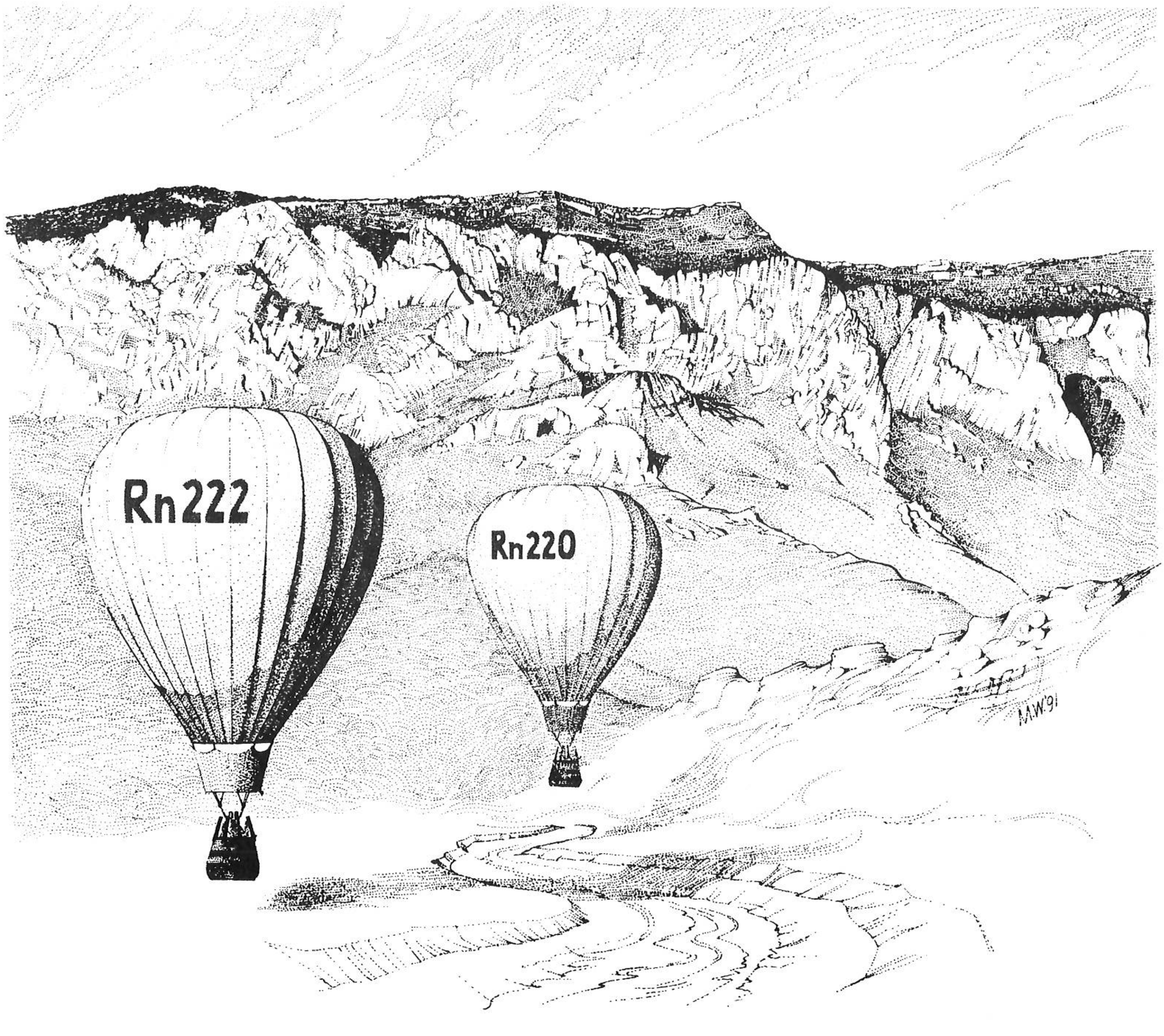
NEW MEXICO RADON SURVEY

1987 - 1989



by

Ralph A. Manchego, Virginia T. McLemore and John W. Hawley

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THE ENVIRONMENTAL IMPROVEMENT DIVISION (E.I.D.) OF THE NEW MEXICO HEALTH AND ENVIRONMENT DEPARTMENT IS QUOTED THROUGHOUT THIS REPORT. THE E.I.D. IS NOW KNOWN AS THE NEW MEXICO ENVIRONMENT DEPARTMENT.

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I. INTRODUCTION

Concern about public health risks to the general population of the State of New Mexico from exposure to radon gas and its decay products in homes, schools, places of employment and office buildings, has been raised over the past few years by the medical and scientific communities, and government agencies. Concern raised by these interest groups has subsequently alerted the general public. While other factors such as cigarettes contribute to lung cancer deaths each year, airborne radon gas exposures may be accountable for 15% to 20% of all lung cancer deaths in the United States.

In 1989, in an effort to evaluate the levels of radon which contribute to public health risks associated with radon exposure in New Mexico, the Radiation Licensing and Registration Section (RLRS) of the Environmental Improvement Division (EID) and the Environmental Protection Agency (EPA) initiated a random radon-screening survey of private homes throughout the State. Such a screening test offers the homeowner an indication of indoor levels of radon gas at a given point in time. This test is of short duration and does not provide information over a long period of time. The EPA recommends that exposure levels be calculated in terms of an annual average before any further action is undertaken. The short screening test is only an indication of the indoor-radon level; and, for this reason, the charcoal canisters are placed in individual homes where they would produce the highest measurements or "worst case conditions." Therefore, tests are conducted in the winter months when closed-house conditions are most likely to be observed. If these screening tests show radon levels of 4 pCi/L or above, then it is recommended that long term testing be conducted. If follow-up testing confirms high radon levels, the EPA suggests that a mitigation program should be undertaken. This report outlines the methods used in the random selection of homes for radon-exposure measurements, and gives a preliminary interpretation of the results from this screening.

Results from 1772 houses tested during January to March of 1989 indicate that about 25% of those tested had radon screening results at or above the EPA "action-level" guideline of 4 picocuries per liter of air (pCi/L). All of the results of this radon survey indicate "worst case" screening conditions for radon gas tests. The resulting numbers only indicate the homes with a potential radon problem. Results from the radon-in-air screening test indicate that about 75% of homes in New Mexico had concentrations of less than 4 pCi/L. Values in about 25% of the tested houses ranged from 4 pCi/L to 20 pCi/L, and about one percent exceeded 20 pCi/L with a maximum value of 105 pCi/L.

The New Mexico radon survey was unique in that it was the first in the nation to successfully use a decentralized strategy in the attempt to place charcoal radon test canisters randomly across a state. The eighteen states which had previously participated jointly with EPA in randomly placing canisters in owner-occupied homes had relied upon centralized phone calling and canister distribution. Additionally, New Mexico utilized Environmental Improvement Division staff resources (central office, district and field offices) in placing the canisters as well as volunteers from the City of Albuquerque Environmental Health staff and other organization volunteers. This strategy was selected since EID District and Field office staff were known to be familiar with the population centers in their areas as well as with the more isolated areas. Project staff predicted that increasing the proximity of staff to homeowners contacted would also increase the success of the canister placement. Other states had either contracted outside private companies in their canister placement program or had utilized staff and volunteers working from one central location.

New Mexico's decentralized program resulted in the placement of 50 canisters in two days for use in the pilot survey. Past experience in other states had resulted in a pilot project placement time of seven days. While other states required an average of two to three months to place over 2000 canisters, New Mexico successfully placed 1772 canisters in less than six weeks (see Table 3, Appendix I).

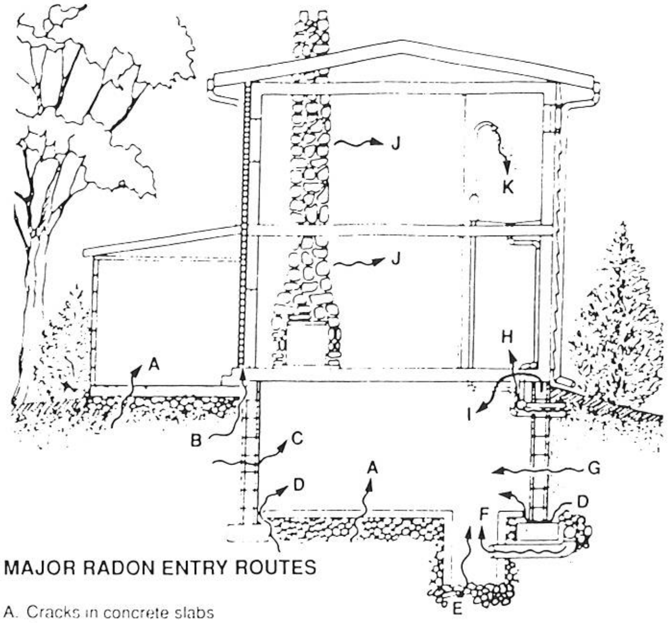
Staff believe that the decentralized radon canister placement method used in New Mexico is more cost effective, utilizes existing staff, can be implemented in a more timely fashion and provides indoor radon analytical results more quickly to Health and Environment staff at the local levels. Staff also recommend that the decentralized placement method be used in other states with sparse and widely distributed populations. New Mexico's experience has demonstrated the usefulness of such a strategy.

Another important aspect of the New Mexico survey was the evaluation of geologic, soil and hydrologic conditions that might contribute to elevated levels indoor radon throughout the state. This work was done by the staff of the Office of State Geologist, New Mexico Bureau of Mines and Mineral Resources (NMBMMR). During the first phase of this investigation, New Mexico counties were placed in three provisional radon-availability categories (high, moderate and low). Data sources included 1) aerial radiometric surveys; 2) uranium-resource evaluations, 3) reports on lithology and structure of major geologic units; 4) hydrogeologic and geochemical information and 5) soil surveys (including data on particle size, clay minerals, moisture regimes, and permeability). This information was used to help the EPA in the random selection of homes for the initial screening survey just discussed.

II. GENERAL BACKGROUND ON RADON IN THE ENVIRONMENT

A. Introduction

Radon is a naturally-occurring, chemically inert, radioactive gas. Because radon is chemically unreactive with most materials, it is free to travel as a gas. It can move easily through very small spaces such as those between particles of soil and rock. Radon is odorless, invisible, and without taste; thus, it cannot be detected with the human senses. Radon is also moderately soluble in water and, therefore, can be absorbed by water flowing through fractures or pores in rock or unconsolidated deposits containing this gas. Its solubility depends on the water temperature; the colder the water, the greater the radon's solubility. Radon entering the home in this manner can escape into the air when the water is used in a shower, washing appliances, etc. Figure 1 (Appendix I) illustrates some of the possible routes by which radon can enter a home. Once radon is captured inside a home, radon can accumulate to levels that can be many times higher than the radon concentrations in ambient air.



MAJOR RADON ENTRY ROUTES

A. Cracks in concrete slabs
B. Spaces behind brick veneer walls that rest on uncapped hollow-block foundation
C. Pores and cracks in concrete blocks
D. Floor-wall joints
E. Exposed soil, as in a sump
F. Weeping (drain) tile, if drained to open sump
G. Mortar joints
H. Loose fitting pipe penetrations
I. Open tops of block walls
J. Building materials as some rock
K. Water (from some wells)

Figure 1 (EPA87)

B. Natural Sources of Radon

Uranium and thorium are common, naturally-occurring elements that are found in low concentrations in rock and soil. Through radioactive decay (see Appendix I, Figures 2-1 and 2-2), both are constant sources of radon. Radon is produced from the radioactive decay of the element radium, which is itself a decay product of either uranium or thorium.[3]

Average soil activity concentrations of uranium-238 and thorium-232 are each about .068 picocuries per gram (Ne83). Uranium-238 decays in several steps to radium-226, which decays into radon-222. Radon-222 has a half-life of 3.8 days and, therefore, has enough time to diffuse through dry, porous soils or to be transported in water for a considerable distance before it decays. Similarly, thorium-232 decays into radon-220 (a different radon isotope, also called thoron), which has a half-life of only 55 seconds. Because of its short half-life and limited ability to migrate into residences, radon-220 is usually a less important source of radon exposure to humans. The average exposure from indoor radon-220 decay products has been estimated to be about 25 percent of that from radon-222. Only radon-222 is addressed specifically in "A Citizen's Guide" (EPA, 1986) and is the radon isotope of most concern to the public. Although radon-220, or thoron, has not been measured separately in most homes[4], radon control actions will also reduce exposure to thoron. Radon-222 is in the uranium-238 decay series, illustrated in Figure 2-1 (Appendix I). The thorium-232 decay series, which includes radon-220, is illustrated in Figure 2-2 (Appendix I).

C. Uranium-238 Decay Series

Radon-222 is preceded in the uranium-238 decay series by radium-226, which has a half-life of 1,600 years. Radon-222 decays in several steps to form radioactive isotopes with short half-lives; polonium-218, lead-214, bismuth-214, and polonium-214 (see Figure 2-2, Appendix I). These isotope particles are commonly referred to as radon decay products.[5] Radon decay products are chemically reactive and can attach themselves to walls, floors, or airborne particles that are inhaled and, subsequently, can become deposited on lung tissue.

D. Radon Decay Products

The four radon-222 decay products just mentioned all have half-lives of less than 30 minutes. This short half-life is significant since, once deposited on lung tissue, the radon decay products can undergo considerable decay before the action of mucus in the bronchial tubes can clear these radioactive particles. Two of the short-lived decay products, polonium-218 and polonium-214, emit alpha particles[7] during the decay process.

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[3] Radioactive decay is a process in which an unstable atomic nucleus undergoes spontaneous transformation, by emission of particles of electromagnetic radiation, to form a new nucleus (decay product), which may or may not be radioactive. The level of radioactivity is measured in *curies*, where 1 curie equals 37 billion disintegrations per second. The time required for a given specific activity of an isotope to be reduced by a factor of two is called its half-life. A picocurie (pCi) is equal to one-trillionth of a curie. Specific activity concentrations are typically measured in picocuries per gram (in a solid) or picocuries per liter (in a gas, such as air).

[4] The State of New Mexico in conjunction with New Mexico Institute of Mining and Technology (New Mexico Tech) of Socorro, New Mexico, is actively studying and measuring radon-220 in special study that started in late 1989 and early 1990. Information on this study was not available for inclusion in this report.

[5] Radon decay products are also often referred to as radon daughters or radon progeny.

[7] An alpha particle is a subatomic particle that has two protons and two neutrons and has a double positive electrical charge. It is identical to a helium nucleus.

