were significant radiation exposures received by members of Western Shoshone and Southern Paiute communities as a result of nuclear weapons testing in Nevada?
2. Does DOE dose reconstruction provide an adequate basis for assessing these exposures?
3. Can the inadequacies of the dose reconstruction be remedied by using information that DOE has already?
4. On the basis of presently available information, approximately how severe were the radiation doses received by community members, particularly those doses not adequately described in the DOE dose reconstruction?
5. Assuming additional information will be needed for any dose reconstruction, what is a suitable approach to obtaining such information and to designing the dose reconstruction?

Although our analysis directed to the first four questions is conducted by using methods compatible with the DOE reconstruction, we expect that creation of a dose reconstruction that will be useful to affected communities will involve a reformulation of the questions asked and, correspondingly, adjustments to the analytical methods and the information base. Such reformulations have not been made by communities around the test site, and our concern in question (5) is with who participates in designing and conducting studies.

2. KEY RESULTS FROM THE OFF-SITE RADIATION EXPOSURE REVIEW PROJECT FOR THE NEVADA TEST SITE

The DOE Dose Reconstruction for the Nevada Test Site was the first major effort by DOE to compile estimates of radiation doses resulting from its facilities. Like other efforts, it was developed in response to expressed public concerns and actual or potential lawsuits. The methods used and the models developed have strongly influenced subsequent dose reconstruction efforts. The initial challenge was to assess the historical information available for its suitability in estimating doses. As described by Thompson and McArthur:[3]

> Ideally, dose calculations for areas affected by fallout from nuclear tests at the NTS would be based on external radiation exposures and on levels of radiation in the air, food, and water consumed by residents in the days and weeks after a test. Although these quantities were measured in some places and for some tests, there were not enough such data to allow all the necessary doses to be calculated. Instead a computational scheme was developed that used historical data on fallout deposition as the fundamental data set and used computer models of ingestion, inhalation, and external exposure as the mechanism for calculating dose . . . (p. 470)

Accordingly, the historical data base included (1) extensive but scattered measurements of radiation and radioactivity after the tests; these measurements were, however, taken for other purposes than assessing doses to members of the population; and (2) survey information on agricultural practices and markets and on lifestyles of the exposed population. The computational scheme used this information to develop estimates of external and internal doses. External doses were based on measurements of total radioactivity after each test. Internal doses used the same deposition data and depended on models for food production and consumption based on the survey data. The DOE dose reconstruction did not provide for significant public participation in the design of the study or in the development of its information; nor did it provide for any participation in the review of the methods and models or in the assessment of results.

Native Americans were not included in the surveys and the dose reconstruction did not specifically identify Native American lifestyle characteristics, including agricultural, hunting and gathering practices and diets. When asked to provide dose estimates to representative members of Native American communities, DOE gave estimates for a "shepherd lifestyle" as representative of an outdoor lifestyle.[10]

The DOE estimates indicate that external whole body exposures were significant, on the order of 10 mSv (1 Rem), for residents of many Native American communities such as Duckwater, Ely, and Moapa, and external exposures at some locations off-site in Nevada and Utah were substantially greater.[3,10] Internal dose estimates for most organs were smaller; however, doses to the thyroid were as much as .1–.2 Sv (10–20 Rem) for adults, and in excess of 1 Sv (100 REM) for small children.[3,10][4] There is substantial uncertainty in these estimates as well as considerable interindividual variability in the doses received by individuals residing in the same location at the same times.[5] However, quantitative estimates of the uncertainty and variability are not routinely provided in the ORERP materials.

How well do the dose estimates for the shepherd lifestyle represent what happened to Native Americans at the various locations? The lifestyle may describe external exposures with reasonable accuracy. Before concluding this, however, several questions should be answered. One is to what extent the mobility of these populations, who traveled extensively to hunt, gather pine nuts, and visit relatives, affects exposure estimates based on residence. In particular, hunting and gathering pine nuts may have led people to travel relatively close to the NTS. A second question is whether terrain and special meteorological conditions (such as fog) will have systematic effects on deposition at locations—particularly high altitude

[4] The next highest internal doses were to the lower digestive tract, which reflects the passage of a variety of insoluble radionuclides.

