RADON-HAZARD POTENTIAL OF WESTERN SALT LAKE VALLEY, SALT LAKE COUNTY, UTAH

by
Bill D. Black
Utah Geological Survey

SPECIAL STUDY 91 **1996**
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES
in cooperation with
U.S. ENVIRONMENTAL PROTECTION AGENCY

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SIXTH-YEAR GEOLOGIC STUDIES FOR THE U.S. ENVIRONMENTAL PROTECTION AGENCY STATE INDOOR RADON GRANT PROGRAM

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ABSTRACT

Radon is a radioactive gas of geologic origin that is an environmental concern because of its link to lung cancer. Radon is derived from the decay of uranium and can accumulate indoors in sufficient quantities to pose a health hazard to building occupants. Although the influence of non-geologic factors such as construction type, lifestyle, and weather is difficult to measure, geologic factors that influence indoor-radon levels can be quantified to assess the hazard potential.

Geologic factors that influence indoor-radon levels have been studied for western Salt Lake Valley to indicate where indoor radon may be a hazard and radon-resistant techniques should be considered in new construction. The western Salt Lake Valley study area is between the eastern base of the Oquirrh Mountains and the Jordan River, and is in the depositional basin of Pleistocene Lake Bonneville. The study area is bordered on the southwest by the Bingham stock, a Tertiary-age hydrothermally altered and mineralized granitic pluton.

A primary factor affecting indoor-radon levels is the presence of uranium-enriched geologic materials. Significant sources of uranium to unconsolidated sediments in western Salt Lake Valley are phosphatic sedimentary rocks in the Oquirrh Mountains, and granitic and volcanic rocks in and around the Bingham stock. Uranium-238 levels are commonly highest in piedmont slopes along the mountain front, and along drainages originating near the Bingham stock.

Soil permeability and shallow ground water are factors which affect soil-gas migration and radon-hazard potential. High-permeability soil and deep ground water facilitate radon migration in soil gas, whereas low-permeability soil and shallow ground water restrict soil-gas migration. Soil permeability in western Salt Lake Valley is primarily moderate to low, and generally decreases toward the valley interior away from the front of the Oquirrh Mountains. Moderate- (and locally high) permeability soils are commonly found in areas underlain by coarse-grained lake and alluvial-fan deposits, whereas low-permeability soils are found in areas underlain by clay-rich sediments and the Harkers Alluvium. Ground water is deep in the western part of the study area, but is shallow along the Jordan River and in the low-lying areas in the northern part of the study area.

A numerical rating system was used to assess and map the relative radon-hazard potential in western Salt Lake Valley. The hazard potential is highest in the western part of the study area, where high uranium levels, moderate-permeability soils, and deep ground water are common. The hazard potential is lowest in the northern part of the study area and along the Jordan River, where low uranium levels, low-permeability soils, and shallow ground water are found. Although soil-gas and indoor-radon concentrations broadly correlate to mapped hazard potential, the correlation is imperfect because of atmospheric contamination of soil-gas samples, the presence of locally anomalous concentrations of radon which are beyond the resolution of the sampling grid or map scale, and the effects of non-geologic factors which are not considered in this geologic assessment.

INTRODUCTION

In 1988, Congress enacted Title III, Indoor Radon Abatement Act (IRAA), in response to the growing national concern over the threat of radon gas. The IRAA, an amendment of the Toxic Substances Control Act, is intended to reduce public-health risks from radon gas by rendering air in buildings in the United States free of radon (U.S. Environmental Protection Agency, 1989). Section 306 of the IRAA, the State Indoor Radon Grants (SIRG) Program, authorizes the Environmental Protection Agency (EPA) to provide grants to support the development and implementation of state radon assessment and mitigation programs. A principal activity of the Utah Geological Survey (UGS) under the SIRG Program is to identify and study areas of high radon-hazard potential in Utah.

The western Salt Lake Valley study area (figure 1) was identified by the UGS for further study because preliminary data indicated a potential radon hazard. A 1988 statewide survey conducted by the Utah Division of Radiation Control (UDRC), Department of Environmental Quality, measured locally high indoor-radon levels in this area (Sprinkel and Solomon, 1990). In addition, Black (1993) shows a high potential for radon hazards in western Salt Lake Valley. Based on this information, the UGS conducted an investigation of geologic factors controlling radon levels in this area. This investigation defines the hazard potential in more detail, and designates areas where the need for additional indoor-radon testing is more urgent and where radon-resistant techniques for new construction should be considered.

INDOOR-RADON HAZARDS

Radon is a radioactive element of geologic origin. Because it is a gas, radon easily moves from its source in soil and rock, through the geologic environment, and indoors through small openings in building foundations (Tanner, 1980). Radon is nearly inert and does not chemically react with most of the materials through which it moves. Once indoors, radon is difficult to detect because it is odorless, tasteless, and colorless.

Three types, or isotopes, of radon form as daughter products of radium from the radioactive decay of either uranium or thorium. Radon-222, which forms by decay of uranium-238 (table 1), is generally the most significant contributor to indoor radon because it is the most abundant radon isotope and its relatively long half-life of 3.83 days allows it to travel the greatest distance before it, in turn, decays. Radon-228 (commonly called thoron) forms by decay of thorium-232 and is about as common as radon-222, but has a half-life of only 55.65 seconds. However, radon-228 may also be a significant contributor to indoor-radon problems when present in sufficient concentrations (Durrance, 1986). Radon-219 (commonly called actinon) forms by decay of uranium-238 and does not contribute significantly to indoor-radon problems because of its very short half-life (3.96 seconds) and relative rarity in the environment. The abundance of radon-222 stems from the abundance of its parent element, uranium-238, which is 138 times more common than uranium-235 (Nielson and others, 1990).

Unlike most geologic hazards which are natural, dynamic earth processes that adversely affect both life and property, radon is a hazard only to living things. Health officials believe that breathing elevated levels of radon over time increases an individual's risk of lung cancer (Jacobi and Eisfeld, 1982; National Council on Radiation Protection and Measurements, 1984a, 1984b; Samet, 1989). Inhalation of radon and radon-decay

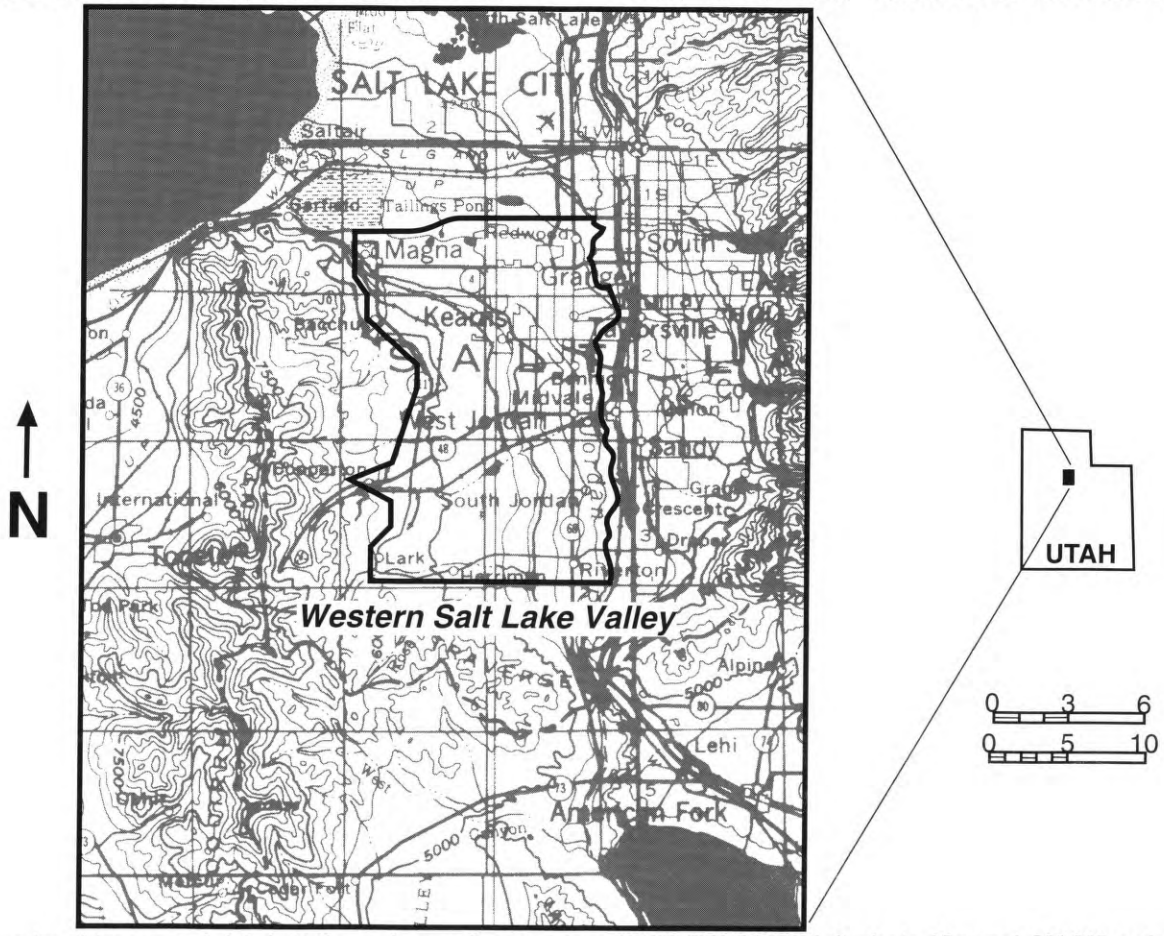

Figure 1. *Location of the western Salt Lake Valley study area. Base map from STATE OF UTAH U.S. Geological Survey 1:500,000-scale topographic map. Contour interval is 500 feet (152 m).*

Table 1.
Uranium decay series showing the half-lives of isotopes. Radon's half-life is less than four days (Sprinkel and Solomon, 1990). a=alpha; b=beta; Mev=million electro volts.

Isotope	Symbol	Half-life	Decay Particle	Energy (MeV)
Uranium	U-238	4.468 billion years	a	4.195 4.14
Thorium	Th-234	24.1 days	b	0.912 0.10
Protactinium	Pa-234m Pa-234	1.18 minutes 6.7 hours	b b	2.31 2.3
Uranium	U-234	248,000 years	a	4.768 4.717
Thorium	Th-230	80,000 years	a	4.682 4.615
Radium	Ra-226	1,602 years	a	4.78 4.59
Radon	Rn-222	3.825 days	a	4.586
Polonium	Po-218	3.05 seconds	a,b	6.0
Astatine	At-218	2 seconds	a	6.7 6.65
Lead	Pb-214	26.8 minutes	b	0.7 1.03
Bismuth	Bi-214	19.7 minutes	a,b	a = 5.5 b = 3.2
Polonium	Po-214	0.000164 seconds	a	7.68
Thallium	T1-210	1.32 minutes	b	5.43
Lead	Pb-210	22.3 years	b	0.015 0.061
Bismuth	Bi-210	5.02 days	a,b	a = 4.7 b = 1.16
Polonium	Po-210	138.3 days	a	5.3
Lead	Pb-206	Stable	—	—

progeny was recognized as a health problem in the 1950s and early 1960s, when studies on workers in underground uranium mines concluded that high radon concentrations in the mines contributed to an increased lung-cancer rate among miners (National Council on Radiation Protection and Measurements, 1984b). The EPA estimates that from 8,000 to 40,000 Americans will die each year from lung cancer caused by long-term radon inhalation (Schmidt and others, 1990).