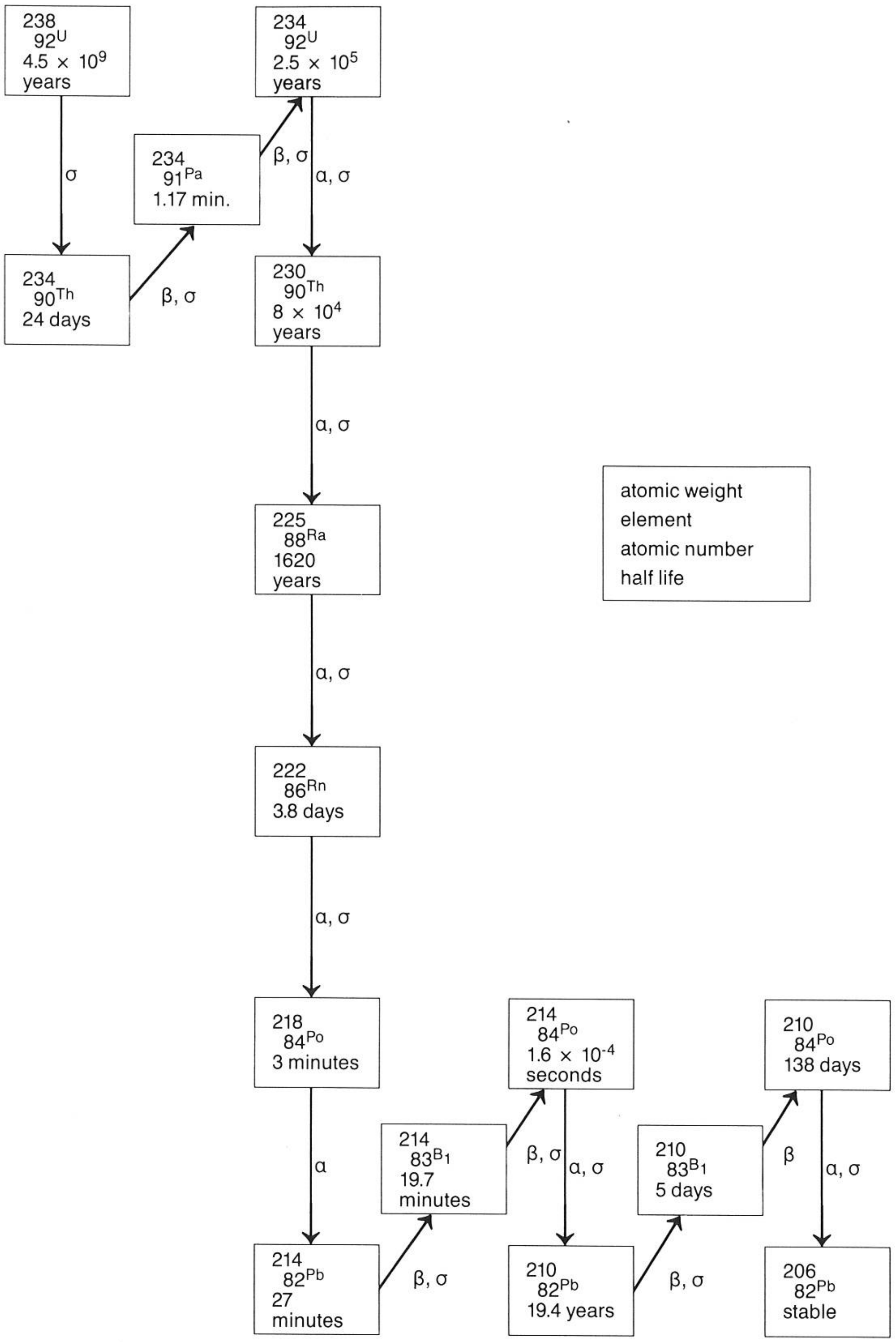

Figure 2-1 URANIUM-238 DECAY SERIES. MAJOR DECAY PRODUCTS OF THE NATURAL URANIUM-RADIUM SERIES

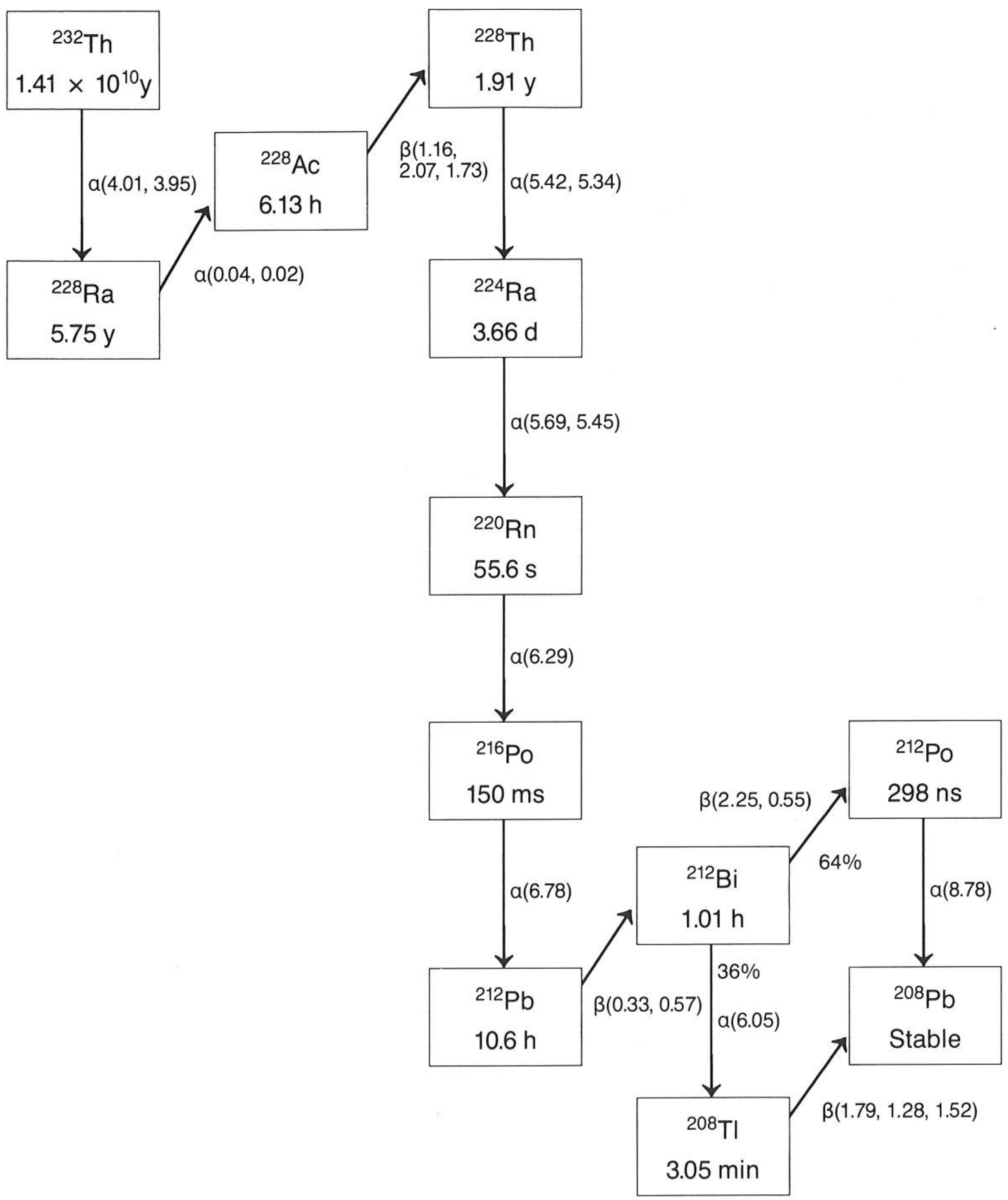

Figure 2-2 Thorium 232 decay chain, including ^{220}Rn and its decay products.

Radon 220 and its parent, ^{232}Th decay series. Airborne concentrations of ^{212}Pb and ^{212}Bi are of prime radiological interest due to their potential for retention in the lung, leading to subsequent irradiation by the alpha decay of ^{212}Po. Cf. Figure 2-1 for ^{238}U decay chain. Half-lives and alpha energies (in MeV) taken from Browne and Firestone (1986); beta end-point energies (in MeV) are from NCRP (1985).

E. Radon Detection and Measurement

There are many methods for determining airborne radon and radon progeny levels that have been designated as "acceptable" by the EPA. Radon itself can be detected using a continuous radon monitor (CRM), an alpha-track detector (ATD), an activated charcoal adsorption detector (CC-for charcoal canister), and a detector known as an electret-PERM (EP) (Kotrappa et al., 1988). Radon progeny measurements can be achieved utilizing a continuous working level monitor (CWLM), a radon progeny integrating sampling unit (RPISU), and a grab radon progeny sampling device (GW). Protocols for taking measurements using all of the above testing equipment and protocols for their appropriate use as initial screening and follow-up testing devices have been described by the EPA (Ronca-Battista et al., 1987). The EPA also administers the National Radon Measurement Proficiency (RMP) Program under which any company offering measurement services is invited to demonstrate its proficiency at measuring radon gas and/or radon decay product concentrations. Listings of these "proficient" companies are available to the public from the New Mexico Radiation Licensing and Registration Section.

Radon gas levels are generally expressed in pCi/L (picocuries per liter of air). The working level (WL) is another unit used to express the exposure rate to radon and radon progeny. This unit was developed to measure the cumulative exposure of uranium miners to radon, with exposures expressed in working level months (WLM). For example, exposure to 1 WL for 1 working month of 170 hours equals 1 WLM. Based on assumptions about equilibrium between radon and radon progeny levels, the two units of measurement (pCi/L and WL) can be compared with 1.0 WL-200 pCi/L.

The EPA has recommended 4 pCi/L as a guideline for annual average exposure to radon. This level represents a balance between health risks and practicality. The following paragraphs describe the various approaches to radon testing and the two-phased approach that the EPA suggests for determining whether the occupants of a home will be exposed to concentrations above this guideline of 4 pCi/L.

Radon detection can be divided into three major categories: initial screening tests, follow-up measurements, and diagnostic testing as part of the mitigation process.

The screening measurement is an initial test "made to quickly and inexpensively determine whether a house has the potential for causing high exposures to its occupants" (Ronca-Battista et al., 1987). Screening tests are made in the lowest potentially livable level of the home (typically the ground floor in houses without basements) and under closed-house conditions. These considerations are especially important because of the great variability of radon levels over time due to weather, temperature, seasonal variation in ventilation rates, and anything that affects the pressure differences between the inside and outside of a home. The EPA recommends that screening tests are most appropriately done during the winter months and in the lowest livable level where the radon concentrations tend to be the highest and most stable. In this manner, screening measurements determine the "maximum concentrations to which the house occupants may potentially be exposed" (Ronca-Battista et al., 1987).

If screening tests are made in this fashion, it is extremely unlikely that a home with a low result (less than 4 pCi/L) will yield a long-term average exposure to the occupants above the level at which the EPA recommends remedial action (4 pCi/L). Therefore, if screening test results are below 4 pCi/L "the homeowner can eliminate the need for further measurements with confidence" (Ronca-Battista et al., 1987).

If the initial screening yields a result over 4 pCi/L, the EPA then recommends that follow-up measurements be made in accordance with a sliding scale based on the severity of the initial result. With screening results between 4 and 20 pCi/L the follow-up measurements should be made on the lived-in levels of the home under normal living conditions over a 12-month period to determine the annual average radon concentrations.

If the screening is between 20 and 200 pCi/L, annual average measurements are not recommended because exposures to these levels over a 1-year period may increase the health risk significantly. In this situation it is recommended that shorter term follow-up testing be done with several months on each of the lived-in levels of the home and under closed-house conditions.

If the initial screening results is over 200 pCi/L, the need for follow-up measurements is even more immediate. Short-term testing should be done on the living levels of the home as soon as possible. Easily implemented actions to reduce the radon levels (such as increasing ventilation) should be seriously considered while a more permanent solution is being evaluated and implemented.

This two-phased approach to radon testing is recommended by the EPA to minimize the number of false negative test results. In other words, "a home that contains concentrations at which the EPA recommends that remedial action be considered but which would not be identified as such because of a low measurement result". On the other hand, a false positive test result would indicate the need for follow-up testing. "In the interest of reducing radon exposures, therefore, the EPA believes that a significant fraction of false positives is preferable to a high rate of false negatives" (Ronca-Battista et al., 1987).

Testing as a diagnostic procedure during the mitigation process is the last type of radon testing of concern. This is a very specific type of testing that is used to assess potential entry routes and also to evaluate the effectiveness of any remedial action that was taken to reduce radon levels.

It is also possible to test the concentration of radon in soil gas as an attempt at site evaluation. However, because there are no standard methods for radon in soil testing and no standards for correlating these test results with subsequent indoor radon levels, the EPA does not consider this to be an appropriate technique at the present time.

F. Radon Mitigation

Perhaps the most important thing to realize about radon is that it is a fixable problem. Various approaches to the mitigation (reduction) of radon in air (resulting from soil gas levels of radon) have been investigated by many different groups and are outlined by the EPA (EPA, 1988). Once elevated radon levels have been detected and confirmed in an appropriate manner, the home needs to be evaluated to determine which method(s) for radon mitigation are appropriate. The solutions to a radon problem can vary widely depending upon the home's design and the level of radon reduction desired. Similarly, the cost of the radon reduction strategy will also vary. The general consensus at the present time appears to be that the majority of homes can be effectively mitigated for between $100 and $2,500 (possibly higher if several methods are needed). The cost of mitigation obviously will vary with the extent of the work needed and whether the job is done by a contractor or on a "do-it-yourself" basis.

The methods of radon reduction fall into two basic categories. The first category involves actions taken to prevent radon from getting into a home while the second is methods employed to remove radon from a house after it has entered (or to dilute the radon concentration). Examples of preventing radon entry into a home include "sealing soil gas entry routes, ventilating the soil to divert soil gas away from the house, and adjusting the pressure inside the house to reduce or eliminate the driving force for soil gas entry" (Figures 3 and 4, EPA, 1986, 1988). Examples of removing radon after entry include: increasing ventilation (natural or fan-driven), heat-recovery ventilation (Figure 5), block-wall ventilation (Figure 6), and air cleaning (although the EPA has not yet recommended the latter approach). It should be noted that energy efficiency is significantly affected by implementation of most radon mitigation strategies.