[5] The importance of distinguishing uncertainty from variability is discussed at length in the National Academy report Science and Judgment in Risk Assessment.[11] Variability represents actual differences in people's experience, whereas uncertainty represents lack of knowledge. The two have very different implications in most practical situations.[12]

locations—which were used by people but remote from the roads where radiation measurements were made. It is clear from experience with Chernobyl(13) and from acid deposition studies(14) that there can be very substantial local variation in amounts deposited. A third question is whether other specific aspects of lifestyle affect external exposures significantly: did the use of fur and fresh basket material contribute significantly to exposure? The effect of taking these issues into account will surely be to increase the estimated variability in doses; it may increase the mean dose estimates as well.

For internal exposures, the shepherd lifestyle is clearly unrepresentative: it ignores the contribution of hunting to the diet; this represents a missing pathway from the DOE analysis. It is very likely that the DOE assumptions about how cattle and other livestock were fed during the year do not apply,[6] and the DOE-assumed seasons for vegetables may not describe the collecting and eating of both fresh produce and wild vegetation within the native communities. Furthermore, the assumptions about variability in diet and in other individual characteristics must be examined anew for these populations. As a result the DOE estimates for internal doses cannot be relied upon; they are almost certainly underestimates because they neglect the important pathway of hunting and because the communities' cattle feeding practices rely less on stored feed.

3. FEASIBILITY OF CORRECTING THE DOE DOSE RECONSTRUCTION TO ACCOUNT FOR NATIVE LIFESTYLES

Two kinds of adjustments are needed in the dose reconstruction models: (1) models for missing pathways must be added, and (2) the included pathway models must be corrected to reflect Native American practices. The initial step must be a pathway analysis. This can be done effectively only in collaboration with the affected communities. Simon and Graham(8) observed at the conclusion of their work on dose assessment from nuclear weapons testing in the Marshall Islands:

> The single most important conceptual requirement for conducting valid assessments is recognizing important exposure pathways. . . . One lesson learned repeatedly in Marshall Islands studies has been to rely on local expertise to provide information important to acquiring an understanding of pathways. No better information can be produced than that provided by the population whose quality of life is under examination. (p. 453)

The ORERP modeling approach can be adapted naturally to an appropriate revision of the pathway analysis. This is because the DOE dose reconstruction creates an estimate of the amount of fallout for each test over the geographical areas of concern and because amounts of fallout are the starting point for estimating doses through all pathways. New information that pertains to each pathway is needed on how members of the Native American communities lived during the periods of testing. The required information can be developed reliably only by the communities. Furthermore, it is important to remember that lifestyles may well be different in different communities and among different tribes. Such information will vary by season and includes key elements of diet including practices in hunting and preparing game, agricultural practices, livestock management, and the collection of wild plants. Factors affecting external exposures include housing characteristics and outdoor living practices and the use of various natural materials. Members of the communities may have traveled substantially to hunt and to gather pine nuts, and many community members may have moved during the periods of testing. Therefore, information from the communities about people's movements may also be needed to relate to the geographical distribution of fallout from the various tests.

Hunting and eating game is at least one major pathway that does not appear in the present version of the model. To demonstrate the feasibility of adjusting the dose reconstruction, we present an illustrative model developed with particular Western Shoshone and Southern Paiute communities for one particular hunting pathway.

4. A MODEL FOR RADIO-IODINE DOSES FROM THE HUNTING AND EATING OF RABBITS[7]

Small game, especially rabbit,[8] was an important staple in the Western Shoshone and Southern Paiute

[6] For instance, Shoshone cattle supplying milk to community residents—the most important ORERP pathway—were grazing for more of the year than the ORERP assumptions indicate.

[7] Details on this model and the numerical assumptions appear in the MA thesis of Eric Frohmberg.(15)

[8] Other important animals hunted and eaten include Yellow-Bellied Marmot (*Marmota flaviventris*, locally called groundhogs), various species of ground squirrel (*Spermophilus spp.*), porcupines, sage hen, blue grouse, and dove.(16)

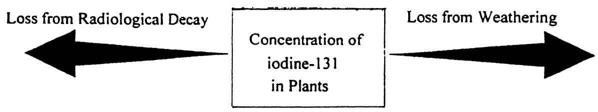

Fig. 3. Schematic illustrating the vegetation submodel.