Inhaled radon, itself, is not thought to be the primary source of internal cancer-causing radiation because radon atoms are inert and do not easily attach themselves to lung tissue. In addition, most radon atoms are exhaled before they can decay and emit dangerous alpha particles. The radioactive isotopes formed from radon decay are of more concern because they are not inert and can attach themselves to the first charged surface they contact (typically dust or smoke in the air). People who smoke place the occupants of a building at greater risk because smoke increases the number of airborne particles to which radon progeny attach. Once airborne particles are lodged in the lungs, the attached radon progeny can directly bombard tissue with energetic alpha particles from radioactive decay.

Radon is highly mobile and travels in both air and water. Radon enters buildings through water supplies, small basement cracks, or other foundation penetrations such as utility pipes

(figure 2). Waterborne radon can be a problem when radon gas is released from water and enters household air, but drinking household water containing radon is not considered a health risk. Although radon concentrations in the atmosphere never reach dangerous levels because air movement dilutes and dissipates the gas, people can be subject to a radon hazard in buildings having poor air circulation. Maximum airborne-radon concentrations are often found in basements or low crawl spaces (Fleischer and others, 1982) which are in contact with geologic materials surrounding the building foundation and usually poorly ventilated.

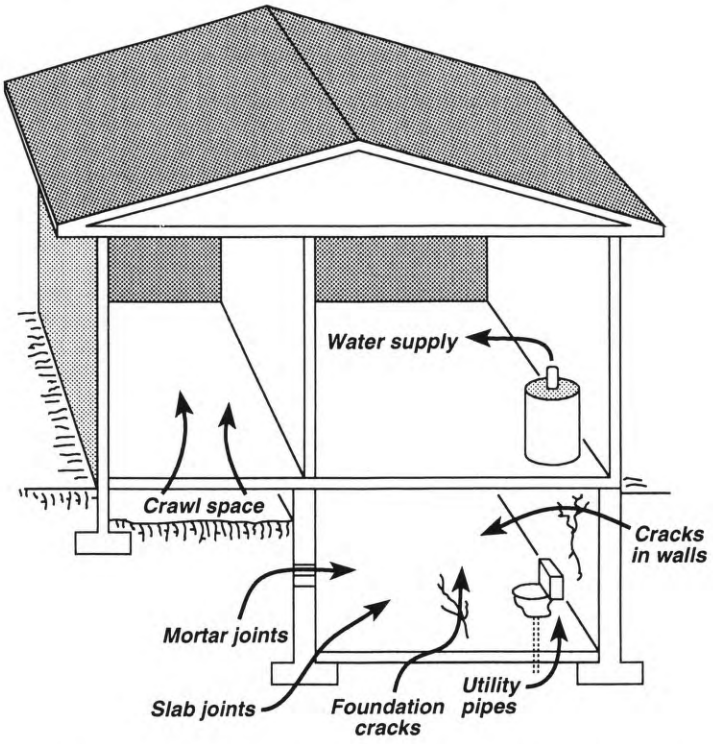

Figure 2. *Various pathways (shown by arrows) for radon to enter a home. Most entry routes are in the basement because this part of the house has the greatest surface area in contact with the surrounding soil (modified from U.S. Environmental Protection Agency, 1992).*

Changes in building practices during the past 22 years have contributed to the radon problem. Buildings constructed before the 1973 oil embargo, including single-family homes, often did not use energy-efficient measures and allowed indoor air to escape through above-grade joints, uninsulated walls, and attics. Since 1973, conservation of non-renewable energy resources through energy-efficient practices has been a national goal. The building industry has made structures energy efficient by preventing the loss of indoor air, but they have not improved ventilation systems to accommodate restricted air flow. Studies have shown that energy-efficient buildings having inadequate ventilation systems generally have higher indoor-radon levels than conventional buildings (Fleischer and others, 1982; Nero, 1986).

Radon concentration is measured in picocuries per liter (pCi/L) of air; one pCi (3.7×10^{-2} Becquerels [Bq]) represents a decay of about 2 radon atoms per minute. The U.S. Environmental Protection Agency (1992) recommends that action be taken to reduce indoor levels when they exceed 4 pCi/L (148 Becquerels per cubic meter [Bq/m^3]). Radon has been found in buildings throughout the United States in sufficient concentrations to pose a significant health hazard to occupants, but most buildings have concentrations less than 3 pCi/L (111 Bq/m^3) (Nero, 1986). Estimates of the contribution of radon in water to airborne radon range from 1 to 2.5 pCi/L (37-92.5 Bq/m^3) in air for every 10,000 pCi/L (3.7×10^5 Bq/m^3) in water.

Factors Affecting Indoor-Radon Levels

Indoor-radon levels depend on a complex relationship between geologic and non-geologic factors. Four principal factors contribute to elevated indoor-radon levels: (1) elevated uranium levels in the soil or rock on which a structure lies, (2) soil and ground-water conditions that do not restrict the movement of radon, (3) porous building materials or foundation openings below grade, and (4) lower atmospheric pressure inside a building than outside (Tanner, 1986). Factors (1) and (2) are geologic factors that can be measured and characterized regionally; the magnitude of their effects can vary locally but generally remains constant. Factors (3) and (4) are non-geologic factors that are difficult to measure and cannot be characterized regionally; the magnitude of their effects is variable and fluctuates with weather, type of construction, and occupant lifestyle. Thus, although geologic factors may suggest a similar radon-hazard potential in adjacent structures, indoor-radon levels can vary from one structure to the next.

Geology influences indoor-radon levels by controlling the local concentration, emanation, and migration of radon in the ground. A primary geologic factor affecting indoor-radon levels is the presence of uranium-enriched geologic materials. Meussig (1988) shows a correlation between areas that have mean equivalent uranium (eU) concentrations greater than 2.4 ppm and indoor-radon levels exceeding 4 pCi/L (148 Bq/m^3), the remedial action level recommended by the U.S. Environmental Protection Agency (1992). Thorium-enriched rock and soil may also affect indoor-radon levels and may be a dominant contributor in areas having high ^{232}Th concentrations (Stranden, 1984). However, few studies have been done on indoor-radon hazards from thorium, and it is not known what contribution thorium-enriched geologic materials make to indoor-radon levels.

During radioactive decay of uranium and thorium in mineral grains, radon atoms at and near the surface of the grains may escape and move into the pore space between grains. The fraction of radon atoms which escape the grain is defined as the emanating power. Factors affecting emanating power include grain size, pore size, porosity, and moisture content of a geologic material. Grain size and emanating power are inversely related

(Tanner, 1980). Geologic materials containing smaller grains generally have a higher emanating power. Radon atoms produced in grains larger than 1 micron (4×10^{-5} in) are unlikely to escape into pores unless they are on or near the grain's surface. Pore size and porosity are directly related to emanating power. Geologic materials having small pore size or low porosity have a lower emanating power, because escaping radon atoms are more likely to be trapped in adjacent grains than in pore spaces. However, radon emanation can be higher if water occupies pore spaces. When pore spaces are dry, some escaping radon atoms may pass through the pore space and become embedded in adjacent grains. However, water absorbs the energy of escaping radon atoms and traps a higher percentage of them in the pore space.

Movement of radon gas through geologic materials generally results from a combination of diffusion and convection (Tanner, 1980). Diffusion is the process of random movement of radon atoms by natural vibration, whereas convection is gas flow due to pressure differences in the soil, between the soil and atmosphere, or between the soil and a structure's foundation. Although the distance that radon may travel by diffusion during its half-life is generally negligible (Barretto, 1975), both diffusion and convection can be active methods of radon migration. Diffusion is the dominant mechanism of movement in intergranular channels, capillaries, and smaller soil pores, whereas convection dominates in larger pores (Tanner, 1980).

Because radon is highly mobile and nearly inert, once it enters the pore spaces of rock or soil, radon can be transported by air or water to the surface without changing its chemical composition. The ability of radon to migrate to the surface is affected by shallow ground water and soil permeability. Although water provides an effective means for transporting dissolved radon, saturated rock or soil can impede soil-gas movement and inhibit upward soil-gas migration by reducing diffusion and blocking upward flow (Tanner, 1980). Permeable soils provide excellent pathways for radon migration, whereas impermeable soils (which commonly contain clay-rich layers) inhibit the flow of soil gas (Tanner, 1980; McLemore and others, 1991). Studies have shown a correlation between permeable soils and elevated radon levels (Tanner, 1980; Schery and Siegel, 1986; Otton and Duval, 1990).

Measurement of Indoor-Radon Levels

Although many geologic factors which affect indoor-radon levels may be measured and their regional influence predicted, the influence of non-geologic factors is more variable. As a result, indoor-radon levels fluctuate and must be measured in each building to determine if a problem exists. Radon-testing devices are either passive or active. Passive devices do not need external power to function, whereas active devices do. Professional radon testers use passive or active devices to measure a building's radon level, but devices typically used by homeowners are passive.

Whether passive or active, radon-testing devices are designed to measure short-term or long-term indoor-radon levels. Short-term measurements, usually conducted for less than three months, provide quick and accurate results for the testing period, but may not reflect fluctuations in indoor-radon levels during longer time intervals. Weather conditions (such as wind, precipitation, barometric pressure, and temperature) directly affect indoor-radon levels by modifying radon migration, and indirectly affect indoor-radon levels by influencing occupant lifestyles (need for indoor heating, cooling, and building ventilation). Heating, cooling, and ventilation modify indoor-radon levels by changing the relative proportions of outdoor air and soil gas exchanged with indoor air. Because of weather and lifestyle changes, indoor-radon levels fluctuate daily, weekly, monthly, and seasonally. Long-term measurements, usually conducted for three or more months, provide a more realistic picture of the varied radon levels to which individuals are exposed.

The EPA established radon-measurement protocols to assure accuracy and consistency of indoor-test data (U.S. Environmental Protection Agency, 1993a). The protocols balance the need for quick results with the need to acquire measurements that best reflect long-term indoor-radon levels. Although long-term monitoring is recommended throughout a house to accurately determine yearly average indoor-radon levels, short-term screening measurements which follow EPA protocol (closed-house conditions) may be conducted in the lowest living area to determine if long-term tests are needed (U.S. Environmental Protection Agency, 1992). EPA protocols emphasize follow-up testing in homes having screening measurements of 4 pCi/L (148 Bq/m^3) or higher. The EPA recommends reducing indoor-radon levels if a long-term follow-up test measures 4 pCi/L (148 Bq/m^3) or higher. If the follow-up test is short term, the EPA recommends reducing indoor-levels if the average of the first and second short-term tests is 4 pCi/L (148 Bq/m^3) or higher. Additional testing is not needed if a short-term screening measurement is less than 4 pCi/L (148 Bq/m^3).

Radon can be released into the air during household water use (U.S. Environmental Protection Agency, 1992). However, radon entering a home through water is a smaller risk than radon entering a home through soil (U.S. Environmental Protection Agency, 1992). If there is no measured airborne radon problem in a home, there is generally no need to test household water for radon. However, if indoor levels of airborne radon are high, it may be necessary to test household water to identify the source of airborne radon. Excessive levels of waterborne radon are more common in well water than in public supplies.