Sealing Cracks and Openings

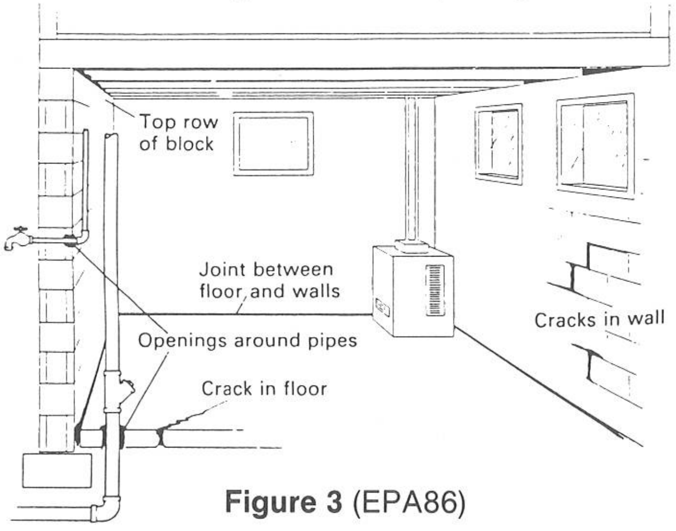

Figure 3 (EPA86)

Sub-Slab Suction

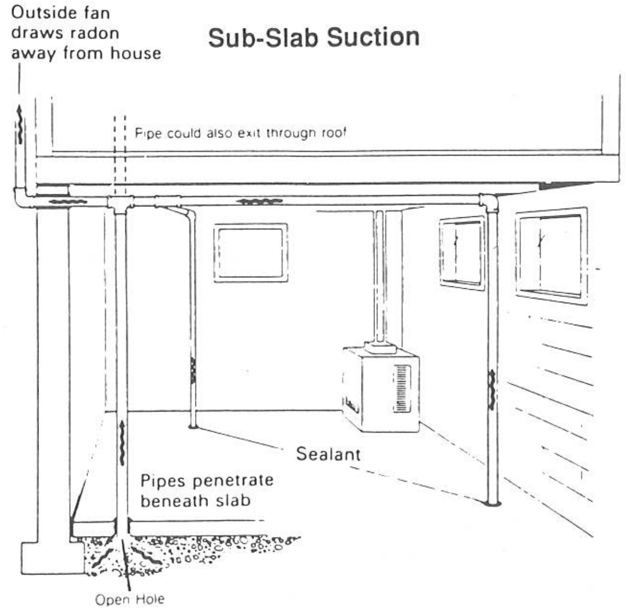

Figure 4 (EPA86)

Heat-Recovery Ventilation

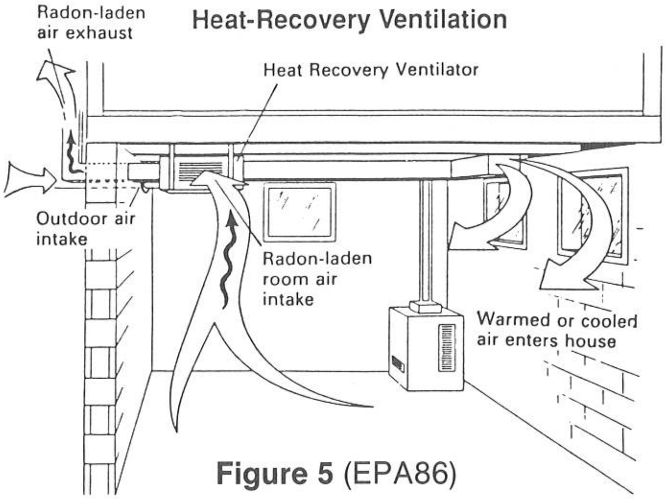

Figure 5 (EPA86)

Block-Wall Ventilation

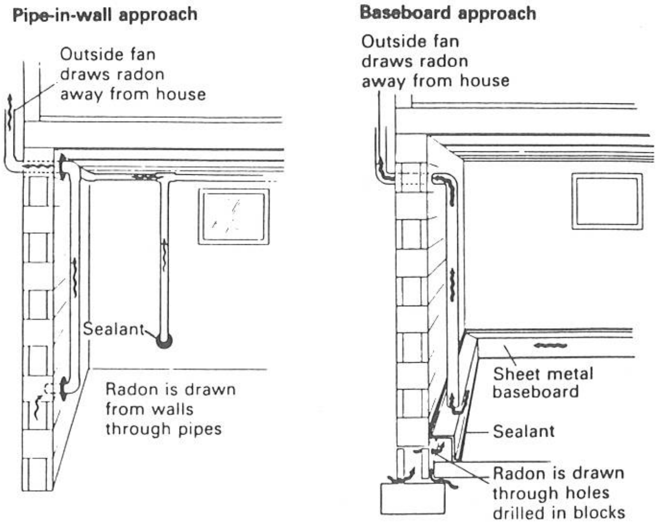

Figure 6 (EPA86)

G. Health Risks

The potential health threat from radon is an increased risk of developing lung cancer. The elevated levels of radon found in underground uranium, zinc, and other mining environments have been linked with significant increases in the lung cancer rate among miners (NCRP, 1984). Data from these studies have been extrapolated to estimate expected lung cancer rates for residential exposures, assuming an occupancy rate of 75% and a 70-year life expectancy. Because the studies supporting the lung cancer-to-radon link are of actual human populations, it is thought that the risk estimates are much more accurate than those derived from animal studies alone. The EPA has implicated radon as the second leading cause of lung cancer (and the leading cause among non-smokers) in the United States today. The EPA estimates that between 5,000 and 20,000 lung cancer deaths per year nationwide may be attributed to radon (EPA, 1986).

The major health threat from radon exposure is actually from a sequence of radioactive isotopes or "progeny" formed when radon undergoes radioactive decay. These isotopes (polonium-218, polonium-214, and lead-214, and bismuth-214), unlike radon, chemically Once inhaled (either attached to particulates or unattached), the progeny can then become lodged in the lining of the lungs. The progeny then undergo radioactive decay and can thus irradiate the lung tissues directly. Because the half-lives of the progeny are short (ranging from 164 microseconds to 27 minutes), the possibility that radioactive decay will occur during the residence time in the lung is very likely. The most damage comes from the alpha particles emitted when the two isotopes of polonium decay (EPA, 1988). Half lives of polonium-218 and polonium-214 are, respectively, 138.4 days and 21 years.

The health risks from radon are considerably higher than those for other environmental hazards. The risk estimate derived by the EPA for radon at the average outdoor air level of radon has been estimated to be 1-3 lung cancers per 1,000 people exposed. Typical "acceptable" health risk levels for other toxic substances are usually on the order of 1 per 100,000 to 1 per 1,000,000. Figure 7 (Appendix I) illustrates the number of lung cancer deaths that can be expected at various average residential levels of radon. The radon levels are annual average exposures that include all levels of the home and all seasons of the year, and are based on a 75% occupancy rate over a lifetime of 70 years.

III. PRELIMINARY STUDIES (1986-1988)

Preliminary studies prior to the 1989 survey involved 1) random, short-term screening during the winter of 1986-1987 of homes in north-central New Mexico, and 2) a 1988 statewide evaluation of natural conditions that could significantly influence elevated indoor radon levels.

A. Preliminary Screening Survey of Homes

In order to evaluate the distribution and concentration of radon gas throughout the State of New Mexico, the Radiation Licensing and Registration Section (RLRS) of the NMEID, in conjunction with the 4 (four) district offices began the screening survey of randomly pre-selected homes in New Mexico.

NMEID staff provided the man hours for the screening process. Materials for testing were provided by EPA, training for EID personnel was handled by EPA staff. Materials for public outreach and educational materials were also provided by EPA. The list of homes was randomly selected by the EPA Statistical Staff. Homeowners' names, phone numbers and addresses after being randomly selected by EPA staff, were used to do the screening.

Another important aspect of the screening survey was a study of the geographic distribution of radon gas in an indoor environment. A preliminary study was conducted in the winter months of 1986-1987 by EID staff in the north-central areas of the State using working level meters in volunteer homes. Either a 24- or a 48-hour period was used to determine the average radon gas concentration and these two values were averaged for reporting purposes. Standard EPA protocol was adhered to throughout the screening process. Results of this preliminary survey were tabulated by counties.

B. Preliminary Evaluation of Natural Conditions Influencing Indoor Radon (1988); New Mexico Bureau of Mines and Mineral Resources

A major objective of the preliminary phase of this study was to identify and characterize areas in New Mexico where natural conditions (e.g. geology, hydrology, and soils) had the potential for making significant contributions to elevated indoor radon values. Such areas needed to be identified so that a larger percentage of radon detectors could be allocated to those localities during the 1989 survey conducted by the NMEID in cooperation with the U.S. Environmental Protection Agency. This phase of the investigation (McLemore and Hawley, 1988) was conducted by the New Mexico Bureau of Mines and Mineral Resources-Office of State Geologist (NMBMMR).

Rocks and soils in New Mexico were initially grouped into three radon-availability categories based on geologic and hydrologic interpretations, which are specific to New Mexico conditions. Subsequently, each county and the major cities in the state were given a radon-availability rating based on the predominant availability category established for geologic units in that area (Tables 1.1 and 1.2, Appendix I).

Ten counties were assigned a *preliminary high-availability rating* (Table 1.1) for radon based on interpretation of available geologic and soils data; they are Doña Ana, Hidalgo, Los Alamos, Luna, McKinley, Rio Arriba, Sandoval, Socorro, Santa Fe, and Taos. Seven of the most populated cities (1984 estimates) were rated high: Santa Fe, Las Cruces, Roswell, Carlsbad, Gallup, Deming, and Los Alamos, White Rock. Thirteen counties (Bernalillo, Catron, Cibola, Chaves, Colfax, Eddy, Grant, Lea, Lincoln, Quay, San Juan, Sierra, and Union) were assigned a *preliminary moderate-availability rating*. Six of the most populated cities were rated moderate (Table 1.2) (Albuquerque, Rio Rancho, Clovis, Hobbs, Grants-Milan, and Lovington). The remaining ten counties in New Mexico (Curry, De Baca, Guadalupe, Harding, Mora, Otero, Roosevelt, San Miguel, Torrance, and Valencia) were assigned a *preliminary low-availability rating*, although some homes in these areas may still have elevated levels of indoor radon. Six of the most populated cities in these counties were also rated low: Farmington, Alamogordo, Las Vegas, Silver City, Portales, and Artesia. It should be emphasized that, even in counties with moderate and high availability ratings, many houses may have very low levels of indoor radon. Procedures used in developing the preliminary rating scheme are discussed in more detail in the following section.

IV. RADON AVAILABILITY AS A FUNCTION OF GEOLOGY AND SOILS

A. Introduction

The first step in formulating a sample plan for the survey of indoor radon levels in New Mexico was to evaluate the rocks and soils for radon-availability (McLemore and Hawley, 1988). Major geologic factors influencing radon-availability include 1) lithology and uranium or radium content of bedrock and unconsolidated geologic deposits, 2) rock structure (faults and fractures), 3) porosity and permeability, and 4) nature of the water in both the saturated and unsaturated zones. Texture, structure, mineralogy, and moisture regimes of surficial soils (upper 2 meters of unconsolidated earth materials) are also major factors influencing radon availability (Brookins, 1986, 1990; Brookins and Enzel, 1989).

The primary information sources used to evaluate the rocks and soils in New Mexico were published reports and unpublished records in the NMBM&MR files including data from 1) aerial radiometric surveys, 2) geologic maps, Figure 8, Appendix I, 3) uranium resource surveys, and 4) soil surveys. Other sources of information include special reports on geochemical and groundwater investigations, and a limited amount of data on indoor radon concentrations. This information was compiled by McLemore and Hawley (1988) in order to provide the EPA and the NMEID with a preliminary estimate of radon-availability for their 1989 program to randomly sample individual New Mexico homes.

In the fall of 1989 about 50 sites in north-central New Mexico with elevated indoor radon levels (10-105 pCi/L) detected in the random survey were visited as part of a cooperative study with the EPA on indoor-radon mitigation strategies. At that time, detailed observations were also made of on-site geologic and soil conditions that could contribute to indoor radon. This is the only follow-up verification of preliminary test results made to date.

B. Aerial Radiometric Surveys

Aerial radiometric surveys (Duval, 1988) provide a regional estimate of uranium concentrations in the surficial rocks and soils and correlate well with the amount of radon in the ground (Peake and Schumann, in press). However, it must be emphasized that the amount of radon that is available to enter a house from the ground is dependent upon many other variables. The primary source for aerial radiometric data in New Mexico is a series of reports prepared as part of the National Uranium Resource Evaluation (NURE) program.[1] The NURE program was established in 1974 and terminated in 1984 and the main objectives were 1) to provide an assessment of the uranium resources in the United States and 2) to identify areas of uranium mineralization.

Aerial radiometric data are dependent upon a constant altitude above the ground. However, in some areas of New Mexico where there are steep mountains and deep canyons, constant altitude could not be maintained, resulting in erroneous measurements. Both airplanes and helicopters were used to collect data in New Mexico and helicopters were able to better maintain constant altitude than airplanes.

The NURE aerial radiometric data has been released in reports based on 1° x 2° topographic quadrangles and on magnetic tape. The quadrangle reports include a brief narrative and graphs of the flight line data, uranium anomaly maps, and histograms of the radioactivity data by lithology. Aerial gamma-ray contour maps of regional surface concentrations of uranium, potassium, and thorium in New Mexico has been recently published by the U.S. Geological Survey at a scale of 1:750,000 (Duval, 1988). A colored contour map of the state showing radiometric equivalent uranium (eU) concentrations was also prepared by the U.S.G.S. at a scale of 1:1,000,000 from the computerized aerial radiometric data. Copies of this map are available for inspection at the NMBM&MR and NMEID.

Several problems exist with the aerial radiometric data. Most 1° x 2° quadrangles in New Mexico were flown with east-west flight line spacings of three miles. However, parts of the Tularosa and all of the Carlsbad, Raton, and Ft. Sumner quadrangles (parts of Chaves, Colfax, De Baca, Doña Ana, Eddy, Guadalupe, Lincoln, Sierra, Taos and Torrance Counties) were flown with six mile spacings. Large unmeasured areas exist between these flight lines and localized anomalies may be overlooked. In addition, not all areas of New Mexico were flown. The largest area of no data is in the vicinity of the White Sands Missile Range north of Las Cruces and west of Alamogordo, primarily in Doña Ana and Otero Counties.

In the southwestern part of New Mexico, atmospheric inversions are known to occur frequently and may result in uncompensated U-air anomalies. Atmospheric plumes generated by copper smelters in southwestern New Mexico and southeastern Arizona also may result in uranium anomalies in the surveys. The effect of these atmospheric anomalies in predicting elevated levels of indoor radon is unknown.

The extremely high uranium anomalies in the aerial radiometric data (>5 ppm eU) near Grants, Cibola County, are a result of high values measured over mill tailings at four uranium mill sites. The computer-generated aerial radiometric maps produced by the U.S. Geological Survey exaggerate the significance of these anomalies; the actual area affected by the mill tailings is small. Surveys conducted by the NMEID and Homestake Mining Company suggest that mill tailings have not contributed to indoor radon levels in nearby houses. Capping of mill tailings and other remedial measures are in progress in this area of New Mexico.

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[1] NURE aerial radiometric maps are available from the New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico.

C. General Geologic and Soils Information

Information on the type and distribution of the lithologic and structural units in New Mexico is important in identifying areas of radon-availability for indoor-radon generation. Published geologic maps, primarily the New Mexico Geological Society (1982) State Map and NMBMMR State Uranium Resources Map (McLemore and Chenoweth, 1988), were used in preliminary phase of the study (see Figure 8, Insert Map).

There are very few direct measurements of radon or radium concentrations in the rocks and soils of New Mexico; however, data on uranium concentrations in rocks and soils of New Mexico is more plentiful. Rocks with uranium concentrations exceeding 5 ppm U are sufficient to produce elevated levels of indoor radon (Peake and Hess, 1987). In New Mexico, most rock types could provide a source for indoor radon.

In addition to lithology, structural features also play an important role in many areas. Fault zones and other areas of highly jointed rocks are likely sites of uranium mineralization; and they also provide a pathway for radon to migrate into houses (Ogden et al., 1987). Karst (rock dissolution) features in carbonate and gypsiferous terranes may also provide pathways for migration of radon. Highly permeable and porous rocks and soils (such as pumice, poorly welded tuffs, sand and gravel, and expansive clays) are potential source materials that need to be evaluated throughout the state.

D. Uranium Occurrences

Areas of uranium and thorium occurrences (as well as mine-mill sites) are well known in New Mexico (Figure 8, Appendix I; McLemore, 1983; McLemore and Chenoweth, 1989). The majority of these areas are found in relatively unpopulated parts of the state; however, there are a number of important exceptions. Uraniferous coals in the Gallup area, McKinley County, were once mined for uranium, and the host rocks are probably a good source for radon. Other areas, such as northern Santa Fe County, and White Signal in Grant County, occur at sites of uranium mineralization near or at the surface that could provide radon in nearby houses. Some indurated caliche (calcrete) horizons in soils and surficial geologic formations may also be sources of elevated uranium-radium-radon levels. More detailed studies of the correlation of known uranium and thorium occurrences, population distribution, and indoor radon levels are required.