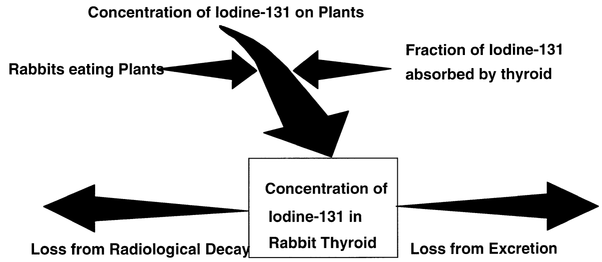

Fig. 4. Schematic illustrating the rabbit submodel.

diets during the period of testing. We have learned from the affected communities that very little of the animals was wasted, and, in particular, that the animal thyroids were routinely eaten.[9] On the basis of information from community members on rabbit hunting and on a set of measurements of radio-iodine in vegetation and in rabbit thyroids collected by DOE after the Sedan nuclear test in July 1962, we have constructed an illustrative model for radiation doses to the thyroid from eating jackrabbits.[10]

The model has three components: (1) a vegetation submodel, which describes variations in the amount of radio-iodine in vegetation and its disappearance with time; (2) a rabbit thyroid submodel, which relates the amount of radio-iodine in the rabbit thyroid to the amounts of radio-iodine in vegetation; and (3) a human dose model, which relates the dose to the human thyroid to the amount of radio-iodine in the rabbit thyroid. The third submodel uses Dunning and Schwart's ingestion dose coefficients[(17)] to estimate human doses. The three submodels are illustrated schematically in Figs. 3, 4, and 5.

After the Sedan test in 1962, DOE collected data on radio-iodine concentrations in vegetation and in rabbit thyroids at four locations (Groom Valley, Penoyer Valley, Railroad Valley, and Currant) for several weeks.[(18–21)] These data were used to define the vegetation and rabbit submodels. The approximate locations where vegetation and rabbit thyroid data were collected after the Sedan test are shown in Fig. 6.[11]

The vegetation submodel has three components: (1) a lognormal distribution fit to the data of Turner and Martin[(21)] describing the initial concentrations of radioactive iodine in vegetation at each of the four locations; (2) a lognormal distribution again representing a fit to the data of Turner and Martin[(21)] and describing weathering rates of the iodine from the vegetation; and (3) the radiological half-life of iodine-131, which is approximately 8 days.

The rabbit submodel uses the vegetation submodel as an input. It has four additional components: (1) a vegetation ingestion rate for the rabbits eating vegetation, chosen to be a narrow lognormal distribution following an argument of Turner;[(20)] only limited data are available on this factor; (2) a thyroid uptake factor representing the amount of ingested iodine that is absorbed and stored in the thyroid; again little data are available. We created a lognormal distribution by modifying Turner's argument[(20)] to use only absorption data pertaining to jackrabbits; (3) a biological half-life or excretion rate; again we modified Turner's estimated distribution[(20)] by using only data for jackrabbits in creating a lognormal distribution for this quantity; and (4) the half life for iodine-131.

The human submodel has two components: (1) a distribution describing a range of estimates for the number of rabbits people ate per week—this was based on a small survey of Western Shoshone and Southern Paiute community members and should not be regarded as having general application; and (2) dose-conversion estimates relating amounts of iodine ingested to doses; the coefficients and the lognormal distribution describing their variability were

[9] Cleaning methods minimize waste. A rabbit, marmot, or ground squirrel is gutted by removing the intestines through a slit either in the stomach or under the armpit. The intestines are discarded. Organs not discarded include the heart, lungs, liver, and upper gastrointestinal tract (including the esophagus and associated organs like the thyroid). When a larger mammal (such as a deer) is harvested, the esophagus would be removed and discarded because of its large size and ease of removal. As the esophagus is removed the thyroid would likely also be removed.[(16)]

[10] The Western Shoshone eat both black-tailed jackrabbits (*Lepus californica*) and white-tailed jackrabbits (*Lepus townsendii*). They also eat various species of cottontail rabbits (*Sylvilagus spp.*). Most of the measurements from the Sedan test were on jackrabbits and we use properties of jackrabbits (such as weight and weight of thyroid) in constructing the model. Cottontails and other small mammals would give similar results per weight of animal (amount of food provided).