Low-cost "do it yourself" kits for measuring indoor-radon levels are available through the mail and in hardware stores or other retail outlets. Charcoal canisters are commonly used for short-term measurement; alpha-track detectors are commonly used for long-term measurement. Low-cost water-test kits are available from commercial laboratories. To insure accuracy, buy a test kit that has passed EPA's testing program. These kits will usually display the phrase "Meets EPA Requirements." If preferred, a trained contractor can be hired to do the testing. Check that the contractor is listed in EPA's Radon Measurement Proficiency (RMP) program. RMP program participants are required to show their ability to make accurate tests and follow quality assurance and EPA test guidelines. The UDRC maintains lists of EPA-approved test kits and RMP-qualified companies and individuals.

Hazard Reduction

A number of methods can be used to reduce elevated radon levels in a home. These methods fall into two categories: (1) preventing radon from entering the house, and (2) removing radon (or decay products) after entry. The specific method chosen depends upon the initial radon concentration, as well as house design and construction.

Some actions may be taken immediately, and can be done quickly at minimal expense (U.S. Environmental Protection Agency, 1988). Discouraging smoking inside a home reduces the risk of developing lung cancer not only from smoking but also from radon exposure. Spending less time in areas of higher radon concentration, such as a basement and other low areas of a home that are in contact with the soil and have inadequate ventilation, will also reduce the risk. Opening windows and turning on fans improves ventilation but is not always possible during cold winter months.

Although immediate actions are effective, they are not long-term solutions. The selection of permanent radon-reduction methods requires identification of radon-entry routes and driving forces, and diagnostic testing to aid in the selection of the most effective method. Methods of permanent radon reduction include: (1) increasing ventilation by using ventilators, (2) sealing soil-gas entry routes to restrict entry of radon into a house, (3) ventilating soil to withdraw radon, (4) altering pressure differentials between the house and soil to restrict flow of soil gas into a house, and (5) cleaning air to remove radon-decay products (which are solid particles) (U.S. Environmental Protection Agency, 1993b). Once appropriate radon-reduction methods are chosen and implemented, diagnostic tests should be conducted to ensure that radon levels have been sufficiently reduced.

An effective method of hazard reduction is preventing radon from entering a structure. Restricting radon entry may be difficult in existing buildings, but is advisable for new construction (particularly in areas that have a high-hazard potential). New structures may incorporate methods to restrict radon entry (Clarkin and Brennan, 1991) by minimizing: (1) soil-gas entry pathways, and (2) indoor-outdoor pressure differences, since these differences are the driving force for soil gas to enter a home. Features can also be incorporated during construction that facilitate radon removal after home completion.

If there is a significant contribution of waterborne radon to indoor air, this radon may either be removed from the water before it reaches the indoor air or removed from the air after it has left the water (U.S. Environmental Protection Agency, 1987). In many cases, good ventilation of bathrooms, laundry facilities, and the kitchen during periods of water use may be adequate, although impractical during cold weather. Water may also be stored before use for several days to allow the radon to decay, but a large storage tank is needed if water use is high. Devices which use granular activated charcoal to remove radon from water are presently the least costly for a single home using its own well and, to date, are the most extensively tested and used radon-reduction technique for water.

Professional assistance is usually needed to reduce elevated indoor-radon levels. Without the proper equipment and technical knowledge, radon levels might actually be increased or other hazards created during an attempt at radon reduction by inexperienced individuals. If a radon contractor is used, choose one listed in EPA's Radon Contractor Proficiency (RCP) program. RCP contractors are trained, must pass a comprehensive exam, and must agree to follow radon-reduction standards. The UDRC maintains a list of RCP contractors.

SAMPLING METHODS

Two types of radiometric surveys were conducted for this study: (1) gamma-ray spectrometry, and (2) radon emanometry. Gamma-ray spectrometry measures the concentration of selected radioactive elements, including uranium and thorium, in soils. Radon emanometry measures soil-gas-radon concentrations from decay of these radioactive elements. Radiometric data collected for this survey reflect the areal distribution of measured parameters at sampled horizons, and do not reflect vertical inhomogeneities, temporal variations due to meteorologic effects, or radioactive decay imbalances.

Concentrations of selected gamma-emitting elements in soil were measured using an Exploranium GR-256 portable gamma-ray spectrometer. The GPS-21 detector assembly contains a 3 x 3 inch (7.5 x 7.5 cm) sodium-iodide crystal and an integral bi-alkali photomultiplier tube. Values for total gamma, potassium-40 (K), equivalent uranium-238 (eU), and equivalent thorium-232 (eTh) were collected. The spectrometer used peak energy levels of 1.46 million electron volts (MeV) for potassium (which has only one emission line), 1.76 MeV for eU (corresponding to bismuth-214), and 2.62 MeV for eTh (corresponding to thallium-208). Calibration of the spectrometer was done at the factory using calibration pads. Sampling stations were spaced roughly 0.5 to 1.0 miles (0.8-1.6 km) apart, depending on access. Measurements were generally taken on vacant lots or undeveloped, non-irrigated land to minimize cultural influence and sample the native soil. However, access was limited in heavily developed areas and measurements were taken in less-developed areas surrounding schools and parks. Measurement on roadbeds was avoided to reduce the possibility of masking due to foreign materials. The detector was held at a height of about 2 feet (0.6 m) to correct for the influence of local topography and non-homogeneous materials.

Concentrations of radon in soil gas were measured using an RDA-200 portable alpha-sensitive scintillometer manufactured by EDA Instruments. Soil gas is pumped into scintillator cells which are placed in the scintillometer for measurement of radon concentrations. Scintillator cells are coated with a phosphor sensitive to alpha particles in the 5.5 MeV range emitted by the decay of isotopic radon in its gaseous phase. The cells were calibrated in an alpha-track chamber by Geotech, Inc. to determine the efficiency of the phosphor material coating the cells. The scintillometer was calibrated at the factory, and the unit's sensitivity was checked using a standard scintillator cell of known count rate.

The soil-gas sampling tool consists of a hollow, 0.5-inch (1.3 cm) diameter, 26-inch (66-cm) long steel probe that has perforations in the lower 6 inches (15 cm) (figure 3). A hole of the same diameter was made in the soil by pounding a solid steel rod into

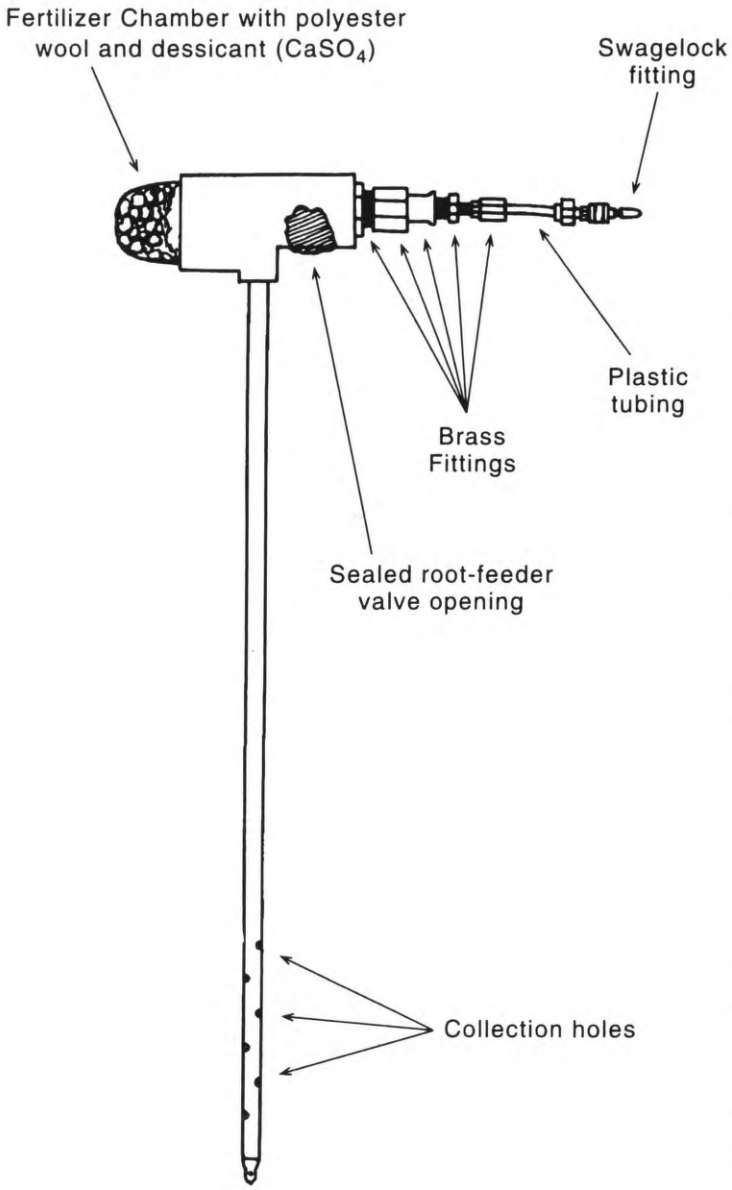

Figure 3. *Soil-gas probe modified from Ross Root Feeder Model 102 manufactured by Ross Daniels, Inc.*

the ground. The probe was inserted into the hole to a depth of roughly 26 inches (65 cm). A hand-held evacuation pump was used to purge the probe of ambient air and pump soil gas into the scintillator cells through the probe perforations, which are generally below the root zone for most grasses, in the lower B and upper C soil horizons, and close to sampling depths which provided consistent and reproducible data to other researchers (Reimer and Bowles, 1979; Hesselbom, 1985; Reimer and Gundersen, 1989). Soil-gas samples were collected from about one-third of the spectrometer-measurement stations, but the spacing between soil-gas sample sites is irregular because of the probe's inability to penetrate dense and gravelly soils.

DATA AND DISCUSSION

Setting and Geology

The western Salt Lake Valley study area is in Salt Lake County, and extends roughly 15 miles (24 km) south from Highway 201 to Riverton, and west from the Jordan River to the base of the Oquirrh Mountains (figure 4). This area is part of a rapidly expanding Wasatch Front region, and includes the communities of Copperton, Herriman, Kearns, Magna, Riverton, South Jordan, Taylorsville (formerly Bennion and Taylorsville), West Jordan, and West Valley City (figure 4). Total population of these communities was approximately 253,000 in 1990 (Utah Office of Planning and Budget, 1991).

Surficial deposits of western Salt Lake Valley are mainly sediments of Pleistocene Lake Bonneville, and pre- and post-lake alluvium. Pre-lake deposits consist of local Cutler Dam lake cycle deposits (Keaton and Currey, 1993) in the northeastern part of the study area, and semi-consolidated dissected alluvial fans (termed the Harkers Alluvium) along the front of the Oquirrh Mountains in the southwestern part (Tooker and Roberts, 1971). The lake of the Cutler Dam cycle occupied Salt Lake Valley from 82,000 to 58,000 years ago, and deposited sand, silt, and clay below an elevation of 4,400 feet (1,341 m) (McCalpin, 1986; Oviatt and others, 1987). Lake Bonneville occupied Salt Lake Valley from 32,500 to 13,900 years ago (Oviatt and others, 1992; D. R. Currey, University of Utah, written communication, 1995). This lake deposited shore facies of sand and gravel along the mountain front between about 5,200 feet (1,585 m) and 4,800 feet (1,463 m), and deep-water deposits of clay, silt, and fine sand at lower elevations in the valley interior (Marsell and Threet, 1960; Miller, 1980). Post-Lake Bonneville sediments include Holocene debris-flow and alluvial-fan deposits at canyon mouths, stream alluvium, and fine-grained Jordan River deposits (Marsell and Threet, 1960; Miller, 1980).