E. Soil Surveys

Soil textural, permeability, and mineral data from soil surveys prepared by the U.S. Soil Conservation Service are an important data base for any assessment of radon availability. Well-drained, permeable soils, typically with hydraulic conductivity measurements exceeding 6 in/hr, provide excellent pathways for radon. Many areas of elevated radiometric- equivalent uranium (eU) concentrations shown on the aerial radiometric map are also associated with permeable soils. However, the soil permeability data used in this preliminary study is generalized and based on very few actual measurements of hydraulic conductivity. Also soil-moisture regimes vary significantly on a seasonal as well as an annual basis, and they can materially affect permeability values. Clay-rich soils with high shrink-swell potential develop wide and deep desiccation cracks when dry (a typical condition in New Mexico) and provide pathways for rapid soil-gas transfer. These soils, however, are very impermeable when moist.

F. Other Sources of Information

Other information sources were examined to support interpretations of aforementioned data. The NURE geochemical data consists of uranium analyses of stream sediment and ground water samples (McLemore and Chamberlin, 1986). Geochemical reconnaissance maps showing the distribution of uranium for each 1° x 2° quadrangle in New Mexico were used to identify areas of high uranium concentrations. Most of these areas correlate well with areas identified using aerial radiometric data. A few problems exist with the NURE geochemical data. Uranium concentrations in stream sediments are actually displaced and diluted values. Very little information, such as host rock and depth of the ground water samples, is available. In addition, many populated areas of New Mexico were not sampled and no data exists.

Ground water data, such as depth, flow direction, and chemical composition, provide additional information on hydrogeologic conditions which may affect the levels of indoor radon. Other data such as distribution and character of geothermal areas were also used in this assessment. In Idaho, houses built in geothermal areas have higher levels of indoor radon (Ogden et al., 1987). This relationship is being tested in New Mexico at present (James Witcher, New Mexico State University, personal commun., Feb., 1990).

Only a limited amount of indoor radon measurements are available on a statewide basis. Much of the data from past studies (prior to 1988) are confidential, at least on a site-specific scale. However, all available published and unpublished data was reviewed during this preliminary investigation.

G. Preliminary Classification of Radon Availability

Prior to placement of detectors in the winter of 1989 random survey, the rocks and soils in New Mexico were geographically grouped into three radon-availability categories according to interpretations of available geologic data (McLemore and Hawley, 1988). These relative radon-availability categories are specific to New Mexico and should be regarded as provisional until many more "on-site" radon investigations are completed. Because the risk of inhaling or ingesting a dangerous amount of radon is controlled by many factors besides geology and soil conditions, "risk" considerations played no part in this preliminary evaluation of "radon-availability." It should be also emphasized that any category area will contain a significant number of localities where one or both of the other two categories occur.

1. High Radon-Availability Category (Provisional)

The provisional high radon-availability category included areas where the rocks and soils were believed to have the greatest potential for generation of indoor radon. These areas included rocks which typically exceed 2.7 ppm eU on the areal radiometric map and, generally (but not always) included well drained, permeable soils. The limit of 2.7 ppm eU was chosen on the basis of prior experiences of EPA elsewhere in the country (T. Peake, USEPA, personal commun., Sept., 1988).

The "high category" included many outcrop areas of Proterozoic granitic rocks with average uranium concentrations of 3-17 ppm (Sterling and Malan, 1970; Brookins and Della Valle, 1977; Brookins, 1978; Condie and Brookins, 1980; McLemore, 1986; McLemore and McKee, 1988). Other lithologic units in the high-availability category include:

a. Tertiary rhyolitic and andesitic volcanic rocks in southwestern New Mexico. The rocks contain anomalously high uranium concentrations (Walton et al., 1980; Bornhorst and Elston, 1981). For example, a sample of the Alum Mountain andesite near Silver City, Grant County, contained 35.1 ppm U (Bornhorst and Elston, 1981). A sample of the Bandelier Tuff in the Jemez Mountains in north-central New Mexico contained 14.8 ppm U (Zielinski. 1981).

b. Tertiary alkalic intrusive rocks in central and eastern New Mexico (New Mexico Geological Society, 1982). Many uranium and thorium occurrences are associated with these units (McLemore and Chenoweth, 1989).
c. Sedimentary rocks. Some Paleozoic and Mesozoic sandstones, shales, and limestones locally contain high concentrations of uranium (Brookins and Della Valle, 1977; Dickson et al., 1977).
d. Coal. Some Cretaceous coals in the San Juan Basin contain 3-9 ppm U (Frank Campbell, NMBM&MR, personal commun., Oct. 3, 1988).
e. Permeable basin-fill sediments of Tertiary to Quaternary age. Although only very few analyses of these rocks are reported, they need to be (at least locally) considered as radon sources (Brookins, 1990; Brookins and Enzel, 1989).
f. Any areas of intense shearing and faulting, especially in areas of uraniferous rocks.

A few areas in New Mexico contain rocks with greater than 5 ppm eU from the aerial radiometric map. These areas typically merited a high availability ranking; but there is one exception, the Grants area. The Grants anomaly is a result of uranium mill tailings and has been assigned a moderate availability ranking.

Most of the aerial radiometric anomalies (>5 ppm eU) can be explained geologically. The Gallup anomaly is the only one near a major city. It is a result of uraniferous coals, some of which were mined for uranium. The other anomalies occur in sparsely populated areas. The Vermejo Park anomaly is associated with a uraniferous Proterozoic granite and pegmatites; epithermal uranium veins may occur in the area (Goodknight and Dexter, 1984; Reid et al., 1980). The anomalies in the Cornudas Mountains, Otero County and at Laughlin Peak, Colfax County are associated with Tertiary alkalic intrusives; uranium and thorium veins occur in the area (McLemore and Chenoweth, 1989; Zapp, 1941; Staatz, 1982, 1985, 1986, 1987). Several anomalies occur in southern Socorro County, east of Las Cruces in Doña Ana County, west-central Hidalgo County, and in the Black Range that are associated with Tertiary rhyolitic and andesitic volcanics. Only two of these anomalies are associated with known uranium occurrences: the Nogal cauldron in Socorro County (Berry et al., 1982) and Bishop Cap in Doña Ana County (McLemore and Chenoweth, 1989; McAnulty, 1978).

One of the aerial radiometric anomalies, north of Gallup in McKinley County, cannot be readily explained by geological interpretations. It correlates with the Tertiary Chuska Sandstone, Cretaceous Menefee Formation, and associated surficial cover; no mining activity is in the area. Field examination of this area of the Navajo Reservation and indoor-radon testing is needed, but was not part of the preliminary investigation.

2. Moderate Radon-Availability Category (Provisional)

This provisional category included areas where preliminary evaluation of geology and soils data indicated that rocks and soils only have a moderate potential for generation of elevated indoor radon. These localities include rocks with 2.3-2.7 ppm eU on the areal radiometric map (Duval, 1988) and are dominated by areas underlain by moderately permeable soils. This category includes many outcrop areas of Proterozoic metamorphic rocks, Paleozoic and Mesozoic sedimentary rocks, and Tertiary-Quaternary sedimentary rocks. Some rocks and soils in the Pecos Valley area in eastern New Mexico are rated moderate even though they have less than 2.3 ppm Eu. Numerous high uranium ground water anomalies occur in that area, suggesting that uranium is highly mobile and could result in elevated levels of indoor radon.

3. Low Radon-Availability Category

This category includes the remaining parts of New Mexico where the rocks and soils are believed to have low radon availability. These areas include rocks with less than 2.3 ppm eU on the aerial radiometric map (Duval, 1988) and include areas dominated by soils of low permeability. Some houses in these areas may still have elevated levels of indoor radon, but there were no obvious geologic reasons for predicting their existence in the preliminary assessment of radon availability.

H. Preliminary Classification by County

The EPA's nationwide survey of indoor radon levels in houses required that each county be ranked for radon-availability. Ranking by counties was required for two reasons:

(1) Population statistics required to establish a sample allocation plan are available for each county throughout the United States. (2) It provides a way to standardize the reporting of indoor radon surveys throughout the country.

New Mexico is the fifth largest state in the United States, yet it contains only 33 counties. Some of these counties are as large or larger than some states in the eastern United States. The geology and terrain of New Mexico are quite diverse (New Mexico Geological Society, 1982), and major geologic and landform units cut across most county boundaries, creating obvious problems in ranking counties for radon availability.

For the purpose of the preliminary assessment of geology and soil factors, each county in New Mexico was ranked according to the predominant availability category established for geologic units in the state (high, moderate, or low). If a county was represented by more than one availability category, the county was assigned the highest classification where that category represented more than 25% of the total county area. Some exceptions are explained below. Preliminary county rankings are listed in Table 1.1 (Appendix I). Similar procedures were used in evaluating counties in other states.

Since New Mexico is sparsely populated in most places and is geologically diverse, the major cities in terms of population (preliminary census data, 1984) were also assessed for radon-availability (Table 1.2, Appendix I). Some cities were rated higher than the rest of the county. In order to emphasize population distributions, counties with large urban-suburban populations were assigned the higher classification (Table 2).

I. Preliminary Ranking of Counties

Ten counties were assigned a high-availability rating for elevated indoor radon (Table 1.1, Appendix I). Large areas of these counties typically contain rocks and soils with greater than 2.7 ppm eU and the soils are permeable. Two counties, Doña Ana and Santa Fe Counties, were assigned a high ranking even though the majority of the rocks in the county contain 2.3-2.7 ppm eU. This was because the major cities in both counties (Las Cruces and Santa Fe) were ranked as having a high radon-availability potential as noted in Table 1.2 (Appendix I). The preliminary ranking indicated that Gallup in McKinley County was the most likely area in New Mexico to encounter a large number of houses with elevated levels of indoor radon. Testing to date has not been detailed enough to test whether or not this prediction is valid (refer to Table 5, Appendix I).

Thirteen counties were assigned to the moderate-availability category (Table 1.1, Appendix I). Large areas of these counties contain rocks and soils with 2.3-2.7 ppm eU. Soil permeabilities and lithologies vary. Three counties, Chaves, Eddy, and Lea, were assigned a moderate rating because cities in these counties were rated moderate even though most geologic evidence suggests a low ranking. In addition, NURE ground-water data suggested that uranium in ground water is highly mobile and could contribute radon. A study of uranium and radium mobility in ground water in southeastern New Mexico indicates that uranium and radium concentrations correlate with high chloride concentrations; however, higher radium concentrations occurred in chemically reducing ground water, which is not common in New Mexico (Hecrzeg et al., 1988).

Four counties, Colfax, San Juan, Grant, and Sierra, contain large areas of rocks that exceed 2.7 ppm eU and could be assigned a high rating. A moderate rating was assigned to these counties because 1) the uranium-bearing rocks and soils of many areas are reported to be moderately permeable to impermeable, 2) the cities in these areas are rated moderate, not high, and 3) the areas containing rocks exceeding 2.7 ppm eU are in sparsely populated portions of the county.

Ten counties were assigned a low availability (Table 1.1, Appendix I). These counties are underlain by rocks with less than 2.3 ppm eU. However, the lithology and permeability of the rocks and soils vary. Undoubtedly, some houses in these counties will exceed the EPA's recommended action level, but there are no obvious geologic reasons for predicting their existence.

V. THE 1989 STATEWIDE SURVEY

A. Objectives

The preliminary objective of this survey was to locate and identify areas within the State of New Mexico which may have homes with elevated indoor levels of radon and to characterize radon levels statewide. A secondary objective was to determine how geology affects radon levels and to determine whether or not geology can be used to predict indoor radon levels. This was a "screening" survey.

B. Target Population

The target population in this survey was restricted to owner-occupied homes selected at random from telephone listings. This eliminated high-rise structures from the survey. Since radon concentrations tend to be low in such structures and the intent of this survey was to identify areas where radon could be a potential problem, the elimination of high-rise structures from the survey should provide the most efficient use of the sampling detectors. The type of dwellings that were excluded from the survey were:

- Mobile Homes
- Group Quarters
- Apartments, defined as housing units in multi-unit structures

The survey was restricted to owner-occupied dwellings to simplify procedures in gaining permission to sample radon. Although this type of selection essentially negates a true random sampling for statistical purposes, the study had to be structured to fit workable sampling parameters.

C. Survey Method

Radon measurements were made with charcoal canisters supplied by EPA. Measurements were made under closed-house conditions and in the lowest liveable area of the dwelling in conformance with EPA screening measurement protocols. Samples were analyzed by EPA's laboratory in Montgomery, Alabama. Alpha track detectors were utilized at 10% of the homes utilizing the charcoal canisters for radon daughter determination.

D. Potential Contributions from the Natural Environment

As a preliminary step in the statewide survey of indoor radon concentrations, the soils and rocks of New Mexico were grouped on a county level into preliminary availability categories according to estimated potentials for the generation of indoor radon (Chapter IV). This information was used by the EPA in allocation of detectors in the random sampling program discussed in this chapter.

E. Statewide Detector Allocation and Quality Control

Three thousand canister detectors for sampling radon and 562 Alpha track detectors for sampling radon daughters were available for use in this survey. Table 3 and Table 4, Appendix I give an account of distribution of charcoal canisters. Fifty of the charcoal and five of the alpha track detectors were used to conduct a pilot study of fifty homes to evaluate participant response rate and workability of survey forms. This pilot study was conducted before initiating the main part of the survey. The next phase of the study attempt to sample 2,250 randomly selected homes throughout the State to identify radon "hot spots" and to accomplish a statewide characterization of radon. The list of randomly selected homes was provided by the EPA. Alpha track detectors not utilized by the State of New Mexico were returned to the EPA.

In the final phase of the study, the remainder of the charcoal canisters and additional alpha track sampling detectors are being used to sample in high suspect areas of counties which did not receive high priority sampling in the initial phase. These sampling detectors are also being used to establish boundaries of problem areas identified in the initial phase. This has been accomplished by concentrated sampling efforts in these problem areas. Alpha track sampling detectors not used will be returned to EPA. At the writing of this report this phase was in progress; and the data are not available for citation. An additional 200 charcoal canisters are needed for concurrent sampling in homes being tested with alpha track detectors to determine seasonal impacts on radon concentrations in homes. The alpha track detectors would remain in place during the entire testing period while charcoal canisters will be changed during seasonal periods.

Quality assurance for the radon measurements taken in this survey were established by collecting duplicate radon samples in 5 percent of the homes tested. Standard estimates for the data was provided by laboratory analysis of radon samples containing known concentration of radon. Blank samples were submitted to the laboratory at a rate of 2 percent of the total number of samples collected.

F. Detector Allocation by EID District and County

For classification the State is subdivided into the four EID Districts. The distribution of counties by district is listed in Table 4, Appendix I. The New Mexico plan implemented the survey utilizing EID district as well as central office staff resources; and the survey was coordinated from district offices. EID district staff are familiar with the population centers in their Districts, as well as with isolated homes in their areas. Knowledge of home location proved to be invaluable in the sparsely populated areas of New Mexico.

Allocation of radon detectors in the study phase utilizing 2,250 sampling devices was initially based on population or number of households. The number of acceptable homes in each county is shown in Table 4, Appendix I. Sample size was then adjusted by the EPA based on evaluation of the natural (geologic and soil) conditions.

Given the final sample sizes for each district, the expected allocation to counties was proportional to number of homes in the county. Consider, for example, Socorro County in District 1., the number of detectors expected to be placed in homes in Socorro County, on the average over all possible samples, was 200.

G. Information Forms

Upon receiving a list of randomly selected homes for the survey from the EPA, each potential participant was sent a letter (see Appendix II, Figure 1 and Figure 2.-2a.-2b.). This letter explained how the NMEID planned to conduct the radon survey and was accompanied by general information on the radon issue (e.g. EPA, 1986). The letter also informed the potential participant that a telephone interviewer would contact him or her in the near future to discuss the participation. These letters were mailed in batches at the District level.