[11] The Sedan test on July 6, 1962, was one of the largest tests at NTS. It was an approximately 100-kton test designed to produce a large crater. Sedan was part of the Plowshare project testing the use of nuclear weapons for excavation.[(22)] Although large, the test was not considered one of the dirtier tests (in terms of total U.S. fallout).[(6)]

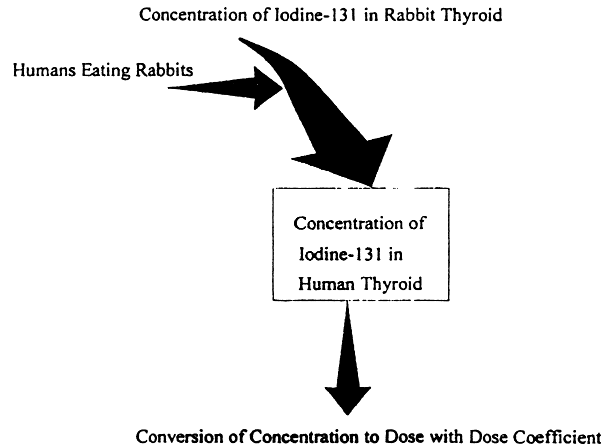

Fig. 5. Schematic illustrating the human submodel.

taken from Dunning and Schwarz.[17] These estimates and their variability have been reviewed by Ng;[23] they are similar to those found in ICRP 56 and Snyder et al. [24,25]

Predicted values from the vegetation and rabbit submodels were compared with measured concentrations of radio-iodine in vegetation and in rabbit thyroids for the four locations and for the various times of measurements (extending over 30 days after the Sedan test) with the data of Turner and Martin.[21] On average—for each location and time period—the predictions and data agreed within a factor of 3 and there were no obvious biases. The models thus provide a consistent representation of these data.

Developing illustrative dose estimates in steps is convenient. The dose to an individual from eating one rabbit after a test such as the Sedan test will depend on the location from which the rabbit was taken—because the amount of fallout was different at different locations; it will depend on the amount of time that elapsed after the test before shooting the rabbit—because radio-iodine first is added to the thyroid as the rabbit eats contaminated vegetation but then declines as the concentrations on vegetation decline from weathering and radioactive decay and as radio-iodine is lost from the rabbit by excretion and radioactive decay. The dose also depends on the age of the individual. Similarly, there will be considerable variability in the dose received from one rabbit compared with another, which reflects the variability described in each of the three submodels. An interesting initial step is to calculate the dose to an individual from eating one rabbit at the time a few days after the test when the concentrations of iodine in the rabbit thyroid were at their highest.

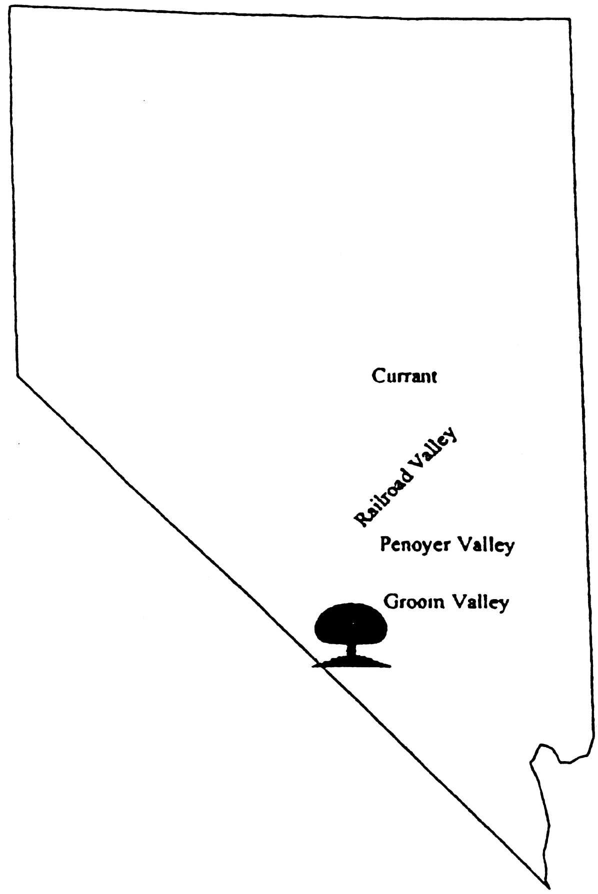

Fig. 6. Approximate locations where data were collected on concentrations of I-131 in vegetation and rabbit thyroids after the Sedan nuclear test in 1962.