Bedrock in the Oquirrh Mountains west of the study area consists of Pennsylvanian to Permian sedimentary rocks, and Tertiary intrusive and volcanic rocks. Pennsylvanian to Permian rock units include the Erda, Bingham Mine, and Kessler Canyon Formations of the Oquirrh Group, and the Curry Peak, Park City, and Kirkman-Diamond Creek Formations (Tooker and Roberts, 1971; Swensen, 1975). Tertiary intrusive and volcanic rocks are found in and around the Bingham stock, a hydrothermally altered and mineralized granitic pluton near the southwestern part of the study area. These Tertiary rocks include latite and andesite flows; latite breccia and tuff; and latite, quartz latite, rhyolite, and quartz monzonite porphyry (Bray and others, 1975; Swensen, 1975). Mining of mineralized deposits in the Bingham stock formed the Bingham open-pit mine, one of the largest engineered excavations in the world (figure 5; Gwynn and Tripp, 1990).

Mapping Methods

Characteristic geologic factors which influence indoor-radon levels (uranium concentration, ground-water depth, and soil permeability) were used to classify the relative hazard potential

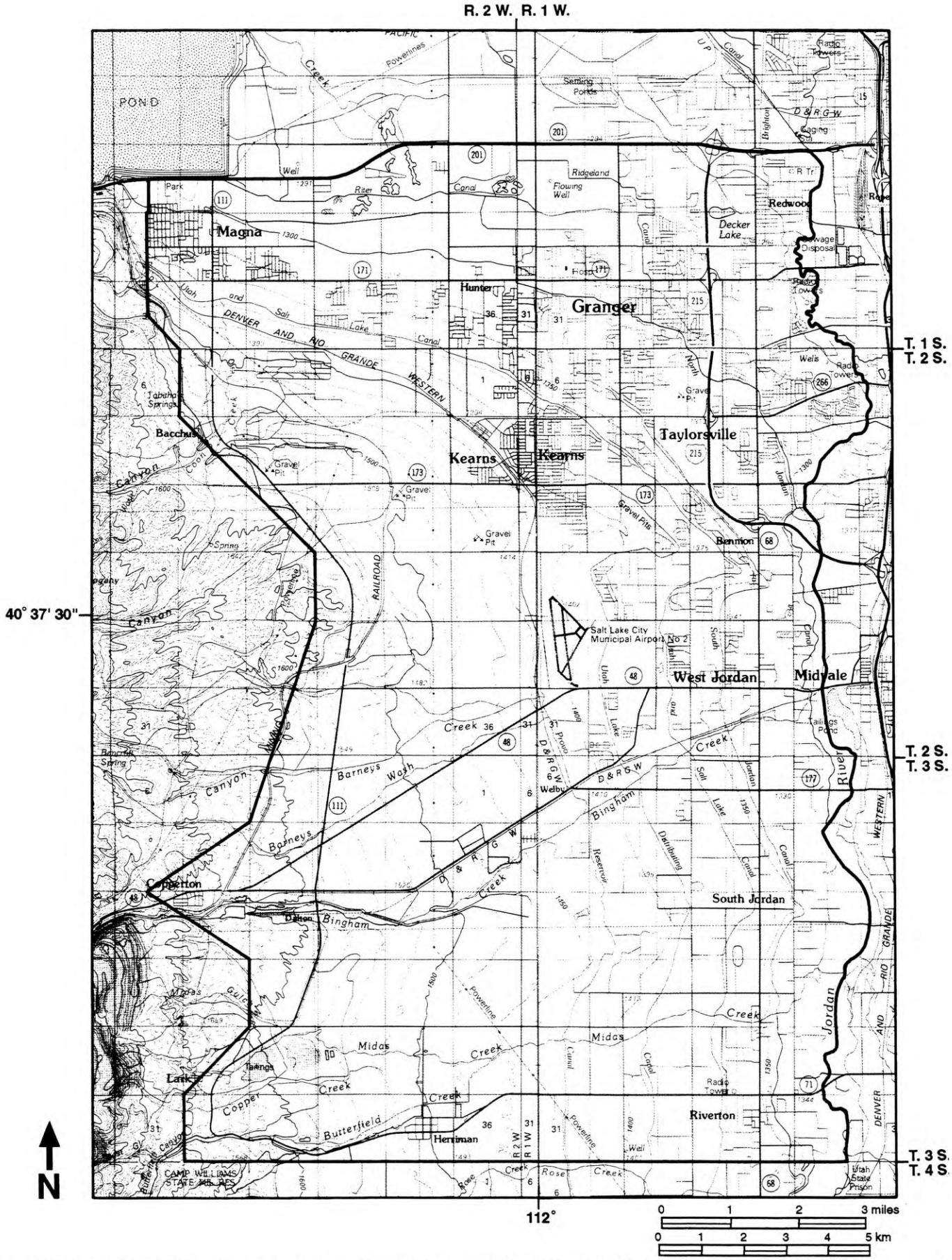

Figure 4. Western Salt Lake Valley study area. Base map from TOOELE and SALT LAKE CITY U.S. Geological Survey 30 x 60 minute topographic quadrangles. Contour interval is 50 meters (164 ft).

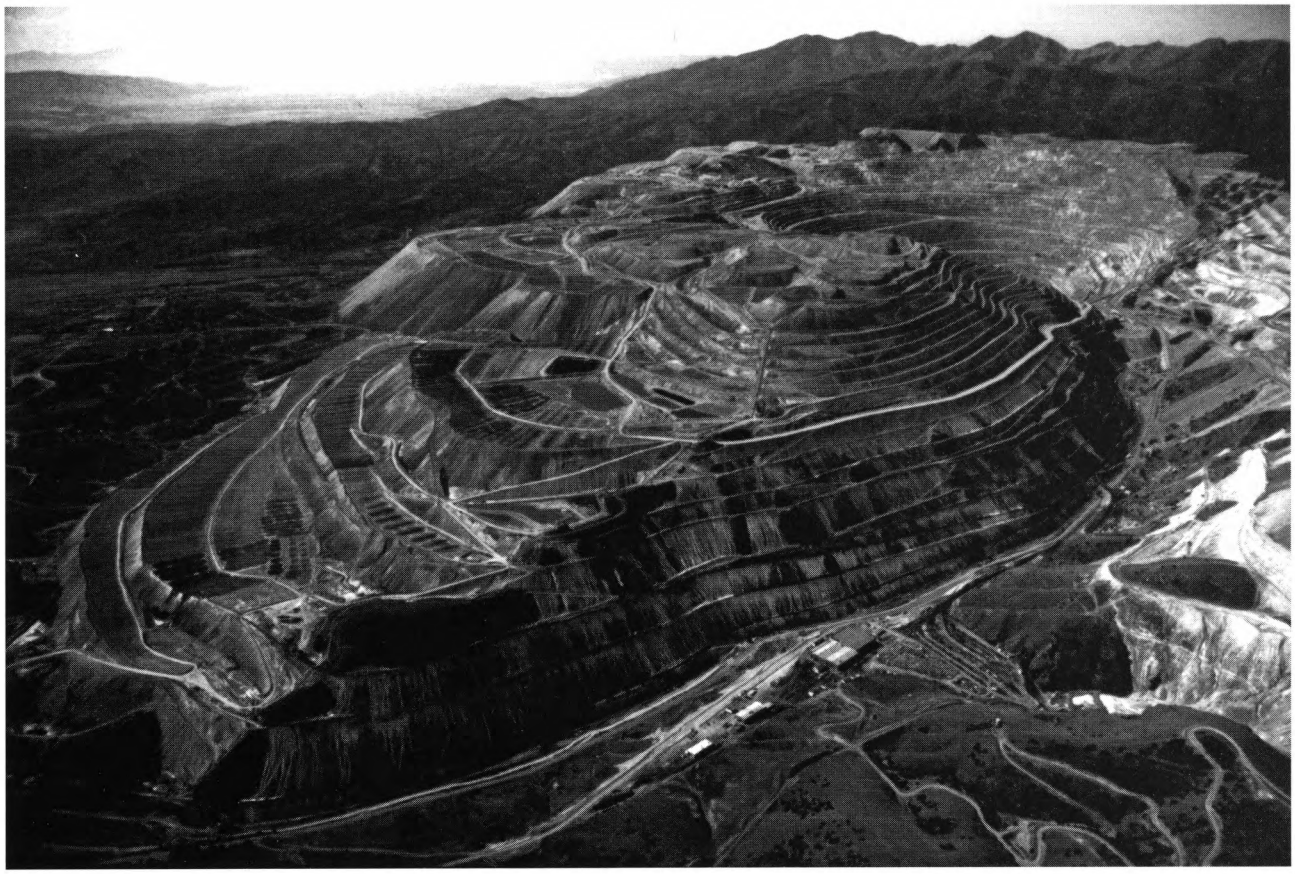

Figure 5. *South view of the Bingham mine and associated workings.*

of western Salt Lake Valley. Radiometric data collected for this study were combined with existing data on ground-water depth and soil permeability to determine distribution of these factors. Indoor-radon test data from UDRC surveys were also compiled to determine if a correlation exists between hazard potential and indoor-radon levels. Uranium concentrations and other radiometric data for western Salt Lake Valley are statistically summarized in table 2. Radiometric data for each sample location are listed in the appendix.

Previous studies developed hazard-classification schemes to accommodate geologic factors affecting radon hazards in specific settings. For example, Solomon and others (1991, 1994) emphasize the significant role that stratigraphy plays in characterization of radon hazards by assigning a hazard potential to each mapped geologic unit based on the distinctive qualities of the unit which affect radon emanation and migration. However, Solomon (1992) recognizes that such factors are not necessarily uniform in each geologic unit, and maps hazard potential irrespective of mapped geologic contacts. The classification scheme of Solomon (1992) is applicable to a wide range of settings, and the same scheme is used here. This classification scheme uses three factors to evaluate radon-hazard potential: (1) uranium concentration, (2) ground-water depth, and (3) soil permeability.

Uranium concentration, ground-water depth, and soil permeability were mapped on overlays and assigned numerical ratings from 1 to 3; higher ratings correspond to conditions that contribute to elevated indoor-radon concentrations (table 3). Factor contacts were traced onto a composite map, numerical ratings were added, and the summed ratings were assigned to one of three hazard-potential categories (high, moderate, or low) to indicate the relative potential for indoor-radon hazards (table 4). All rating factors used to determine hazard-potential categories are weighted equally because evidence is insufficient to determine the relative contribution of each factor to the radon hazard. Descriptions of the three hazard-potential categories are: (1) low: areas where no geologic factors contribute to indoor-radon hazards, (2) moderate: areas where some geologic factors contribute to indoor-radon hazards, and (3) high: areas where all geologic factors contribute to indoor-radon hazards.