Approximately one week after the notification letter was mailed out, a telephone interviewer called potential participants and discussed participation. The control/screening form, which was used in conducting the telephone interview was used to log all the calls, times of contact, whether or not the homeowner wished to participate. All pertinent information was logged on the screening form. For details of canister distribution and results of telephone contacts see Table 4, Appendix I.

H. Data Management and Analysis

The information recorded on the field survey form was entered into the State's computer. Information from the laboratory data form was stored in EPA's computer system. The EPA provided this information to the State of New Mexico in a computer readable format. All information from the combined data base are available to both the EPA and the State of New Mexico. Summary statistics and data analyses was generated from this data base (Table 5, Appendix I).

The information on Table 6 is by ZIP codes throughout the state of New Mexico. The first column is the ZIP code; next column indicates the number of samples (canisters placed in homes) and the percentage by radon levels.

I. Discussion Based on Preliminary Data Analysis

Figure 9 (Appendix I) is a map showing distribution by county of major radon- level classes in percent (<4 pCi/l; 4-10 pCi/l; 10-20 pCi/l; and >20 pCi/l) determined during the 1989 random-screening survey of 1772 homes. Table 5 (Appendix I) lists the results by county of the screening survey of the four major radon-level classes showing both the percentage distribution within the four classes and the number of canisters allocated per county.

In this preliminary state survey, only nine counties (Bernalillo, Colfax, Hidalgo, Los Alamos, Luna, Mora, Santa Fe, San Miguel, and Taos) had a significant percentage (> 5%) of homes with indoor-radon measurements greater than 10 pCi/l. All but two of these counties (Hidalgo and Luna) are clustered in the north-central part of the state. This is the Southern Rocky Mountain region identified in earlier phases of radon research where radon-availability could be relatively high in many areas (Table 1.1 and 1.2). The southwestern Basin and Range region, including Hidalgo and Luna counties, is also an area where moderate to high radon-availability conditions have been predicted.

Lower indoor-radon measurements throughout the central and southern part of New Mexico also generally fit the radon-availability projections made in early phases of this study. Radon levels above the EPA "action level" of 4 pCi/l were not detected in this preliminary survey in three counties, Guadalupe, Valencia and Sierra. Twelve other counties (Catron, Chaves, Cibola, De Baca, Doña Ana, Eddy, Harding, Lea, Lincoln, Roosevelt, Quay and Torrance) had no indoor-radon measurements above 10 pCi/l. However, extreme caution should be used in interpreting the data summarized in this report as well as the projections of radon-availability discussed in Chapter IV (see also McLemore and Hawley, 1988). The very small number of charcoal canisters allocated to most areas of the State (Table 5), the very uneven distribution of canisters (most concentrated in small urban areas within very large county areas), and the very short-term nature (24-48 hrs) of the radon-measurement period (Chapter II E) are representative of the significant factors that contribute uncertainty to this type of investigation. Figure 10 is the map of the City of Albuquerque. This map shows the radon level of 4pCi/l and higher by ZIP codes.

CONCLUSION

In conclusion, much additional research is needed in New Mexico (and elsewhere in the Southwest) on both natural and human factors contributing to elevated indoor-radon levels. Studies to date (McLemore, et. al., 1991) suggest that elevated levels are commonly associated with building sites where floors and walls are contiguous to geologic units such as highly-fractured igneous and metamorphic bedrock or coarse-grained sediments derived from these rocks; limestones with solution enlarged joints; and thick pumice deposits. Any bedrock units, associated alluvial and colluvial deposits, and ground water that contain high concentrations of uranium and thorium can locally make a significant contribution and need further study. Some homes built on clay-rich expansive soils also have elevated levels of radon. Areas in the vicinity of uranium mills and mines that have been tested have relatively low levels of indoor radon (below 10piC/l). A better understanding of the natural factors that affect indoor radon concentrations in New Mexico will only be gained through integrated, site-specific investigations which combine more comprehensive indoor-radon measurements and construction information with data on geology, hydrology and soils.

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REFERENCES

A-W Publishers, 1983, Information Please Almanac: A-W Publishers Inc., New York, NY, pp. 665-691, 771.

Berge, L., 1989, Gamma spectra: State Laboratory Division, University of New Mexico Scientific Laboratory

Berry, V. P., Nagy, P. A., Spreng, W. C., Barnes, C. W., and Smouse, P., 1982, Uranium resource evaluation, Tularosa quadrangle, New Mexico: U.S. Department of Energy, Quadrangle Report GJQ-014(82), 22 pp.

Bornhorst, T. J., and Elston, W. E., 1981, Uranium and thorium in mid-Cenozoic rocks of the Mogollon-Datil volcanic field, southwestern New Mexico; in Goodell, P. C., and Waters, A., C., eds., Uranium in volcanic and volcaniclastic rocks: American Association of Petroleum Geologists, Studies in Geology 13, pp. 145-154.

Brookins, D. G., 1978, Radiogenic heat contribution to heat flow from potassium, uranium, thorium in the Precambrian silicic rocks of the Florida Mountains and the Zuni Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Report 98, 13 pp.

Brookins, D. G., 1986, Indoor and soil Rn measurements in the Albuquerque, New Mexico area: Health Physics, v. 51, no. 4, pp. 529-533.

Brookins, D. G., 1990, Controls on indoor radon levels in the Albuquerque, New Mexico area: Geological Society of America, Abstracts with Programs, v. 22, no. 3, pp. 10.

Brookins, D. G., and Della Valle, R. S., 1977, Uranium abundance in some Precambrian and Phanerozoic rocks from New Mexico: Rocky Mountain Association of Geologists, Guidebook to the 1977 field conference, pp. 353-362.

Brookins, D. G., and Enzel, Y., 1989, Soil radon and uranium: Correlation with high indoor radon in the Albuquerque, New Mexico area: Geological Society of America, Annual Meeting Abstracts, pp. A145.

Condie, K. C., and Brookins, D. G., 1980, Composition and heat generation of the Precambrian crust in New Mexico: Geochemical Journal, v. 14, pp. 95-99.

Dickson, R. E., Drake, D. P. and Reese, T. J., 1977, Measured sections and analyses of uranium host rocks of the Dockum Group, New Mexico and Texas: U.S. Energy Research and Development Administration, Report GJBX-9(77), 68 pp.

Durrance, E. M., 1986, Radioactivity in geology, principles and applications: John Wiley & Sons, Inc., New York, NY, 441 pp.

Duval, Joseph S., 1988, Aerial gamma-ray contour maps of regional surface concentrations of uranium, potassium, and thorium in New Mexico: U.S. Geological Survey, Geophysical Investigation Map GP-979, scale 1:750,000.

Environmental Protection Agency (EPA), 1986, A citizen's guide to radon: EPA-86-004, Washington, DC (8/86).

Environmental Protection Agency (EPA), 1988, Radon reduction techniques for detached houses: Technical guidance (second edition): EPA/625-5-87-019, Washington, DC (1/88).

Environmental Protection Agency Advisory Council, 1988, Radon hotline-telephone result codes (TRC), Washington, DC (9/16/88).

Goodknight, C. S., and Dexter, J. J., 1984, Evaluation of uranium anomalies in the southwestern part of the Costilla massif, Taos County, New Mexico; in Reports on field investigations of uranium anomalies: U.S. Department of Energy, Report GJBX-1(84), pp. IVI-IV28.

Herczeg, A. L., Simpson, H. J., Anderson, R. F., Trier, R. M., Mathieu, G. G., and Deck, B. L., 1988, Uranium and radium mobility in ground waters and brines within the Delaware Basin, southeastern New Mexico, USA: Chemical Geology (Isotope Geoscience Section), v. 72, pp. 181-196.

Kotrappa, P., Dempsey, J. C., Hickey, J. R., and Stieff, L. R., 1988, An Electret passive environmental Rn-222 monitor based on ionization measurement: Health Physics, v. 54, no. 1, pp. 47-56.

McAnulty, W. N., 1978, Fluorspar in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 34, 64 pp.

McLemore, V. T., 1983, Uranium and thorium occurrences in New Mexico—distribution, geology, production, and resources with selected bibliography: New Mexico Bureau of Mines and Mineral Resources, Open-file Report OF-183, 950 pp.

McLemore, V. T., 1986, Geology, geochemistry, and mineralization of syenites in the Red Hills, southern Caballo Mountains, Sierra County, New Mexico—preliminary observations: New Mexico Geological Society, Guidebook to the 37th field conference, pp. 151-159.

McLemore, V. T., and Chamberlin, R. M., 1986, National uranium resource evaluation (NURE) data: New Mexico Bureau of Mines and Mineral Resources, 12 pp.

McLemore, V. T., and Chenoweth, W. L., 1989, Uranium resources in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Resource Map 18.

McLemore, V. T., and Hawley, J. W., 1988, Preliminary geologic evaluation of radon availability in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Report OF-345, 28 pp.

McLemore, V. T., and McKee, C., 1988, Geochemistry of the Burro Mountains syenites and adjacent Proterozoic granite and gneiss and the relationship to a Cambrian-Ordovician alkalic magmatic event in New Mexico and southern Colorado: New Mexico Geological Society, Guidebook to the 39th field conference, pp. 83-88.

McLemore, V. T., Hawley, J. W., and Manchego, R. A., 1991, Geologic evaluation of radon availability in New Mexico: A progress report, in the 1991 International Symposium on Radon and Radon Reduction Technology Proceedings: United States Environmental Protection Agency, Offices of Research and Development, and air and Radiating (In Press).

NCRP, 1984, Evaluation of occupation and environmental exposures to radon and radon daughters in the United States: NCRP Report No. 78, Washington, DC (5/84).

New Mexico Geological Society, 1982, New Mexico highway geologic map: New Mexico Geological Society, text, scale 1:1,000,000.

Ogden, A. E., Welling, W. B., Funderburg, R. D., and Boschult, L. C., 1987, A preliminary assessment of factors affecting radon levels in Idaho; in Graves, B., ed., Radon, radium, and other radioactivity in ground water: Lewis Publishers, Inc., Chelsea, Michigan, pp. 83-96.

Peake, R. T., and Hess, C. T., 1987, Radon and geology: Some observations; in Hemphill, D. D., ed., Trace substances in environmental health: University of Missouri, Columbia, pp. 186-194.

Peake, R. T., and Schumann, R. R., 1990, Regional radon characterizations: U.S. Geological Survey, Bulletin, in press.

Pirie, J. C., and Hamilton, J. E., 1989, New Hampshire radon survey 1987-1989: New Hampshire Division of Public Health Services Report #89-015, 44 pp.

Reid, B. E., Griswold, G. B., Jacobsen, L. C., and Lessand, R. H., 1980, National uranium resource evaluation, Raton quadrangle, New Mexico and Colorado: U.S. Department of Energy, Quadrangle Report GJQ-5(80), 83 pp.

Ronca-Battista, M., Magno, P., and Nyberg, P., 1987, Interim protocols from screening and follow-up radon and radon-decay product measurements: U.S. Environmental Protection Agency, EPA-520/1-86-014, Washington, DC.

Sprinkel, D. A., and Soloman, B. J., 1990, Radon hazards in Utah: Utah Geological and Mineral Survey, Circular 81, 24 pp.

Staatz, M. H., 1982, Geologic map of the Laughlin Peak area, Colfax County, New Mexico: U.S. Geological Survey, Open-file Report 82-453, scale 1:12,000.

Staatz, M. H., 1985, Geology and description of the thorium and rare-earth veins in the Laughlin Peak area, Colfax County, New Mexico: U.S. Geological Survey, Professional Paper 1049-E, 32 pp.

Staatz, M. H., 1986, Geologic map of the Pine Buttes quadrangle, Colfax County, New Mexico: U.S. Geological Survey, Geologic Quadrangle Map GQ-1591, scale 1:24,000.

Staatz, M. H., 1987, Geologic map of the Tres Hermanos Peak quadrangle, Colfax County, New Mexico: U.S. Geological Survey, Geologic Quadrangle Map GQ-1605, scale 1:24,000.

Sterling, D. A., and Malan, R. C., 1970, Distribution of uranium and thorium in Precambrian rocks of the southwestern United States: American Institute of Mining Engineering, Society of Mining Engineers, Transactions, v. 247, pp. 255-259.

Walton, A. W., Salter, T. L., and Zetterlund, D., 1980, Uranium potential of southwestern New Mexico (southern Hidalgo County), including observations in crystallization history of lavas and ash tuffs and the release of uranium from them: U.S. Department of Energy, Report GJBX-169(80), 114 p.

Williams, J. L., 1986, Population distribution, 1980; in Williams, J. L., ed., New Mexico in Maps, 2nd edition: University of New Mexico, Albuquerque, pp. 150-152.

Zapp, A. D., 1941, Geology of the northeastern Cornudas Mountains, New Mexico: Unpublished M.S. thesis, University of Texas, Austin, 63 pp.

Zielinski, R. A., 1981, Experimental leaching of volcanic glass: Implications for evaluation of glassy volcanic rocks as sources of uranium; in Goodell, P. C., and Waters, A. C., eds., Uranium in volcanic and volcaniclastic rocks: American Association of Petroleum Geologists, Studies in Geology 13, pp. 1-12.

Another way to think about the risk associated with radon exposure is to compare it with the risk from other activities. The charts below give an idea of how exposure to various radon levels over a lifetime compares to the risk of developing lung cancer from smoking and from chest x-rays. The chart also compares these levels to the average indoor and outdoor radon concentrations.

As you look at the chart, be sure to use the proper radon-level column for your results (either WL or pCi/l).

Radon Risk Evaluation Charts

pCi/l	WL	Estimated number of LUNG CANCER DEATHS due to radon exposure (out of 1000)	Comparable exposure levels	Comparable risk
200	1	440—770	1000 times average outdoor level	More than 60 times non-smoker risk
100	0.5	270—630	100 times average indoor level	4 pack-a-day smoker
40	0.2	120—380		20,000 chest x-rays per year 2 pack-a-day smoker
20	0.1	60—210	100 times average outdoor level	
10	0.05	30—120	10 times average indoor level	1 pack-a-day smoker
4	0.02	13—50		5 times non-smoker risk 200 chest x-rays per year
2	0.01	7—30	10 times average outdoor level	
1	0.005	3—13	Average indoor level	Non-smoker risk of dying from lung cancer
0.2	0.001	1—3	Average outdoor level	20 chest x-rays per year

Annual Radon level	If a community of 100 people were exposed to this level:	This risk of dying from lung cancer compares to:
100 pCi/L	About 35 people in the community may die from Radon.	Having 2000 chest x-rays each year
40 pCi/L	About 17 people in the community may die from Radon.	Smoking 2 packs of cigarettes each day
20 pCi/L	About 9 people in the community may die from Radon.	Smoking 1 pack of cigarettes each day
10 pCi/L	About 5 people in the community may die from Radon.	Having 500 chest x-rays each year
4 pCi/L	About 2 people in the community may die from Radon.	Smoking half a pack of cigarettes each day
2 pCi/L	About 1 person in the community may die from Radon.	Having 100 chest x-rays each year

Levels as high as 3500 pCi/L have been found in some homes.
The average Radon level outdoors is around .2 pCi/L or less.

The risks shown in this chart are for the general population, including men and women of all ages as well as smokers and non-smokers. Children may be at higher risk.