- The average (mean) such dose to an adult (17+ years old) from eating a Groom Valley rabbit a few days after the Sedan test was approximately 10 mSv (1 REM) whereas 5% of adults would have had doses of approximately 30 mSv (3 REM). The mean dose to a small child (½–2 years old) from one Groom Valley rabbit would have been 90 mSv (9 REM), whereas 5% of children would have had doses of 0.3 Sv (30 REM).
- At Currant the corresponding (mean and 5th percent) a doses a few days after the Sedan test were .6 mSv (60 mrem) and 2 mSv (200 mrem), whereas the small child doses were 5 mSv (0.5 REM) and 16 mSv (1.6 REM), respectively.

There was even more variability in the expected doses people received from eating rabbits after the test because there was variability in the time after the

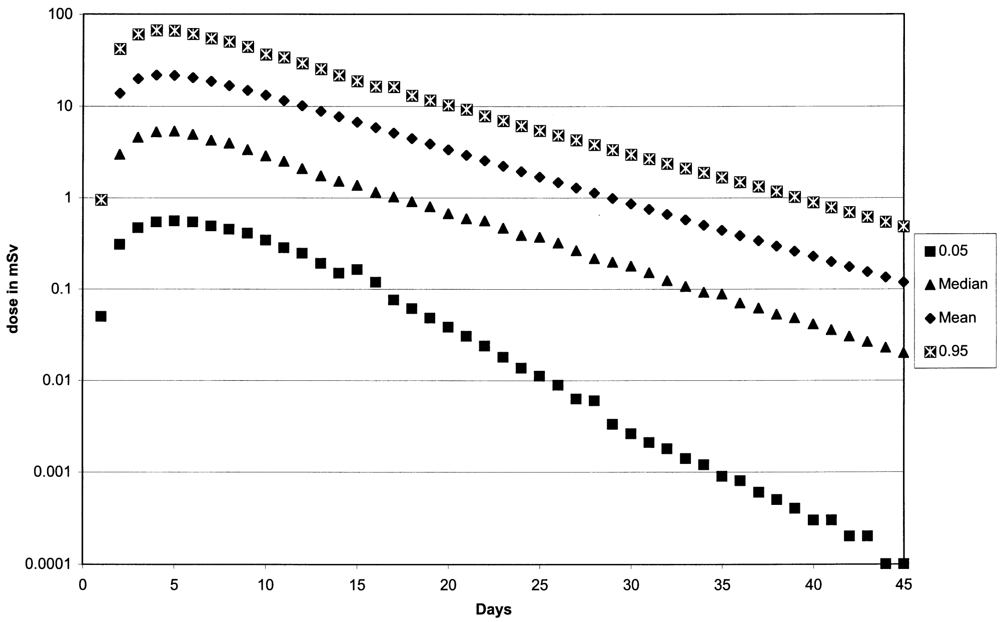

Fig. 7. The distribution of daily dose estimates (mSv) for a 1-year-old child eating rabbits taken from Groom Valley after the Sedan test according to the survey of rabbit consumption. Shown are 5th percentile, 50th percentile, mean, and 95th percentile estimates.

test when a particular rabbit may have been consumed, and there was also variability in the frequency with which people ate rabbits. As an illustration of the range of doses expected and their dependence on time after the test, we show in Figs. 7 and 8 daily dose estimates for a 3-year-old child (½–2 years old) consuming rabbit portions over time after the Sedan test, again for rabbits taken from Groom Valley (Fig. 7) and from Currant (Fig. 8). We use the survey results to estimate frequency of eating rabbits.

Accumulated doses from eating rabbits after the Sedan test may be found by summing the daily values. The result is approximately a factor of 3 times the peak dose from one rabbit described previously. Thus,

- The accumulated dose to be expected for typical consumption of rabbits taken from Groom Valley after the Sedan test is approximately 30 mSv (3 REM) for an average adult and .1 Sv (10 REM) for the most exposed 5%; the accumulated dose for small children is approximately 0.25 Sv (25 REM) for the average child and .8 Sv (80 REM) for the most exposed 5th percent
- The accumulated dose to be expected for typical consumption of rabbits taken from Currant after the Sedan test is approximately 1.8 mSv (180 mrem) for an average adult and 6 mSv (.6 REM) for the most exposed 5%; the accumulated dose for small children is approximately 15 mSv (1.5 REM) for the average child and 50 mSv (5 REM) for the most exposed 5th percent.