The radon-hazard-potential map considers the effects of geologic factors that can be regionally characterized, but not local geologic variations or non-geologic factors such as weather, home construction, and occupant lifestyle that affect indoor-radon concentrations. Thus, indoor-radon concentrations should be broadly correlated to mapped hazard potential, but geologic assessments of radon hazards do not accurately predict indoor-radon levels in specific homes (Fleischer and others, 1982). Areas of low-hazard potential have expected indoor-radon concentrations less than 2 pCi/L (74 Bq/m^3), whereas areas of high-hazard potential have expected concentrations greater than 4 pCi/L (148 Bq/m^3) (table 4).

Other geologic factors such as hydrothermal processes, fluctuations of ground-water levels, active faults, and expansive soil may contribute to locally high indoor-radon levels but were not

Table 2.
Statistical summary of radiometric data for western Salt Lake Valley.

	Total Counts (ppm)	K (%)	eU (ppm)	eTh (ppm)	eU/eTh	Soil-Gas Rn (pCi/L)
Number of Samples	217	217	217	217	217	70
Mean	10.4	1.5	3.2	8.8	0.4	408
Variance	4.1	0.1	0.4	5.3	0.0	149,335
Standard Deviation	2.01	0.34	0.62	2.3	0.11	386
Skewness	2.7	0.01	0.08	8.22	0.00	157,000,000
Minimum	5.8	0.7	1.6	3.7	0.16	98
Median	10.3	1.4	3.2	8.7	0.4	254
Maximum	17.3	2.5	5.2	20.6	0.79	2149

K = potassium 40
eTh = equivalent thorium 232
ppm = parts per million
eU = equivalent uranium 238
Rn = radon 222
pCi/L = picocuries per liter (1 pCi/L = 37 Bq/m^3)

Table 3.
Hazard-potential ratings of geologic factors which affect indoor-radon levels. Soil-permeability classes are characterized by hydraulic conductivity, k.

Factor	Point Value 1	2	3
Uranium (ppm)	<2	2 - 3	>3
Permeability (k, in/hr)	Low 0.06 - 0.6	Moderate 0.6 - 6.0	High 6.0 - 20.0
Ground-Water Depth (ft)	<10	10 - 30	>30

Table 4.
Radon-hazard-potential categories. See table 3 for point values of factors in each category. Probable average indoor-radon concentrations for all homes in each category are also shown, but concentraions in individual homes may not fall within the expected range.

Category	Point Range	Probable Indoor-Rn Concentration (pCi/L)
Low	3 -4	<2
Moderate	5 - 7	2 - 4
High	8 - 9	>4

considered due to the scale of the investigation. Anomalous radon concentrations have been measured in Utah where there is active hydrothermal or ground-water upwelling along faults (Nielson, 1978), however no thermal springs are reported in western Salt Lake Valley (Mundorff, 1970). Fluctuations in the ground-water table, due to well pumping and variations in recharge and discharge, have been suggested as a significant contributor to upward radon transport (LeGrand, 1987), but applied research on this transport mechanism (Gregg and Holmes, 1990) is only beginning. Active faults may also produce elevated indoor-radon levels by increasing permeability and thereby enhancing near-surface radon concentrations (Tanner, 1980; Sprinkel and Solomon, 1990). Localized areas of high radon concentrations may occur along the Granger and Taylorsville faults in the northeastern part of the study area. Expansive soil shrinks or swells as moisture content changes, and repeated expansion and contraction of the soil can damage building foundations, thereby enhancing radon entry into the structure. Expansive soil may also develop cracks upon drying, providing additional pathways for soil-gas transport (Peake and Schumann, 1991). Expansive soil is commonly associated with clay-rich lake sediments, such as those in the northern part of the study area.

Uranium Concentration

The most common isotope of radon (radon-222) forms as a product in the uranium-238 decay series. Although radon is highly mobile in soil, and its concentration is affected by meteorologic conditions, a relatively good correlation exists be-

tween average soil-gas concentrations and average eU values for some soils (Gundersen and others, 1988). Uranium concentrations less than 2 ppm are typically associated with indoor-radon levels of less than 4 pCi/L (148 Bq/m^3), whereas uranium concentrations greater than 3 ppm are consistently associated with elevated indoor-radon levels (Meussig, 1988; Duval and others, 1989; Peake and Schumann, 1991).

Uranium concentrations measured at 217 sample sites in western Salt Lake Valley range from 1.6 to 5.2 ppm; mean concentration is 3.2 ppm and the standard deviation is 0.62 (table 2). Distribution of eU concentrations is nearly normal (figure 6) and has a positive skewness of 0.08. Median concentration is 3.2 ppm (table 2). Mean uranium concentration in western Salt Lake Valley (3.2 ppm) is higher than Tooele Valley (2.2 ppm) to the west, but significantly lower than east Sandy (5.6 ppm) in eastern Salt Lake Valley (Solomon and others, 1994; Black and Solomon, 1996).

Highest uranium concentrations (greater than 4 ppm eU; figure 7) are in lacustrine sediments and alluvium deposited by streams from the Oquirrh Mountains. These sediments are derived from bedrock sources high in uranium, such as the Permian Park City Formation southwest of Bacchus and Tertiary intrusive and volcanic rocks in and around the Bingham stock near Copperton and Lark (Tooker and Roberts, 1971; Bray and others, 1975). Locally high uranium levels in lacustrine sediments may also be due to adsorption of uranium in ground or surface water by clay and organic matter (Durrance, 1986). The Park City Formation consists of dolomite, quartzite, phosphorite, and limestone (Tooker and Roberts, 1971). Although the uranium content of outcrops of the Park City Formation near Bacchus is unknown, rock assays of mineralized deposits in this unit in other areas of Utah show a mean concentration of 25 ppm uranium (Black, 1993). Dolomitic limestones and phosphate rocks (such as the Park City Formation) are also associated with elevated radon levels (Makofske and Edelstein, 1988). Tertiary rocks in and around the Bingham stock consist of quartz monzonite porphyry, and latite and andesite flows, breccias, and tuffs (Marsell and Threet, 1960; Swensen, 1975). Fluorimetric analyses of samples from these rocks average 8.4 ppm uranium and show concentrations up to 65 ppm uranium (Aksell, 1982). Uranium from these volcanic rocks has been recovered as a by-product of copper mining in Bingham Mine operations (Greeley and Gloyn, 1989).

Lowest uranium concentrations (less than 2 ppm eU) are in fine-grained lake sediments near Kearns, South Jordan, and Riverton. Uranium-deficient rocks (such as the Oquirrh Group) are common in the Oquirrh Mountains to the west. However, sediment in western Salt Lake Valley comes from a variety of sources due to complex sedimentation patterns in Lake Bonneville (such as longshore transport) (Currey, 1980). However, areas having low uranium levels are uncommon and isolated, which suggests that the low levels may be due to preferential leaching of uranium by ground or surface waters, rather than sedimentation patterns. Low eU/eTh ratios were also measured in these areas. Although low ratios can reflect the chemistry of the source rock, preferential leaching of uranium under oxidizing conditions results in lower ratios by depletion of uranium with respect to thorium (Durrance, 1986).

Ground-Water Depth

Evaluation of ground-water depth can show areas where water may be an important factor in reducing indoor-radon concentrations. Although radon easily dissolves in water, which provides an effective medium for migration of radon from its source, water saturation of a soil inhibits radon migration into buildings by reducing diffusion and blocking convective soil-gas flow (Tanner, 1980). Conversely, a low soil-moisture content improves radon diffusion and soil-gas flow into buildings, which contributes to elevated indoor-radon levels. Shallow ground water, less than 10 feet (3 m) deep, is commonly found at the same depth as building basements and may reduce potentially high radon levels even in soils having high uranium levels. Ground water deeper than 30 feet (9 m) does not inhibit the flow of soil gas. Ground water at intermediate depths may affect radon migration when seasonal water-table variations cause water levels to rise to depths less than 10 feet (3 m).

Ground water in western Salt Lake Valley is in unconsolidated and semi-consolidated sediments that grade eastward from coarse-grained alluvial-fan and lake deposits along the Oquirrh Mountains to fine-grained lake deposits and alluvium in the valley interior (Waddell and others, 1987). Ground water is under both confined and unconfined (water-table and perched) conditions.

Ground water under confined conditions is primarily in the central and northern portions of Salt Lake Valley. Waddell and others (1987) indicate fine-grained low permeability sediments are common in the deep valley fill of this area, and act as a confining bed that restricts vertical movement of water. No confining bed is present near the mountains (except near the northern end of the Oquirrh Mountains). The principal aquifer in Salt Lake Valley is unconfined at the mountain front, but becomes confined toward the center of the valley below the fine-grained confining beds (Waddell and others, 1987). Water in the confined aquifer generally does not affect radon migration because it is deeper than 30 feet (9 m).

Ground water under unconfined conditions in western Salt Lake Valley is found above the confined aquifer and along the edge of the valley (Waddell and others, 1987). Unconfined ground-water levels in western Salt Lake Valley were mapped by Anderson and others (1986) using soil-boring data obtained from various private consulting firms and government agencies. Unconfined ground water is commonly less than 10 feet (3 m) deep in low-lying areas in the northern portions of the study area and along the Jordan River floodplain, and greater than 30 feet (9 m) deep in piedmont slopes along the Oquirrh Mountains (figure 8). Unconfined ground water generally becomes shallower toward the valley interior above the confined aquifer (Waddell and others, 1987).

Soil Permeability

Soil permeability influences the ability of radon to migrate to the surface. The U.S. Soil Conservation Service (SCS), now the Natural Resources Conservation Service, mapped soils in western Salt Lake Valley (Woodward and others, 1974), and