Figure 7

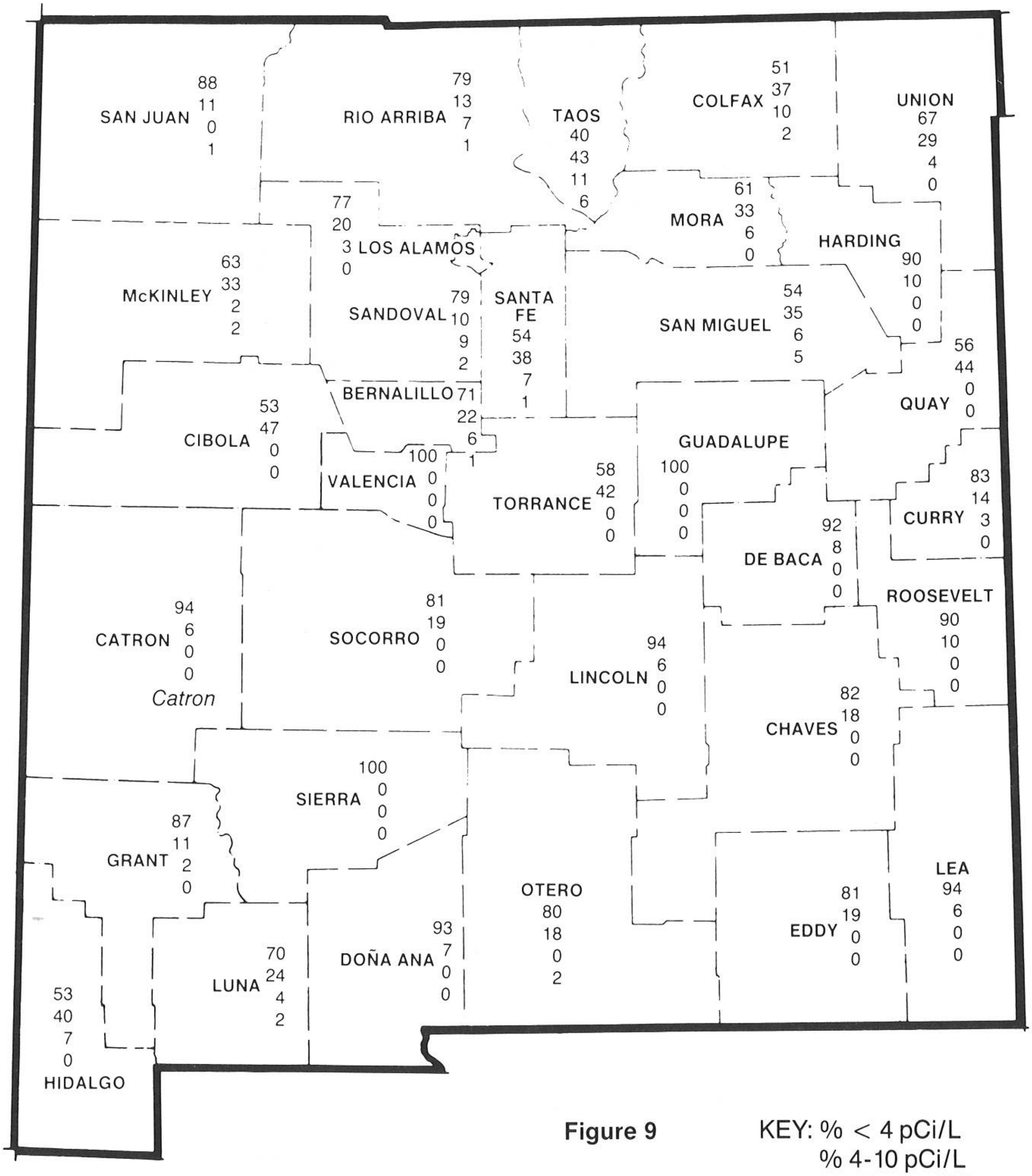

Figure 9

KEY: % < 4 pCi/L
% 4-10 pCi/L
% 10-20 pCi/L
% > 20 pCi/L

Map of City of Albuquerque by ZIP code

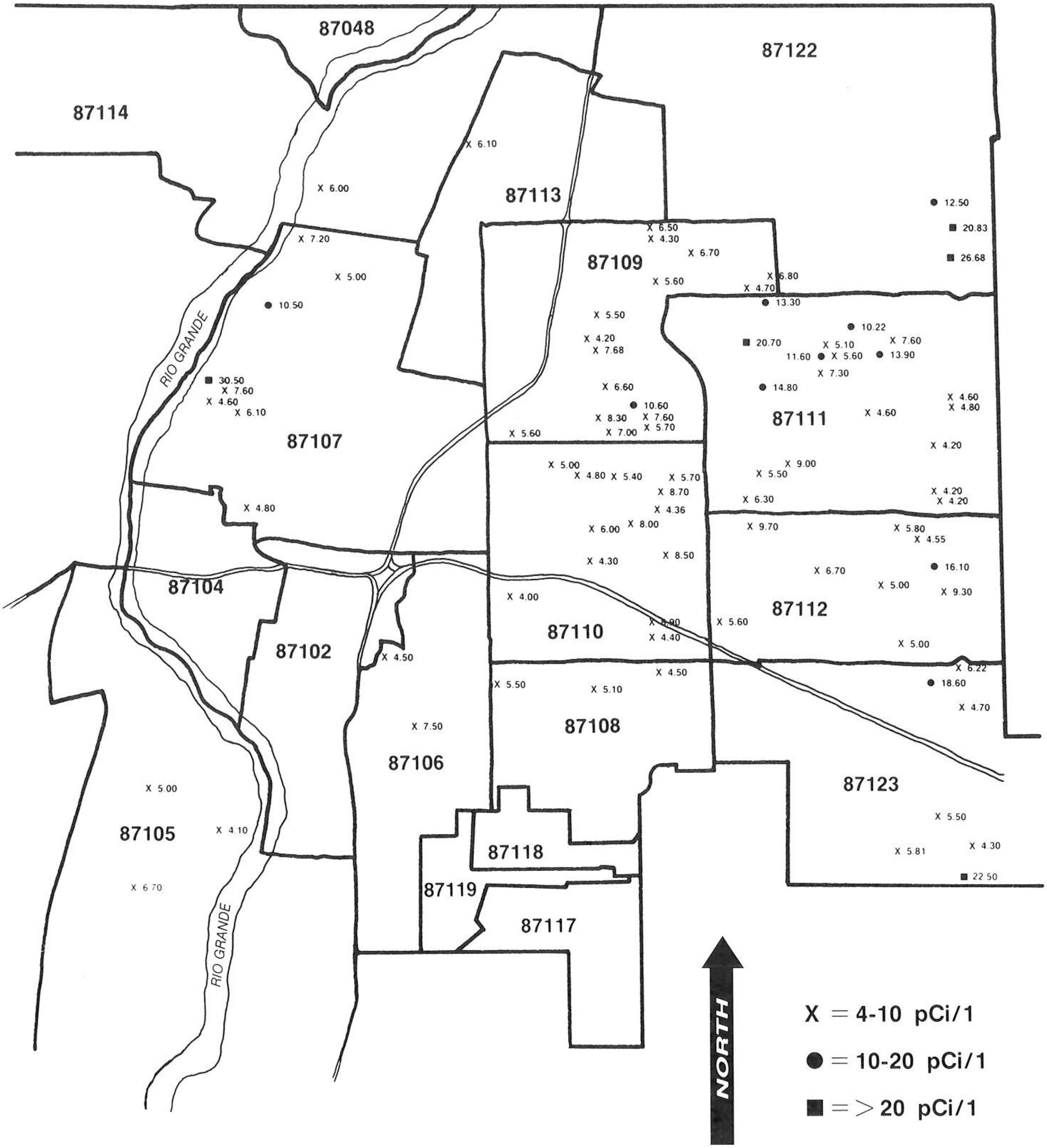

Figure 10

Table 1.1—Preliminary radon-availability rating for counties in New Mexico.

High	Moderate	Low
Doña Ana	Bernalillo	Curry
Hidalgo	Catron	De Baca
Los Alamos	Cibola	Guadalupe
Luna	Chaves	Harding
McKinley	Colfax	Mora
Rio Arriba	Eddy	Otero
Sandoval	Grant	Roosevelt
Santa Fe	Lea	San Miguel
Socorro	Lincoln	Torrance
Taos	San Juan	Valencia
	Sierra	
	Quay	
	Union	

Table 1.2—Preliminary radon-availability rating for the largest cities in New Mexico.

City	County	Population 1984 estimates	Classification
Albuquerque	Bernalillo	350,575	moderate
Santa Fe	Santa Fe	52,274	high
Las Cruces	Doña Ana	50,275	high
Roswell	Chaves	45,702	high
Farmington	San Juan	37,332	low
Hobbs	Lea	35,029	moderate
Clovis	Curry	33,424	moderate
Carlsbad	Eddy	28,443	high
Alamogordo	Otero	27,485	low
Gallup	McKinley	20,959	high
Los Alamos-White Rock	Los Alamos	19,040	high
Las Vegas	San Miguel	15,364	low
Grants-Milan	Cibola	12,823	moderate
Rio Rancho	Sandoval	12,310	moderate
Artesia	Eddy	11,938	low
Lovington	Lea	11,704	moderate
Silver City	Grant	11,014	low
Portales	Roosevelt	10,456	low
Deming	Luna	10,609	high

Table 2—Size and population of counties in New Mexico and several states (Williams, 1986; A-W Publishers, Inc., 1983).

Rank	County	Land Area (square miles)	Population 1987	Population Density per square mile
11	Bernalillo 001	1,169	479,000	409.8
	Catron 003	6,929	2,800	0.4
	Chaves 005	6,066	58,100	9.6
2	Colfax 007	3,762	14,500	3.9
	Curry 009	1,408	42,400	30.1
	De Baca 011	2,323	2,400	1.0
	Doña Ana 013	3,819	126,600	33.2
	Eddy 015	4,184	53,900	12.9
	Grant 017	3,969	27,200	6.9
	Guadalupe 019	3,032	4,300	1.4
	Harding 021	2,122	1,000	0.4
9	Hidalgo 023	3,445	6,200	1.8
	Lea 025	4,390	68,000	15.5
	Lincoln 027	4,832	15,000	3.1
	Los Alamos 028	109	18,600	170.6
8	Luna 029	2,965	18,000	6.1
4	McKinley 031	5,442	63,300	11.6
7	Mora 033	1,930	4,700	2.4
	Otero 035	6,626	51,000	7.7
	Quay 037	2,874	12,000	4.2
	Rio Arriba 039	5,856	33,100	5.7
	Roosevelt 041	2,453	16,700	6.8
5	Sandoval 043	3,707	47,200	12.7
	San Juan 045	5,522	94,000	17.0
3	San Miguel 047	4,709	25,400	5.4
6	Santa Fe 049	1,905	87,500	45.9
	Sierra 051	4,178	9,800	2.3
	Socorro 053	6,625	13,900	2.1
1	Taos 055	2,204	22,600	10.3
10	Torrance 057	3,335	9,000	2.7
	Union 059	3,830	5,200	1.4
	Valencia 061 and Cibola 006	5,616	64,700	11.5
	TOTAL NEW MEXICO	121,336	1,498,100	12.3
	STATE			
	Rhode Island	1,055	947,154	897.8
	Delaware	1,932	638,432	
	Connecticut	4,872	3,107,576	637.8
	Massachusetts	7,824	5,737,037	733.3
	Maryland	9,837	4,216,975	428.7
	Vermont	9,273	511,456	55.2
	New Hampshire	8,993	920,610	102.4
	New Jersey	7,468	7,364,823	986.2

Table 3—ACCOUNT OF DISTRIBUTION OF CHARCOAL CANISTERS

Total homeowners telephones		2387
Canisters distributed SR		2057
Canisters analyzed SR		1772
Canisters mailed out and not returned for analysis		282
Ineligible homes contacted:		
Category	210 no answer/busy signal	144
	212 non-phone, answering machine	15
	214 machine noise	1
	216 non-working phone	26
	218 wrong connection	4
	219 non-residence phone	11
	220 temporary residence	3
	221 ineligible residence	6
	222 renter occupied	69
	224 federal/Indian land	3
	228 unavailable homeowner	4
	230 refusal/no answer	21
	231 partial—answered question 1 to 13	10
	232 partial answered question 1 to 14	2
	236 emotional impairment	6
	241 eligible but refuse detector	5
	TOTAL	330

Table 4

District 1

County	**Number of Acceptable Homes**
San Juan	18,529
McKinley	9,398
Valencia	15,503
Socorro	2,914
Bernalillo	95,533
Torrance	2,167
Sandoval	8,711
Los Alamos	4,629
Rio Arriba*	7,086*
TOTAL	**164,570**

District II

County	**Number of Acceptable Homes**
Union	1,285
Colfax	3,387
Taos	4,855
Mora	1,067
Harding	296
San Miguel	5,123
Santa Fe	17,460
Rio Arriba*	7,086*
TOTAL	**40,559**

***SHARED BY DISTRICT I AND II**

District III

County	**Number of Acceptable Homes**
Hidalgo	1,103
Luna	4,092
Doña Ana	19,494
Grant	6,206
Sierra	2,663
Catron	698
Otero	8,897
TOTAL	**43,153**

District IV

County	**Number of Acceptable Homes**
Eddy	12,053
Lea	13,550
Chaves	12,838
Lincoln	2,989
Roosevelt	3,893
De Baca	769
Curry	9,428
Guadalupe	1,071
Quay	2,883
TOTAL	**59,474**

Table 5
NEW MEXICO ENVIRONMENTAL IMPROVEMENT DIVISION
Indoor Radon Study—Phase 1—Survey type SR

	<4 pCi/L		>4, <10 pCi/L		>10, <20 pCi/L		>20 pCi/L		Total
county	no.	%	no.	%	no.	%	no.	%	cannisters
01 Bernalillo	267	70.6	85	22.5	22	5.8	4	1.1	378
03 Catron	16	94.1	1	5.9	0	0.0	0	0.0	17
05 Chaves	41	82.0	9	18.0	0	0.0	0	0.0	50
06 Cibola	8	53.3	7	46.7	0	0.0	0	0.0	15
07 Colfax	43	51.2	31	36.9	8	9.5	2	2.4	84
09 Curry	35	83.3	6	14.3	1	2.4	0	0.0	42
11 De Baca	12	92.3	1	7.7	0	0.0	0	0.0	13
13 Doña Ana	75	92.6	6	7.4	0	0.0	0	0.0	81
15 Eddy	39	81.3	9	18.8	0	0.0	0	0.0	48
17 Grant	48	87.3	6	10.9	1	1.8	0	0.0	55
19 Guadalupe	6	100.0	0	0.0	0	0.0	0	0.0	6
21 Harding	9	90.0	1	10.0	0	0.0	0	0.0	10
23 Hidalgo	8	53.3	6	40.0	1	6.7	0	0.0	15
25 Lea	47	94.0	3	6.0	0	0.0	0	0.0	50
27 Lincoln	16	94.1	1	5.9	0	0.0	0	0.0	17
28 Los Alamos	30	76.9	8	20.5	1	2.6	0	0.0	39
29 Luna	35	70.0	12	24.0	2	4.0	1	2.0	50
31 McKinley	29	63.0	15	32.6	1	2.2	1	2.2	46
33 Mora	11	61.1	6	33.3	1	5.6	0	0.0	18
35 Otero	35	79.5	8	18.2	0	0.0	1	2.3	44
37 Quay	5	55.6	4	44.4	0	0.0	0	0.0	9
39 Rio Arriba	55	78.6	9	12.9	5	7.1	1	1.4	70
41 Roosevelt	36	90.0	4	10.0	0	0.0	0	0.0	40
43 Sandoval	55	78.6	7	10.0	6	8.6	2	2.9	70
45 San Juan	158	88.3	20	11.2	0	0.0	1	0.6	179
47 San Miguel	34	54.0	22	34.9	4	6.3	3	4.8	63
49 Santa Fe	40	54.1	28	37.8	5	6.8	1	1.4	74
51 Sierra	39	100.0	0	0.0	0	0.0	0	0.0	39
53 Socorro	30	81.1	7	18.9	0	0.0	0	0.0	37
55 Taos	19	40.4	20	42.6	5	10.6	3	6.4	47
57 Torrance	7	58.3	5	41.7	0	0.0	0	0.0	12
59 Union	18	66.7	8	29.6	1	3.7	0	0.0	27
61 Valencia	27	100.0	0	0.0	0	0.0	0	0.0	27