5. EXTENSION OF THE MODEL TO OTHER TESTS AND OTHER LOCATIONS

The model results may be used at other locations and for other tests by multiplying the results by the ratio of the amount of radio-iodine in fallout at the location and test of concern to the amount of radio-iodine in fallout for the Sedan test at Groom Valley or Currant.[26] The ORERP data base contains this information.[2,27,28] Making these adjustments will require combining the ORERP estimates of aggregate radioactive deposition for each nuclear test with test-specific multipliers developed by Hicks[26] for estimates of the amount of each radio nuclide deposited. A coherent development of this method, which should be pursued in the context of a revised dose reconstruction, would compare Martin and Turner's measurements and measurement methods[21] at the four locations with the ORERP and Hicks measurements, measurement methods, and interpolation, both in that region and over the

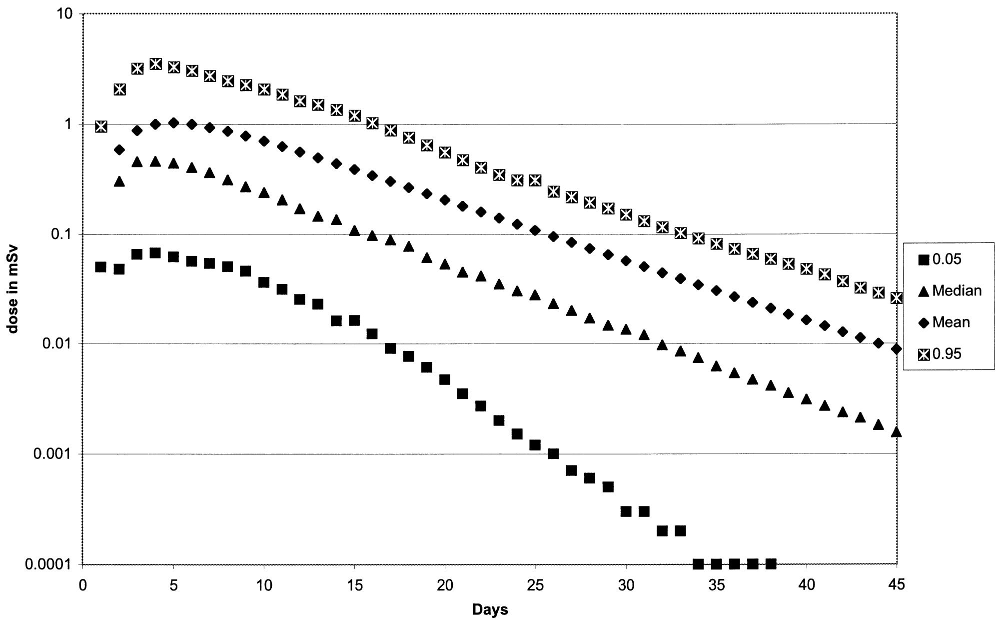

Fig. 8. The distribution of daily dose estimates (mSv) for a 1-year-old child eating rabbits taken from Currant after the Sedan test according to the survey of rabbit consumption. Shown are 5th percentile, 50th percentile, mean, and 95th percentile estimates.

time periods and regions of interest. Such analysis should provide an indication of the deposition measurement component of the uncertainty in dose estimates; however, that analysis was beyond the scope of this project. The following calculation for accumulated exposures at Duckwater illustrates the approach and will give a reasonably good approximation to the results that can be expected to be obtained. Again, this approach should be based on community-specific information.