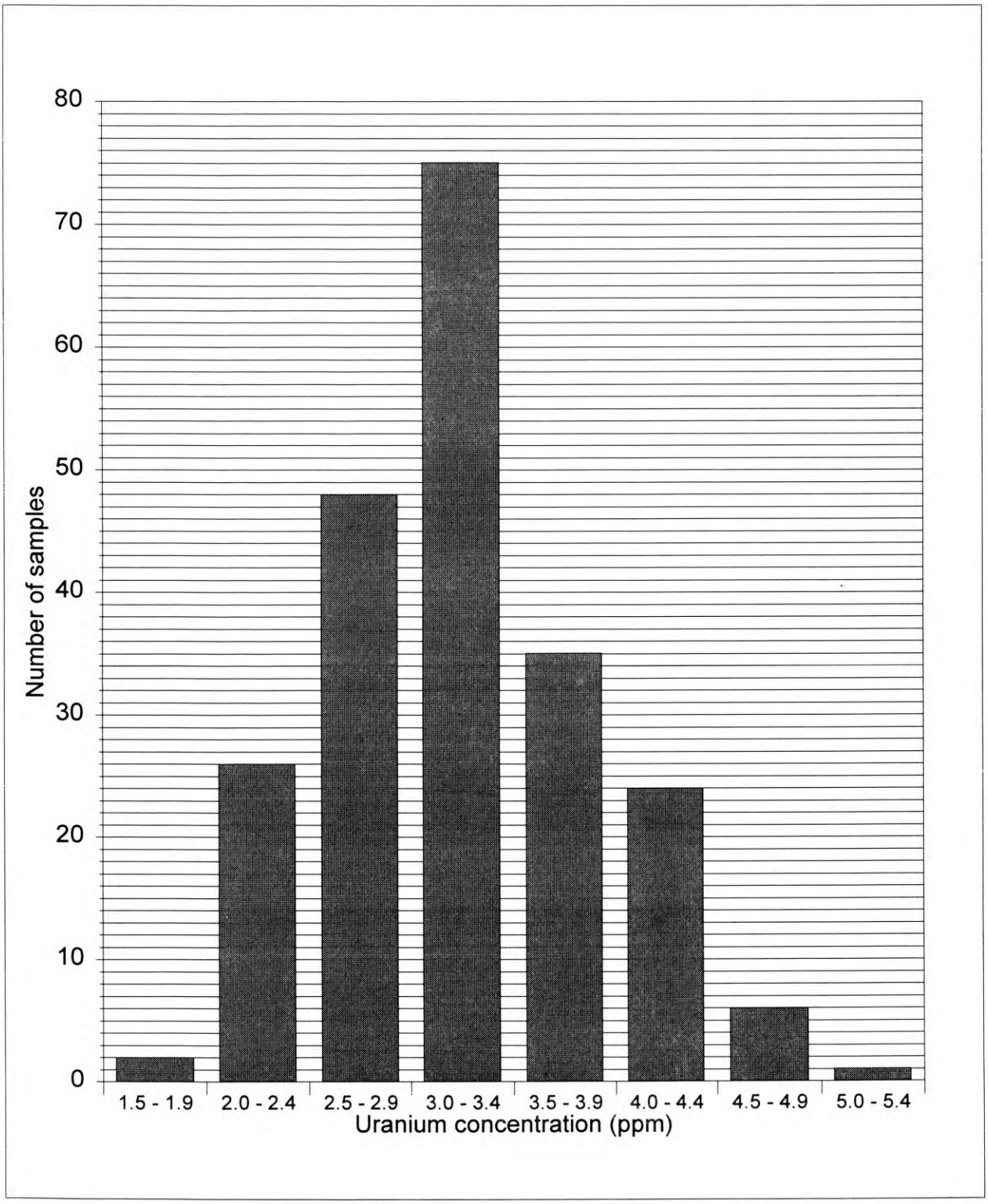

Figure 6. *Histogram of uranium concentrations in western Salt Lake Valley.*

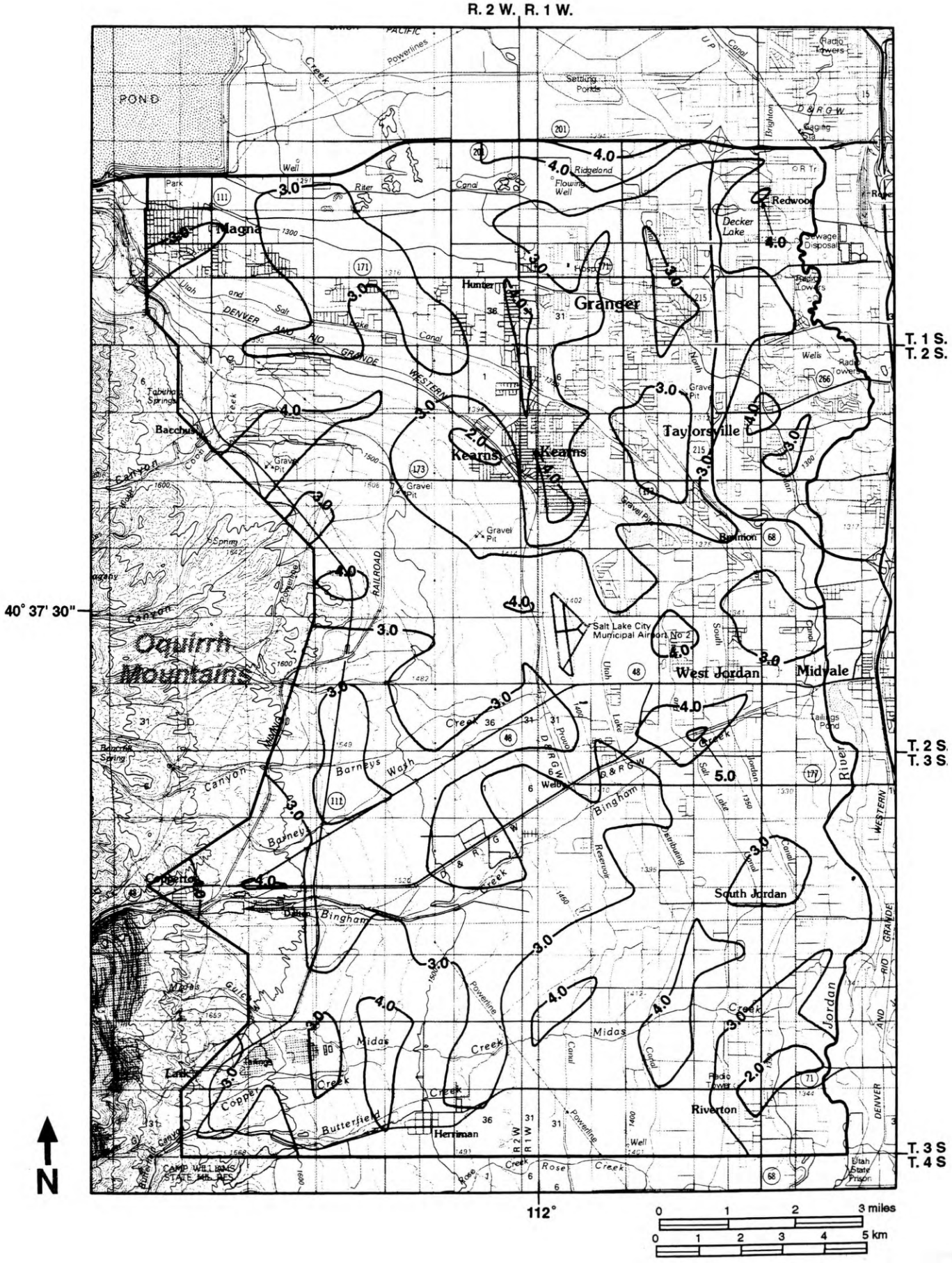

Figure 7. *Contour map of uranium (eU) concentrations in western Salt Lake Valley. Contour interval is 1 ppm.*

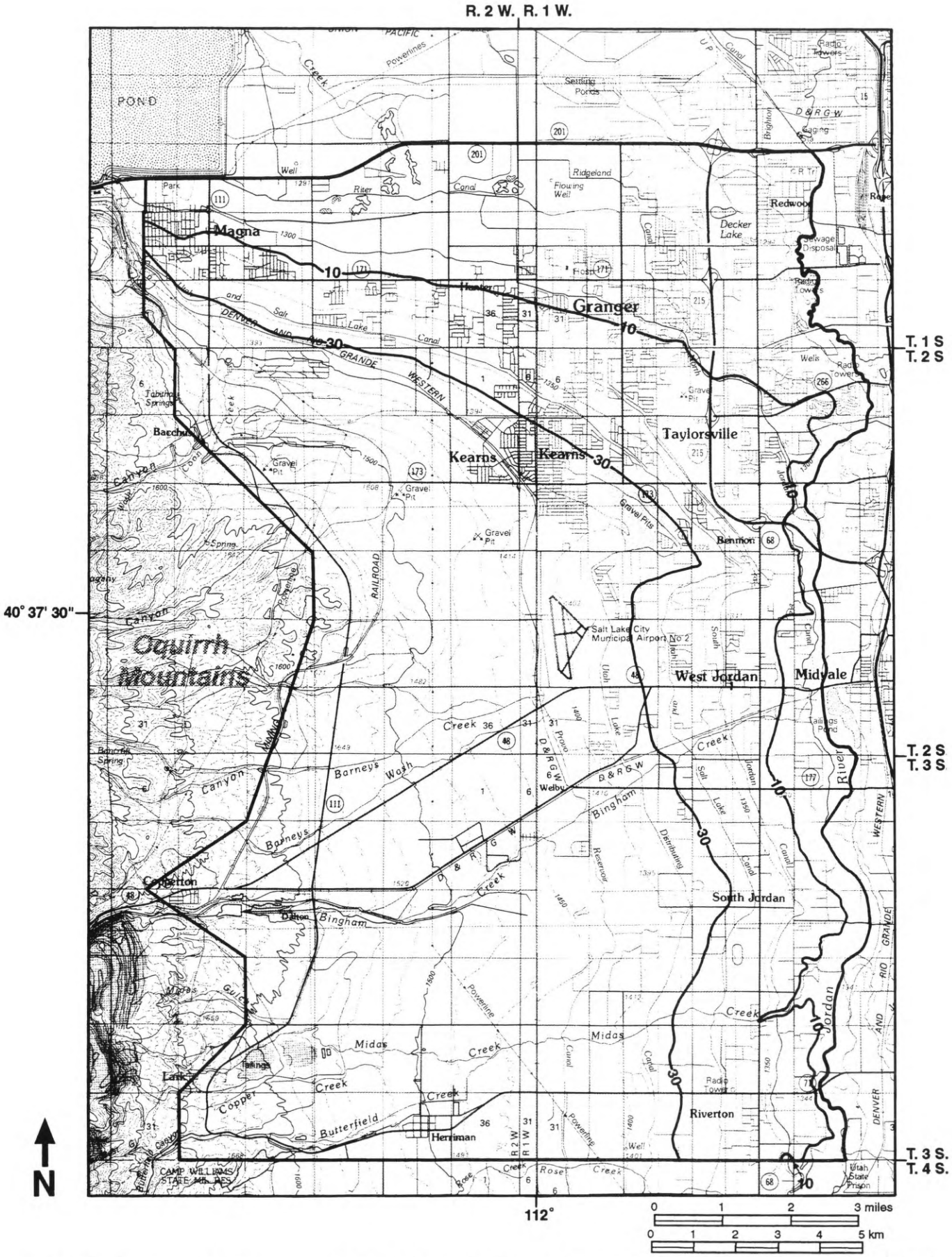

Figure 8. *Depth to shallow ground water in western Salt Lake Valley (modified from Anderson and others, 1994). Contours show depths of 10 feet (3 m) and 30 feet (9 m).*

assigned the soils to permeability classes based on soil structure and porosity. Hydraulic conductivity of these permeability classes ranges from less than 0.06 inches/hour (4.2×10^{-5} cm/sec) to greater than 6.0 inches/hour (4.2×10^{-3} cm/sec). Based on the lowest hydraulic conductivity in the upper 60 inches (24 cm) of soil, the SCS permeability classes were grouped into: (1) impermeable soils, which have hydraulic conductivities less than 0.6 inches/hour (4.2×10^{-4} cm/sec), (2) moderately permeable soils, which have hydraulic conductivities ranging from 0.6 to 6.0 inches hour (4.2×10^{-4} to 4.2×10^{-3} cm/sec), and (3) highly permeable soils, which have hydraulic conductivities greater than 6.0 inches/hour (4.2×10^{-3} cm/sec). Impermeable soils (commonly containing clay-rich layers or indurated hardpan) block the flow of soil gas, whereas highly permeable soils provide excellent pathways for soil-gas migration (McLemore and others, 1991); moderately permeable soils have an intermediate capability for soil-gas migration.

Soil permeability in western Salt Lake Valley is generally moderate to low (figure 9; Woodward and others, 1974), similar to Tooele Valley to the west (Black and Solomon, 1996). Highly permeable soils are not extensive and generally found only near South Jordan (figure 9). Moderate-permeability soils are mainly on piedmont slopes along the Oquirrh Mountains and bluffs along the modern flood plain of the Jordan River (figure 9), and are generally associated with lacustrine shoreline sand and gravel and coarse-grained Holocene alluvium. Low-permeability soils are common throughout western Salt Lake Valley (figure 9), and are generally associated with the Harkers Alluvium, and clay-rich lacustrine lake-bottom, deltaic, and alluvial deposits.