Table 6
NEW MEXICO ENVIRONMENTAL IMPROVEMENT DIVISION
Community Services Bureau
Indoor Radon Study—Phase 1—1988/1989

	<4 pCi/L		>4, <10 pCi/L		>10, <20 pCi/L		>20 pCi/L		
zipcode	no.	%	no.	%	no.	%	no.	%	Total
0	1	100.0	0	0.0	0	0.0	0	0.0	1
82048	0	*****	0	*****	0	*****	0	*****	0
85722	0	*****	0	*****	0	*****	0	*****	0
87001	2	66.7	1	33.3	0	0.0	0	0.0	3
87002	17	100.0	0	0.0	0	0.0	0	0.0	17
87004	4	80.0	1	20.0	0	0.0	0	0.0	5
87008	1	100.0	0	0.0	0	0.0	0	0.0	1
87010	1	100.0	0	0.0	0	0.0	0	0.0	1
87012	0	0.0	1	100.0	0	0.0	0	0.0	1
87013	2	100.0	0	0.0	0	0.0	0	0.0	2
87015	3	100.0	0	0.0	0	0.0	0	0.0	3
87016	0	0.0	2	100.0	0	0.0	0	0.0	2
87017	1	100.0	0	0.0	0	0.0	0	0.0	1
87018	0	*****	0	*****	0	*****	0	*****	0
87019	0	*****	0	*****	0	*****	0	*****	0
87020	5	62.5	3	37.5	0	0.0	0	0.0	8
87021	1	33.3	2	66.7	0	0.0	0	0.0	3
87024	1	100.0	0	0.0	0	0.0	0	0.0	1
87025	2	33.3	1	16.7	1	16.7	2	33.3	6
87031	2	100.0	0	0.0	0	0.0	0	0.0	2
87032	1	100.0	0	0.0	0	0.0	0	0.0	1
87035	2	66.7	1	33.3	0	0.0	0	0.0	3
87036	0	*****	0	*****	0	*****	0	*****	0
87037	1	100.0	0	0.0	0	0.0	0	0.0	1
87039	0	0.0	1	100.0	0	0.0	0	0.0	1
87041	3	100.0	0	0.0	0	0.0	0	0.0	3
87043	5	55.6	3	33.3	1	11.1	0	0.0	9
87044	1	100.0	0	0.0	0	0.0	0	0.0	1
87047	2	66.7	1	33.3	0	0.0	0	0.0	3
87048	10	76.9	2	15.4	1	7.7	0	0.0	13
87049	0	0.0	0	0.0	1	100.0	0	0.0	1
87053	0	0.0	0	0.0	1	100.0	0	0.0	1
87055	0	*****	0	*****	0	*****	0	*****	0
87056	2	100.0	0	0.0	0	0.0	0	0.0	2
87059	3	42.9	3	42.9	1	14.3	0	0.0	7
87060	1	100.0	0	0.0	0	0.0	0	0.0	1
87063	0	*****	0	*****	0	*****	0	*****	0
87064	2	100.0	0	0.0	0	0.0	0	0.0	2
87067	0	0.0	1	100.0	0	0.0	0	0.0	1
87068	6	100.0	0	0.0	0	0.0	0	0.0	6
87101	0	0.0	1	100.0	0	0.0	0	0.0	1
87102	3	60.0	1	20.0	1	20.0	0	0.0	5
87103	4	100.0	0	0.0	0	0.0	0	0.0	4
87104	10	83.3	1	8.3	1	8.3	0	0.0	12
87105	32	88.9	4	11.1	0	0.0	0	0.0	36
87106	19	95.0	1	5.0	0	0.0	0	0.0	20
87107	22	73.3	6	20.0	2	6.7	0	0.0	30
87108	17	85.0	3	15.0	0	0.0	0	0.0	20
87109	14	51.9	9	33.3	4	14.8	0	0.0	27

NEW MEXICO ENVIRONMENTAL IMPROVEMENT DIVISION
Community Services Bureau
Indoor Radon Study—Phase 1—1988/1989

zipcode	<4 pCi/L		>4, <10 pCi/L		>10, <20 pCi/L		>20 pCi/L		Total
	no.	%	no.	%	no.	%	no.	%	
87110	34	73.9	12	26.1	0	0.0	0	0.0	46
87111	35	56.5	17	27.4	9	14.5	1	1.6	62
87112	27	62.8	14	32.6	2	4.7	0	0.0	43
87113	1	33.3	2	66.7	0	0.0	0	0.0	3
87114	7	87.5	1	12.5	0	0.0	0	0.0	8
87120	13	92.9	1	7.1	0	0.0	0	0.0	14
87121	5	83.3	1	16.7	0	0.0	0	0.0	6
87122	2	25.0	2	25.0	2	25.0	2	25.0	8
87123	16	80.0	3	15.0	0	0.0	1	5.0	20
87124	25	96.2	0	0.0	1	3.8	0	0.0	26
87212	1	100.0	0	0.0	0	0.0	0	0.0	1
87301	24	58.5	15	36.6	1	2.4	1	2.4	41
87305	1	100.0	0	0.0	0	0.0	0	0.0	1
87310	1	100.0	0	0.0	0	0.0	0	0.0	1
87316	0	0.0	1	100.0	0	0.0	0	0.0	1
87317	0	*****	0	*****	0	*****	0	*****	0
87321	2	66.7	1	33.3	0	0.0	0	0.0	3
87323	2	100.0	0	0.0	0	0.0	0	0.0	2
87401	96	88.1	13	11.9	0	0.0	0	0.0	109
87410	15	75.0	5	25.0	0	0.0	0	0.0	20
87412	1	100.0	0	0.0	0	0.0	0	0.0	1
87413	25	96.2	0	0.0	0	0.0	1	3.8	26
87415	3	100.0	0	0.0	0	0.0	0	0.0	3
87417	8	88.9	1	11.1	0	0.0	0	0.0	9
87418	3	100.0	0	0.0	0	0.0	0	0.0	3
87421	1	50.0	1	50.0	0	0.0	0	0.0	2
87440	1	100.0	0	0.0	0	0.0	0	0.0	1
87443	1	100.0	0	0.0	0	0.0	0	0.0	1
87499	2	100.0	0	0.0	0	0.0	0	0.0	2
87501	19	51.4	13	35.1	4	10.8	1	2.7	37
87502	1	100.0	0	0.0	0	0.0	0	0.0	1
87505	8	38.1	12	57.1	1	4.8	0	0.0	21
87507	1	100.0	0	0.0	0	0.0	0	0.0	1
87510	2	66.7	1	33.3	0	0.0	0	0.0	3
87511	7	87.5	1	12.5	0	0.0	0	0.0	8
87512	0	0.0	1	100.0	0	0.0	0	0.0	1
87513	2	66.7	1	33.3	0	0.0	0	0.0	3
87514	1	33.3	2	66.7	0	0.0	0	0.0	3
87517	2	100.0	0	0.0	0	0.0	0	0.0	2
87519	0	0.0	0	0.0	0	0.0	1	100.0	1
87520	4	80.0	0	0.0	1	20.0	0	0.0	5
87521	2	66.7	1	33.3	0	0.0	0	0.0	3
87522	7	70.0	1	10.0	2	20.0	0	0.0	10
87523	1	50.0	1	50.0	0	0.0	0	0.0	2
87524	0	0.0	0	0.0	2	100.0	0	0.0	2
87527	3	60.0	1	20.0	1	20.0	0	0.0	5
87529	0	0.0	3	100.0	0	0.0	0	0.0	3
87530	0	0.0	2	100.0	0	0.0	0	0.0	2
87531	3	75.0	1	25.0	0	0.0	0	0.0	4
87532	3	100.0	0	0.0	0	0.0	0	0.0	3

NEW MEXICO ENVIRONMENTAL IMPROVEMENT DIVISION
Community Services Bureau
Indoor Radon Study—Phase 1—1988/1989

	<4 pCi/L		>4, <10 pCi/L		>10, <20 pCi/L		>20 pCi/L		
zipcode	no.	%	no.	%	no.	%	no.	%	Total
87533	7	87.5	0	0.0	0	0.0	1	12.5	8
87535	1	33.3	2	66.7	0	0.0	0	0.0	3
87537	1	100.0	0	0.0	0	0.0	0	0.0	1
87539	1	100.0	0	0.0	0	0.0	0	0.0	1
87544	29	76.3	8	21.1	1	2.6	0	0.0	38
87548	1	100.0	0	0.0	0	0.0	0	0.0	1
87549	1	100.0	0	0.0	0	0.0	0	0.0	1
87550	1	50.0	1	50.0	0	0.0	0	0.0	2
87551	1	100.0	0	0.0	0	0.0	0	0.0	1
87552	6	66.7	1	11.1	1	11.1	1	11.1	9
87553	3	37.5	4	50.0	1	12.5	0	0.0	8
87556	5	62.5	2	25.0	0	0.0	1	12.5	8
87557	1	100.0	0	0.0	0	0.0	0	0.0	1
87558	0	0.0	1	100.0	0	0.0	0	0.0	1
87560	2	66.7	1	33.3	0	0.0	0	0.0	3
87561	1	100.0	0	0.0	0	0.0	0	0.0	1
87563	2	100.0	0	0.0	0	0.0	0	0.0	2
87564	0	0.0	2	100.0	0	0.0	0	0.0	2
87565	0	*****	0	*****	0	*****	0	*****	0
87566	2	100.0	0	0.0	0	0.0	0	0.0	2
87567	0	*****	0	*****	0	*****	0	*****	0
87569	0	0.0	1	100.0	0	0.0	0	0.0	1
87571	0	0.0	2	50.0	2	50.0	0	0.0	4
87574	3	100.0	0	0.0	0	0.0	0	0.0	3
87575	2	100.0	0	0.0	0	0.0	0	0.0	2
87577	0	0.0	0	0.0	0	0.0	1	100.0	1
87578	1	100.0	0	0.0	0	0.0	0	0.0	1
87579	1	50.0	1	50.0	0	0.0	0	0.0	2
87581	0	0.0	1	100.0	0	0.0	0	0.0	1
87582	4	100.0	0	0.0	0	0.0	0	0.0	4
87583	1	100.0	0	0.0	0	0.0	0	0.0	1
87610	1	100.0	0	0.0	0	0.0	0	0.0	1
87701	23	54.8	14	33.3	3	7.1	2	4.8	42
87702	0	0.0	1	100.0	0	0.0	0	0.0	1
87710	3	42.9	3	42.9	0	0.0	1	14.3	7
87711	1	100.0	0	0.0	0	0.0	0	0.0	1
87713	1	100.0	0	0.0	0	0.0	0	0.0	1
87714	2	66.7	1	33.3	0	0.0	0	0.0	3
87715	1	100.0	0	0.0	0	0.0	0	0.0	1
87718	1	33.3	2	66.7	0	0.0	0	0.0	3
87722	1	100.0	0	0.0	0	0.0	0	0.0	1
87723	2	66.7	1	33.3	0	0.0	0	0.0	3
87725	0	0.0	1	100.0	0	0.0	0	0.0	1
87728	2	33.3	3	50.0	1	16.7	0	0.0	6
87729	1	100.0	0	0.0	0	0.0	0	0.0	1
87732	4	57.1	3	42.9	0	0.0	0	0.0	7
87733	1	50.0	1	50.0	0	0.0	0	0.0	2
87736	1	33.3	1	33.3	1	33.3	0	0.0	3
87740	25	47.2	20	37.7	7	13.2	1	1.9	53
87742	0	0.0	1	100.0	0	0.0	0	0.0	1

zipcode	<4 pCi/L		>4, <10 pCi/L		>10, <20 pCi/L		>20 pCi/L		Total
	no.	%	no.	%	no.	%	no.	%	
87743	6	100.0	0	0.0	0	0.0	0	0.0	6
87744	1	100.0	0	0.0	0	0.0	0	0.0	1
87745	1	50.0	1	50.0	0	0.0	0	0.0	2
87746	1	100.0	0	0.0	0	0.0	0	0.0	1
87747	8	80.0	2	20.0	0	0.0	0	0.0	10
87752	1	100.0	0	0.0	0	0.0	0	0.0	1
87801	19	76.0	6	24.0	0	0.0	0	0.0	25
87820	2	100.0	0	0.0	0	0.0	0	0.0	2
87821	1	100.0	0	0.0	0	0.0	0	0.0	1
87823	2	66.7	1	33.3	0	0.0	0	0.0	3
87824	1	100.0	0	0.0	0	0.0	0	0.0	1
87825	7	100.0	0	0.0	0	0.0	0	0.0	7
87827	2	100.0	0	0.0	0	0.0	0	0.0	2
87828	2	100.0	0	0.0	0	0.0	0	0.0	2
87829	2	100.0	0	0.0	0	0.0	0	0.0	2
87830	4	100.0	0	0.0	0	0.0	0	0.0	4
87832	0	*****	0	*****	0	*****	0	*****	0
87901	29	100.0	0	0.0	0	0.0	0	0.0	29
87917	1	100.0	0	0.0	0	0.0	0	0.0	1
87931	1	100.0	0	0.0	0	0.0	0	0.0	1
87932	1	100.0	0	0.0	0	0.0	0	0.0	1
87935	3	100.0	0	0.0	0	0.0	0	0.0	3
87937	1	100.0	0	0.0	0	0.0	0	0.0	1
87942	4	100.0	0	0.0	0	0.0	0	0.0	4
87981	1	100.0	0	0.0	0	0.0	0	0.0	1
87982	0	0.0	0	0.0	1	100.0	0	0.0	1
88001	40	95.2	2	4.8	0	0.0	0	0.0	42
88005	22	88.0	3	12.0	0	0.0	0	0.0	25
88010	1	100.0	0	0.0	0	0.0	0	0.0	1
88011	1	100.0	0	0.0	0	0.0	0	0.0	1
88020	2	40.0	2	40.0	1	20.0	0	0.0	5
88021	3	100.0	0	0.0	0	0.0	0	0.0	3
88023	2	66.7	1	33.3	0	0.0	0	0.0	3
88026	2	100.0	0	0.0	0	0.0	0	0.0	2
88028	2	100.0	0	0.0	0	0.0	0	0.0	2
88029	2	100.0	0	0.0	0	0.0	0	0.0	2
88030	26	74.3	8	22.9	1	2.9	0	0.0	35
88031	4	57.1	1	14.3	1	14.3	1	14.3	7
88032	1	100.0	0	0.0	0	0.0	0	0.0	1
88033	1	100.0	0	0.0	0	0.0	0	0.0	1
88038	2	100.0	0	0.0	0	0.0	0	0.0	2
88039	3	75.0	1	25.0	0	0.0	0	0.0	4
88040	1	50.0	1	50.0	0	0.0	0	0.0	2
88043	6	100.0	0	0.0	0	0.0	0	0.0	6
88044	2	100.0	0	0.0	0	0.0	0	0.0	2
88045	6	60.0	4	40.0	0	0.0	0	0.0	10
88047	2	100.0	0	0.0	0	0.0	0	0.0	2
88048	1	50.0	1	50.0	0	0.0	0	0.0	2
88049	1	100.0	0	0.0	0	0.0	0	0.0	1
88052	1	100.0	0	0.0	0	0.0	0	0.0	1