- At Duckwater, the fallout amounts from the Sedan nuclear test were similar to the amounts at Currant. This can be observed by comparing both external doses and thyroid doses from the ORERP database for both Currant and Duckwater for the Sedan test.
- The ratio of the DOE-estimated median adult thyroid doses (through other pathways), which are proportional to the amount of iodine in fallout summed over 11 tests, to the DOE thyroid dose estimate for the Sedan test is approximately 90. Two of these tests, George (June 1951) and Apple II (May 1955), had thyroid doses approximately 24 times that for Sedan.
- So to estimate doses from eating rabbits from a number of tests at Duckwater, one multiplies the Currant dose estimates for Sedan by a factor of 90. This yields adult doses of 160 mSv (16 REM) and 500 mSv (50 REM) (mean and most exposed 5%, respectively) and child doses of 1.3 Sv (130 REM) and 4 Sv (400 REM), respectively, for the 11 tests.
- To obtain dose estimates for George or for Apple II, one multiplies the Currant dose estimates for Sedan by a factor of 24. This yields adult doses of 40 mSv (4 REM) and 120 mSv (12 REM) (mean and most exposed 5%, respectively) and child doses of 0.3 Sv (30 REM and 1 Sv (100 REM), respectively, for each of these tests.

6. DISCUSSION OF DOSE ESTIMATES

These thyroid dose estimates are substantial. The range of adult dose estimates for eating rabbits from Duckwater extends above the DOE dose estimate covering all pathways. The small child doses exceed the average doses observed in the Utah epidemiological study, which found increased rates of thyroid cancer.[29,30] They are also greater than the lowest levels at which thyroid cancers have been attributed to exposure from Chernobyl.[31] The whole body doses estimated by DOE overlap the range in which leukemias were found in Utah.[32,33]

7. CONCLUSIONS

In the introduction we listed five questions to be answered in the paper. The answers given may be summarized as follows:

1. Native American community members living in their ancestral lands received substantial exposures from Nuclear Weapons testing at the Nevada Test Site.
2. These exposures are not adequately described by DOE's dose reconstruction: (1) missing pathways include iodine exposures from the hunting of small game; (2) the model assumptions about the feeding of cattle that provide dairy products do not generally apply; and (3) assumptions about other food pathways may also not apply.
3. The information base collected by DOE is not adequate to address these important aspects of a dose reconstruction, and this failing stems from the lack of participation by Native community members in the collection, interpretation, and planning for the use of key information about lifestyles and concerns.
4. Approximate estimates of radiation doses to thyroids received from eating rabbit thyroids can be estimated on the basis of scattered data from DOE studies and information selectively gathered from affected communities. We have presented illustrative calculations showing that these exposures were severe.
5. A successful dose reconstruction, i.e., a dose reconstruction that is both useful and reasonably accurate, can be achieved only with active participation by members of the affected communities.

It is worth noting some of the questions we have not answered in this paper:

- We did not provide a corrected dose reconstruction. The dose estimates we present are illustrative on the basis of small samples and special cases of test site experience. Our purpose here was simply to display the gap between the present dose reconstruction and actual experience, to show that the actual experience was radiologically significant, and to show that a technical basis for developing the needed exposure models is available.
- We did not describe a detailed methodology for revising the dose reconstruction. That task includes (1) defining how to usefully characterize dose information, including uncertainties; and (2) establishing sources and procedures for obtaining pathway and other needed data.
- We did not address community concerns about the legacy of radioactive contamination that extend beyond questions about historical exposures immediately following nuclear tests.

Information developed from dose reconstruction will be part of the history of the affected communities. Individuals may wish to know about their own exposures and about the nature of the exposures that occurred in their communities from nuclear weapons testing. Even at this late date, knowledge of radiation doses may be helpful in developing mitigation measures such as medical monitoring. And the information could be used as a basis for assigning compensation to people or communities injured by the exposures. These possible uses exemplify the importance of having the communities maintain an active role in the creation of the study. When and what sort of medical monitoring could help depends on community characteristics and community medical needs. The suitability and appropriateness of compensation for past wrongs vexes many Native communities and different communities with different histories may react differently. The fact that the initial dose reconstructions were constructed while the U.S. government was denying legal responsibility for harm caused by nuclear testing has not helped create confidence in the usefulness of dose reconstruction efforts.

Dose reconstruction for these communities is feasible as demonstrated by the illustrations we have presented. But such reconstruction will require participation and collaboration in developing information appropriate to the variety of affected communities. Furthermore, successful completion of dose reconstructions for communities will occur only with substantial participation and collaboration with the communities in formulating the important questions to be answered and the design and implementation of the studies along with the development of the needed information base.

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