Hazard Potential

The radon-hazard potential of western Salt Lake Valley is mainly moderate to high, and generally decreases away from the front of the Oquirrh Mountains (plate). The hazard potential appears higher than Tooele Valley to the west, but lower than the east Sandy area in eastern Salt Lake Valley (Solomon and others, 1994; Black and Solomon, 1996). This apparent intermediate hazard-potential is likely due to high uranium levels in western Salt Lake Valley (similar to east Sandy), and low soil permeability (similar to Tooele Valley).

The hazard potential is highest in piedmont slopes along the Oquirrh Mountains, where ground water is deep and uranium-enriched lacustrine sand and gravel and Holocene alluvium are found. Localized areas of low hazard potential are found in the northern part of the study area near Granger and Magna, and along the Jordan River near Midvale and Riverton. Poorly drained, clay-rich lake deposits low in uranium are in these areas. The hazard potential is moderate elsewhere in the valley where well-drained lake deposits having moderate uranium concentrations are found. All levels are shown on the plate accompanying this report.

Soil-Gas Radon

Soil-gas radon was measured for correlation to uranium concentrations and comparison to the radon-hazard-potential map. Because radon is a decay product of uranium, the ideal correlation between radon and uranium concentrations at the same site is linear. In reality, this relationship is affected by radioactive disequilibrium between parent and daughter elements measured at different horizons, the effect of grain size on radon emanation, and atmospheric contamination of soil-gas samples by air leaking between the probe and adjacent soil. Therefore, soil-gas concentrations are difficult to accurately characterize, and correlations to uranium concentration and hazard potential are imperfect.

Soil-gas radon measured at 70 sample sites in western Salt Lake Valley ranges in concentration from 98 to 2,149 pCi/L (3.63×10^3 - 7.95×10^4 Bq/m^3); mean concentration is 408 pCi/L (1.51×10^4 Bq/m^3) and the standard deviation is 386 (table 2). Distribution of soil-gas data is lognormal (figure 10) and has a positive skewness of 1.57×10^8. Median concentration is 254 pCi/L (9.4×10^3 Bq/m^3) (table 2).

Linear regression of uranium-radon data pairs in western Salt Lake Valley (figure 11) shows they are related by the formula:

$$Rn = 158.1eU - 102.1$$

where Rn is the soil-gas concentration in pCi/L and eU is the uranium concentration in ppm. At the 95 percent confidence level for 70 samples, the Spearman correlation coefficient of 0.213 exceeds the threshold value of 0.198, indicating that the regression correlation is statistically significant. However, the correlation does not exceed the threshold value (0.280) for the 99 percent confidence level. Although the statistical correlation suggests a fairly consistent relationship between eU and soil-gas radon, the lower confidence level implies some atmospheric contamination of soil-gas samples. This is consistent with the abundance of coarse-grained deposits in western Salt Lake Valley, particularly in piedmont slopes along the Oquirrh Mountains, which are more subject to atmospheric contamination. Average soil-gas concentrations determined by the formula for western Salt Lake Valley are comparable to those determined from other studies in Utah (Solomon and others, 1991, 1994; Solomon, 1995; Black and Solomon, 1996; Solomon, 1996).

A semi-quantitative method of analysis using exclusion isolines was developed by Durrance (1978) to minimize the effects of factors which act to reduce sample concentrations. This method assumes that although many factors can reduce soil-gas measurements, only high radon levels will produce high measurements. Therefore, soil-gas samples in an area of uniform concentration can show varying values, the higher values being true indicators and the lower values merely resulting from factors which produce artificially low measurements (Durrance, 1978). It may be inferred, therefore, that the high concentrations are more significant. Instead of constructing contour lines of equal value, exclusion isolines enclose data points having higher values and ignore inconsistent low values. Areas of high concentrations may then be taken as geologically meaningful.

An exclusion-isoline contour map of soil-gas radon for western Salt Lake Valley (figure 12) shows soil-gas concentrations generally correspond well to the mapped hazard potential (plate). Highest soil-gas levels (greater than 1,000 pCi/L [3.7×10^4

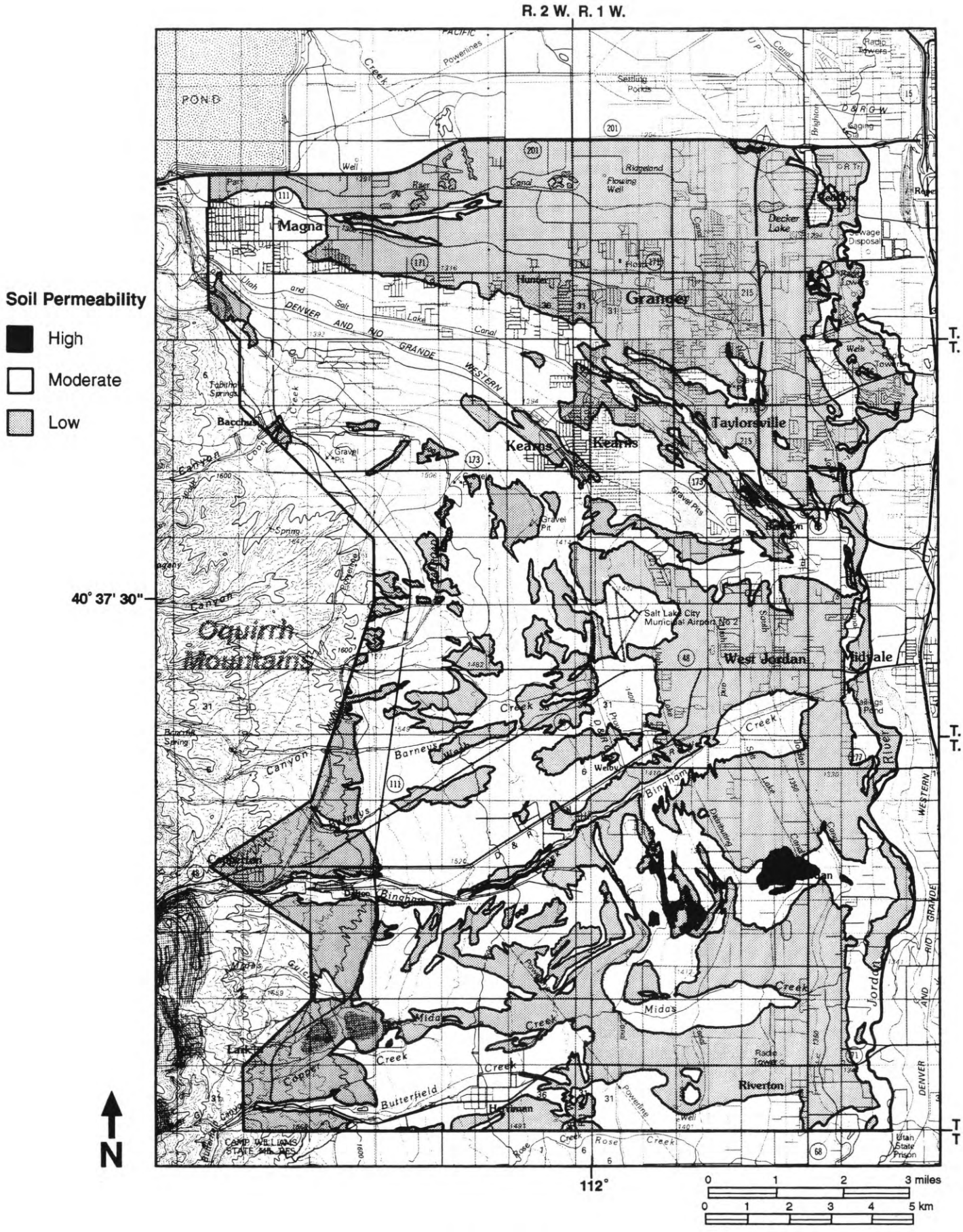

Figure 9. *Soil-permeability classes in western Salt Lake Valley (modified from Woodward and others, 1974). See table 3 for hydraulic conductivities associated with each class.*

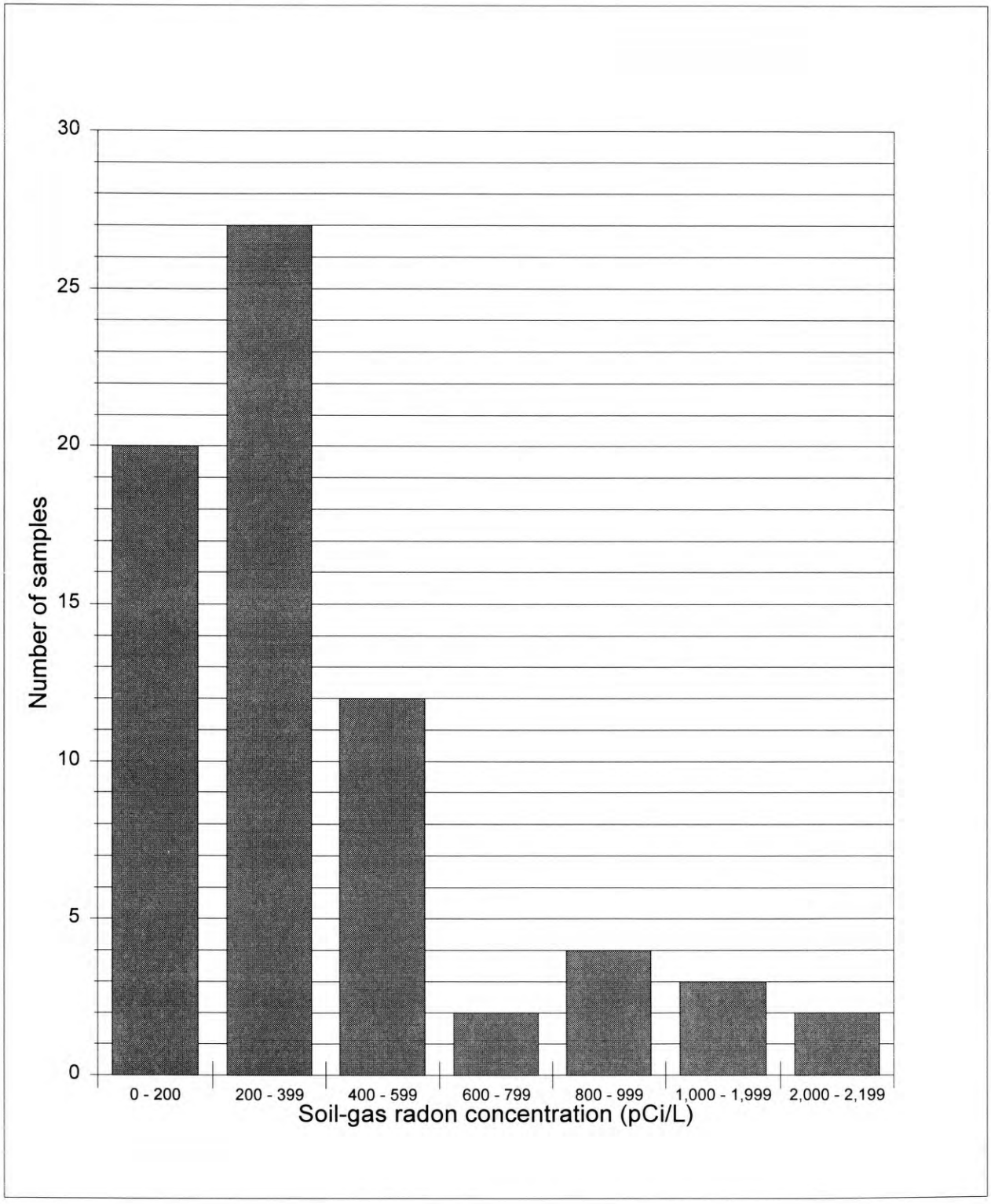

Figure 10. *Histogram of soil-gas-radon concentrations in western Salt Lake Valley.*