NEW MEXICO ENVIRONMENTAL IMPROVEMENT DIVISION
Community Services Bureau
Indoor Radon Study—Phase 1—1988/1989

	<4 pCi/L		>4, <10 pCi/L		>10, <20 pCi/L		>20 pCi/L		
zipcode	no.	%	no.	%	no.	%	no.	%	Total
88053	1	100.0	0	0.0	0	0.0	0	0.0	1
88055	2	66.7	1	33.3	0	0.0	0	0.0	3
88061	19	82.6	3	13.0	1	4.3	0	0.0	23
88062	10	90.9	1	9.1	0	0.0	0	0.0	11
88063	1	100.0	0	0.0	0	0.0	0	0.0	1
88065	1	100.0	0	0.0	0	0.0	0	0.0	1
88101	32	84.2	5	13.2	1	2.6	0	0.0	38
88110	1	100.0	0	0.0	0	0.0	0	0.0	1
88115	1	100.0	0	0.0	0	0.0	0	0.0	1
88116	2	100.0	0	0.0	0	0.0	0	0.0	2
88118	1	100.0	0	0.0	0	0.0	0	0.0	1
88119	12	92.3	1	7.7	0	0.0	0	0.0	13
88120	1	100.0	0	0.0	0	0.0	0	0.0	1
88124	1	100.0	0	0.0	0	0.0	0	0.0	1
88130	30	88.2	4	11.8	0	0.0	0	0.0	34
88132	1	100.0	0	0.0	0	0.0	0	0.0	1
88135	2	100.0	0	0.0	0	0.0	0	0.0	2
88201	36	80.0	9	20.0	0	0.0	0	0.0	45
88210	5	38.5	8	61.5	0	0.0	0	0.0	13
88220	31	96.9	1	3.1	0	0.0	0	0.0	32
88230	1	100.0	0	0.0	0	0.0	0	0.0	1
88231	2	100.0	0	0.0	0	0.0	0	0.0	2
88232	2	100.0	0	0.0	0	0.0	0	0.0	2
88240	28	96.6	1	3.4	0	0.0	0	0.0	29
88241	1	100.0	0	0.0	0	0.0	0	0.0	1
88245	1	100.0	0	0.0	0	0.0	0	0.0	1
88246	1	100.0	0	0.0	0	0.0	0	0.0	1
88250	1	100.0	0	0.0	0	0.0	0	0.0	1
88252	2	100.0	0	0.0	0	0.0	0	0.0	2
88253	1	100.0	0	0.0	0	0.0	0	0.0	1
88256	1	100.0	0	0.0	0	0.0	0	0.0	1
88260	10	83.3	2	16.7	0	0.0	0	0.0	12
88267	3	100.0	0	0.0	0	0.0	0	0.0	3
88310	30	81.1	6	16.2	0	0.0	1	2.7	37
88312	1	50.0	1	50.0	0	0.0	0	0.0	2
88316	1	100.0	0	0.0	0	0.0	0	0.0	1
88317	1	50.0	1	50.0	0	0.0	0	0.0	2
88318	1	100.0	0	0.0	0	0.0	0	0.0	1
88321	0	0.0	1	100.0	0	0.0	0	0.0	1
88325	1	100.0	0	0.0	0	0.0	0	0.0	1
88336	1	100.0	0	0.0	0	0.0	0	0.0	1
88337	2	66.7	1	33.3	0	0.0	0	0.0	3
88339	1	100.0	0	0.0	0	0.0	0	0.0	1
88344	1	100.0	0	0.0	0	0.0	0	0.0	1
88345	10	100.0	0	0.0	0	0.0	0	0.0	10
88352	1	100.0	0	0.0	0	0.0	0	0.0	1
88353	2	100.0	0	0.0	0	0.0	0	0.0	2
88354	0	0.0	1	100.0	0	0.0	0	0.0	1
88401	4	50.0	4	50.0	0	0.0	0	0.0	8
88410	0	*****	0	*****	0	*****	0	*****	0

NEW MEXICO ENVIRONMENTAL IMPROVEMENT DIVISION
Community Services Bureau
Indoor Radon Study—Phase 1—1988/1989

	<4 pCi/L		>4, <10 pCi/L		>10, <20 pCi/L		>20 pCi/L		
zipcode	no.	%	no.	%	no.	%	no.	%	Total
88412	0	0.0	1	100.0	0	0.0	0	0.0	1
88414	0	0.0	1	50.0	1	50.0	0	0.0	2
88415	16	76.2	5	23.8	0	0.0	0	0.0	21
88416	1	50.0	1	50.0	0	0.0	0	0.0	2
88418	0	0.0	1	100.0	0	0.0	0	0.0	1
88419	1	50.0	1	50.0	0	0.0	0	0.0	2
88422	1	50.0	1	50.0	0	0.0	0	0.0	2
88424	1	100.0	0	0.0	0	0.0	0	0.0	1
88434	1	100.0	0	0.0	0	0.0	0	0.0	1
88435	4	100.0	0	0.0	0	0.0	0	0.0	4
88436	2	100.0	0	0.0	0	0.0	0	0.0	2
88544	1	100.0	0	0.0	0	0.0	0	0.0	1
97401	1	100.0	0	0.0	0	0.0	0	0.0	1

New Mexico Health and Environment Department

GARREY CARRUTHERS
Governor

DENNIS BOYD
Secretary

MICHAEL J. BURKHART
Deputy Secretary

RICHARD MITZELFELT
Director

Date

Dear Household Resident:

You may have recently read about radon gas in newspapers or seen stories about this potential health threat on TV. Radon is a radioactive gas that occurs naturally in soil, rocks and building materials. New Mexico is concerned about radon and we want to know more about where in New Mexico radon may be a problem. The New Mexico Environmental Improvement Division (NMEID) has obtained assistance from the U.S. Environmental Protection Agency (EPA) to conduct a radon survey designed to determine whether high radon concentrations exist in homes in New Mexico. Your home, along with 2,250 other homes throughout the State, has been randomly selected for the survey.

In the near future, a telephone interviewer from NMEID will contact you to discuss your participation in the survey. If you decide to participate, you will be helping us determine whether New Mexico residents have high levels of radon in their homes and how New Mexico can best address the problem if it exists. You will be provided a copy of the sample results for your home. This information will not become a permanent part of the NMEID's records.

As a participant in the survey, you may want to know if other people will see the results of the radon test made in your home. The NMEID does not plan to publish names and addresses of those participating in the survey, nor will the EID keep records on results on file.

The enclosed Survey Information Sheet and excerpt from "A Citizen's Guide to Radon" provide information about the survey and radon gas. Please read them closely. If you have any other questions about the study, please call the Radiation Licensing and Registration Section of NMEID at (505) 827-2948.

Your participation is voluntary, but vitally important to the success of the study. Thank you for your consideration.

Sincerely,

Michael J. Burkhart
Director

—ENVIRONMENTAL IMPROVEMENT DIVISION—
Harold Runnels Building
1190 St. Francis Dr.
Santa Fe, New Mexico 87503

Figure 1

Excerpt from "A Citizen's Guide to Radon"

What is radon?

Radon is a radioactive gas which occurs in nature. You cannot see it, smell it or taste it.

Where does radon come from?

Radon comes from the natural breakdown (radioactive decay) of uranium. Radon can be found in high concentrations in soils and rocks containing uranium, granite, shale, phosphate and pitchblende. Radon may also be found in soils contaminated with certain types of industrial wastes, such as the byproducts from uranium or phosphate mining.

In outdoor air, radon is diluted to such low concentrations that it is usually nothing to worry about. However, once inside an enclosed space (such as a home) radon can accumulate. Indoor levels depend both on a building's construction and the concentration of radon in the underlying soil.

How does radon affect me?

The only known health effect associated with exposure to elevated levels of radon is an increased risk of developing lung cancer. Not everyone exposed to elevated levels of radon will develop lung cancer and the time between exposure and the onset of the disease may be many years.

Scientists estimate that from about 5,000 to about 20,000 lung cancer deaths a year in the United States may be attributed to radon. (The American Cancer Society expects that about 130,000 people will die of lung cancer in 1987. The Surgeon General attributes around 85 percent of all lung cancer deaths to smoking.)

Your risk of developing lung cancer from exposure to radon depends upon the concentration of radon and the length of time you are exposed. Exposure to a slightly elevated radon level for a long time may present a greater risk of developing lung cancer than exposure to a significantly elevated level for a short time. In general, your risk increases as the level of radon and the length of exposure increase.

How does radon cause lung cancer?

Radon, itself, naturally breaks down and forms radioactive decay products. As you breathe, the radon decay products can become trapped in your lungs. As these decay products break down further, they release small bursts of energy which can damage lung tissue and lead to lung cancer.

How certain are scientists of the risks?

With exposure to radon, as with other pollutants, there is some uncertainty about the amount of health risk. Radon risk estimates are based on scientific studies of miners exposed to varying levels of radon in their work underground. Consequently, scientists are considerably more certain of the risk estimates for radon than they are of those risk estimates which rely solely on studies of animals.

To account for the uncertainty in the risk estimates for radon, scientists generally express the risks associated with exposure to a particular level as a "range" of numbers. Despite some uncertainty in the risk estimates for radon, it is widely believed that the greater your exposure to radon, the greater your risk of developing lung cancer.

When did radon become a problem?

Radon has always been present in the air. Concern about elevated indoor concentrations first arose in the late 1960's when homes were found in the West that had been built with materials contaminated by waste from uranium mines. Since then, cases of high indoor radon levels resulting from industrial activities have been found in many parts of the country. We have only recently become aware, however, that houses in various parts of the U.S. may have high indoor radon levels caused by "natural" deposits of uranium in the soil on which they are built.

Does every home have a problem?

No, most houses in this country are not likely to have a radon problem; but relatively few houses do have highly elevated levels. The dilemma is that right now, no one knows which houses have a problem and which do not.

"A Citizen's Guide to Radon: What It Is and What To Do About It", United States Environmental Protection Agency, Office of Air and Radiation; U.S. Department of Health and Human Services, Centers for Disease Control (August 1986)

Figure 2

New Mexico Environmental Improvement Division

State Radon Survey

Survey Information Sheet

How was my household selected?

A scientific sample of homes has been selected to represent all single-family owned homes in New Mexico. Survey procedures require that we interview only at those homes in the sample. Although your participation is voluntary, homes that decide not to participate will reduce the usefulness of the entire study. Your participation is very important if we are to obtain accurate information about homes in New Mexico.

What will I need to do?

Participation is simple. First, a telephone interviewer from New Mexico Environmental Improvement Division (NMEID) will contact you to arrange for an interviewer visit to your home. During the visit, the interviewer will ask questions about your home such as construction, ventilation and weatherization and provide you with one or two small radon detectors. The detectors, which require no power or maintenance, will need to be in your home for 2 days. After 2 days, you will seal and mail the detector(s). We will provide instructions for sealing and sending the detector(s) to an EPA laboratory in a postage-paid container.

Who are the interviewers?

The person contacting you will be a trained interviewer from the State and will have a project identification card. You can verify the name of this staff member by calling Ms. Mary Anne Vigil at (505)827-2948.

Who will see the results of the measurements made in my home?

You will be sent a copy of results of the measurements made in your home. The NMEID does not plan to publish names and addresses of those participating in this survey, but the Division's records are considered public information to those who wish to review them.

Why should I participate?

You will be contributing to a vital research project that can improve the quality of live in this State. We expect you will find the experience interesting and valuable. A direct benefit will be a free measurement of the level of radon in your home.

Figure 2a

New Mexico Health and Environment Department

MARALYN BUDKE
Acting Secretary

CARLA L. MUTH
Deputy Secretary

MICHAEL J. BURKHART
Deputy Secretary

RICHARD MITZELFELT
Director

Dear Radon Survey Participant:

You recently participated in a radon survey conducted by the New Mexico Health and Environment Department and the Environmental Protection Agency. As part of this survey, a short-term radon screening measurement was made in your home. The purpose of this letter is to inform you of the results of this test and provide information concerning the meaning of the results.

Obtaining this screening measurement is Step 1 of the process. It is possible, depending on the concentration of radon found in your home, that you may want to consider taking further action.

The analysis of your radon detector gave the following result:

__________ pCi/l

This result is a concentration of radon given in units of picocuries per liter (pCi/l). It is not as important to understand what these units means as it is to determine the range in which your result falls.

Information on the following page indicates concentration ranges with a discussion of appropriate actions. Please find the range in which your result falls under Step 2 on the following page. Then proceed to Step 3, if necessary. We will be glad to answer any questions which you may have after you review your results. Please contact us at (505)827-2948.

You are encouraged to read the information on the following pages, even the parts that do not specifically apply to your results, in an effort to become better informed on this issue. Thank you for your participation.

Sincerely,

William M. Floyd

William M. Floyd
Program Manager, Radiation Section
Environmental Improvement Division

Enclosures

— ENVIRONMENTAL IMPROVEMENT DIVISION —
Harold Runnels Building
1190 St. Francis Dr.
Santa Fe, New Mexico 87503

Figure 3

GUIDANCE FOR INTERPRETING RADON RESULTS

*Step 2: Determining the Need for Further Measurements

In most cases, the screening measurement is not a reliable measurement of the average radon level to which you and your family are exposed. Since radon levels can vary greatly from season to season, as well as from room to room, the screening measurement only serves to indicate the potential for radon problems. Depending upon the result of your screening measurement, you may need to have follow-up measurements made to give you a better idea of the average radon level in your home. The following guidance may be useful to you in determining the urgency of your need for follow-up measurements.

If your screening measurement result is greater than about 200 pCi/l, you should perform follow-up measurements as soon as possible. Expose the detectors for no more than one week. You should consider taking action to immediately reduce the radon levels in your home. If your screening measurement result is about 20 pCi/l to about 200 pCi/l, perform follow-up measurements. Expose detectors for no more than three months. If your screening measurement is about 4 pCi/l to about 20 pCi/l, perform follow-up measurements. Expose detectors for one year or make measurements of no more than one week duration each of the four seasons. If your screening measurement result is less than about 4 pCi/l, follow-up measurements are not required.

**Step 3: Follow-up Measurement

If it is determined in Step 2 that follow-up measurements are needed and after those results are received, the following guidelines can be used to determine how quickly action should be taken.

If your screening measurement result is above 200 pCi/l, you should undertake action to reduce levels as far below 200 pCi/l as possible. We recommend that you take action within several weeks. If this is not possible you should determine, in consultation with appropriate state or local health or radiation protection officials, if temporary relocation is appropriate until the levels can be reduced. If your screening measurement result is about 20 pCi/l to about 200 pCi/l, you should undertake action to reduce levels as far below 20 pCi/l as possible. Exposures in this range are considered greatly above average for residential structures. We recommend that you take action within several months. If your screening measurement result is about 4 pCi/l to about 20 pCi/l, you should undertake action to lower levels to about 4 pCi/l or below. Exposures in this range are considered above average for residential structures. We recommend that you take action within a few years or sooner if levels are at the upper end of this range.

Two publications prepared by the U.S. Environmental Protection Agency, "A Citizen's Guide to Radon" and "Radon Reduction Methods", are available from the Health and Environment Department upon request

***Page 7, "A Citizen's Guide to Radon"**
****Page 11, "A Citizen's Guide to Radon"**

Figure 3a