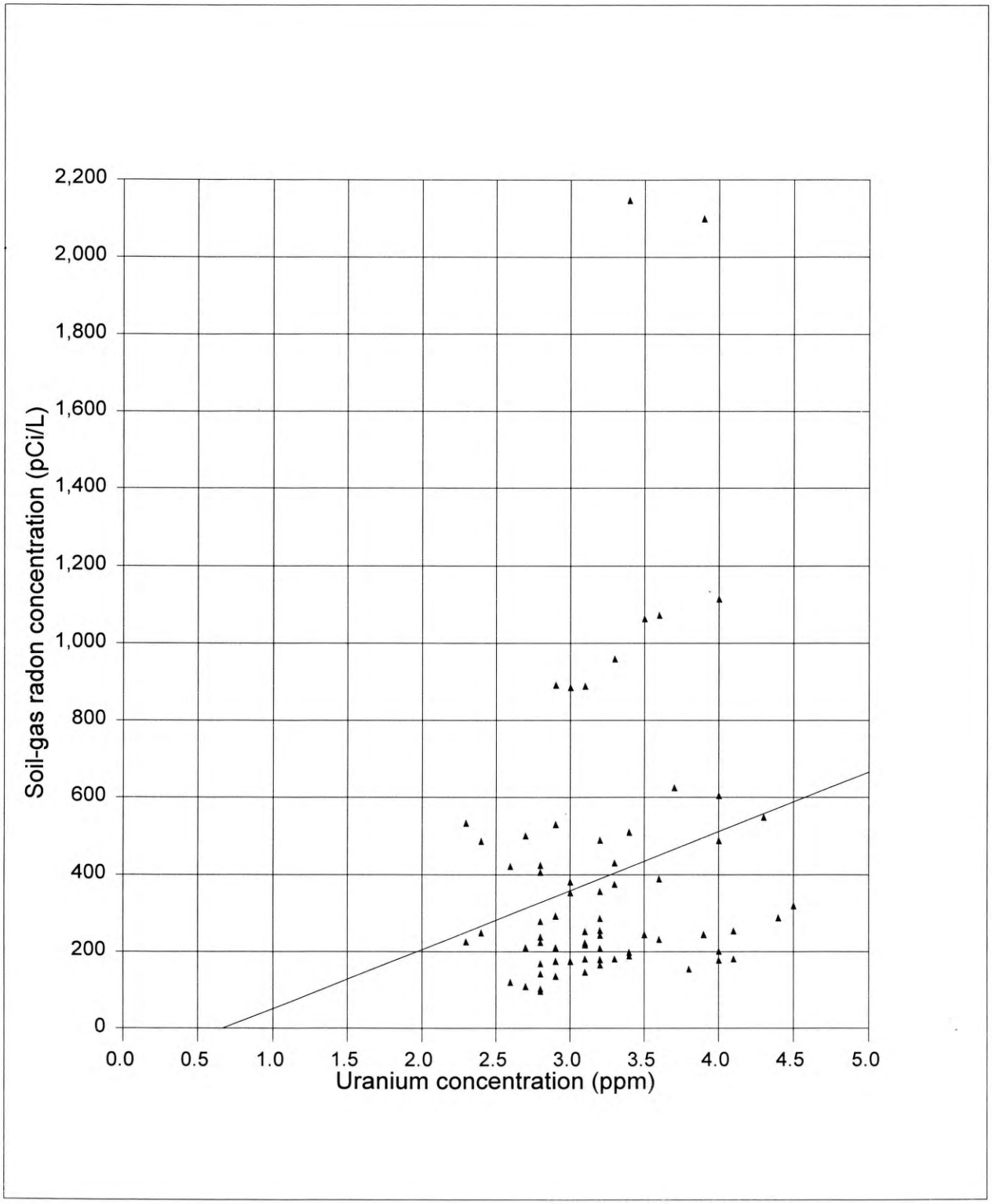

Figure 11. *Scatter plot and linear regression of uranium (eU) and soil-gas-radon (Rn) data pairs in western Salt Lake Valley.*

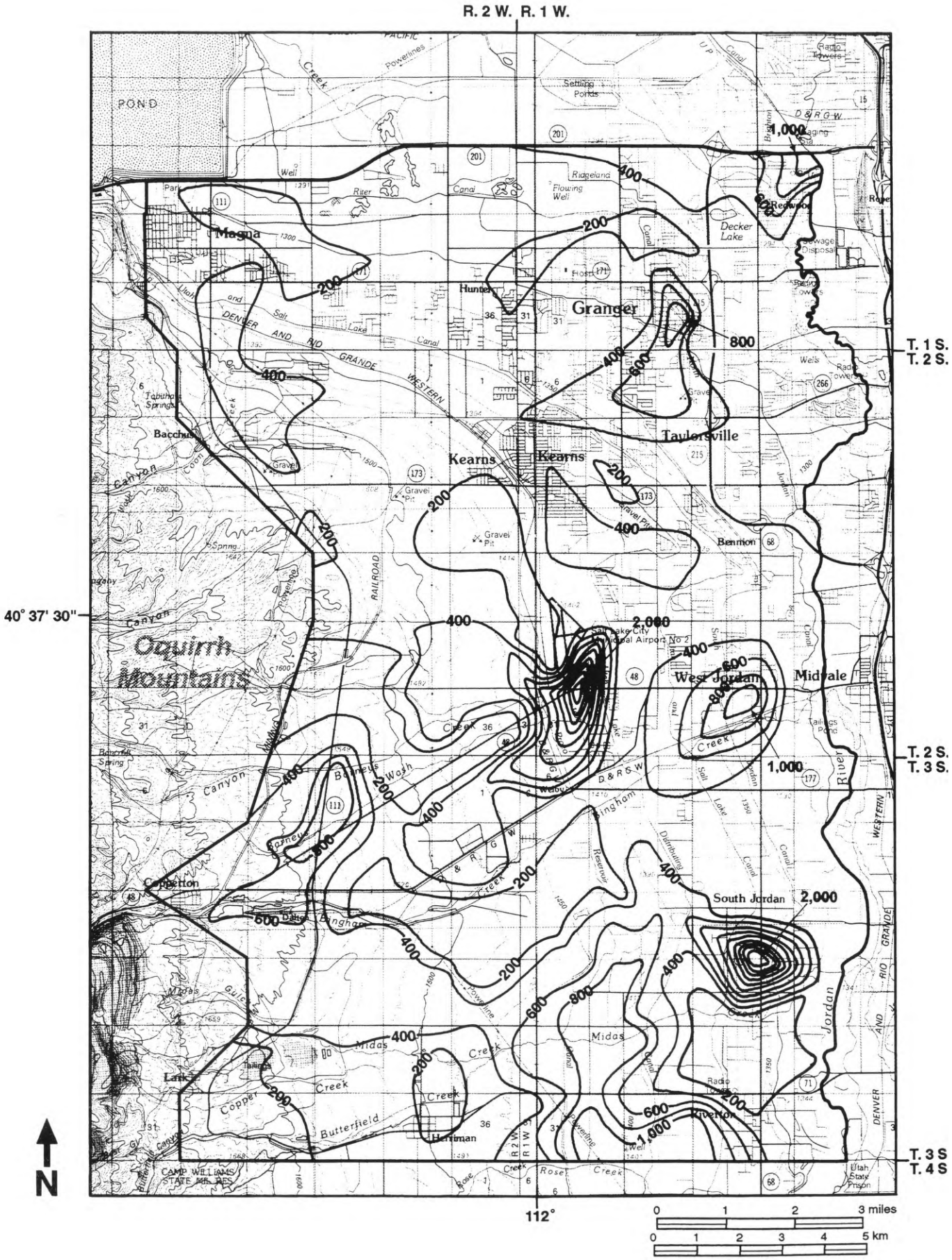

Figure 12. *Exclusion isoline map of soil-gas-radon concentrations in western Salt Lake Valley. Contour interval is 200 pCi/L (7.4 x 10^3 Bq/m^3).*

Bq/m^3]) are primarily in areas underlain by well-drained lacustrine deposits having moderate-to-high uranium concentrations, such as in South Jordan and near the Salt Lake City Municipal Airport No. 2, where the highest level of 2,149 pCi/L (7.95 x 10^4 Bq/m^3) was measured (figure 12). These areas generally have a moderate-to-high hazard potential (see plate). Lowest soil-gas levels (less than 200 pCi/L [7.4 x 10^3 Bq/m^3]) are commonly in areas underlain by clay-rich lacustrine and alluvial deposits, and semi-consolidated deposits of the pre-lake Harkers Alluvium (figure 12). These areas generally have a moderate-to-low hazard potential (see plate). However, the correlation between soil-gas radon and hazard potential is imperfect because factors such as atmospheric contamination can produce artificially low soil-gas measurements.

Indoor Radon

Mean concentration of 129 indoor-radon samples measured in western Salt Lake Valley is 2.7 pCi/L (100 Bq/m^3); 19.4 percent are greater than or equal to 4 pCi/L (148 Bq/m^3) (table 5). The samples consist of 69 long-term (alpha track) and 60 short-term (charcoal canister) measurements conducted by the UDRC (Sprinkel and Solomon, 1990; Solomon and others, 1993; UDRC, unpublished data). Mean concentration of the long-term measurements is 2.4 pCi/L (89 Bq/m^3), whereas short-term measurements have a mean concentration of 3.1 pCi/L (115 Bq/m^3); 16.0 percent of the long-term measurements and 23.4 percent of the short-term measurements exceed 4 pCi/L (148 Bq/m^3) (table 5). Locations of the 69 long-term measurements are shown on the map; locations of the short-term measurements are not shown because street addresses were not reported.

Long-term indoor-radon measurements depicted on the plate are chiefly in areas of moderate-hazard potential. Fifty-eight measurements, including the highest measured value of 12.2 pCi/L (451 Bq/m^3), are in moderate-hazard-potential areas; four measurements are in low-hazard-potential areas and seven are in high-hazard-potential areas (table 6; see plate). Average long-term indoor-radon measurements are within the range of expected levels for the mapped hazard-potential category, but individual levels vary within each category (table 6). Homes showing high indoor levels (greater than 4 pCi/L [148 Bq/m^3]) are in areas of moderate and high hazard potential in West Valley, Herriman, Kearns, Riverton, South Jordan, Taylorsville, and West Jordan (plate). Deep ground-water levels and moderate-permeability soils having elevated uranium levels are commonly found in these areas. Homes showing low levels (less than 2 pCi/L [74 Bq/m^3]) are generally in areas of moderate and low hazard potential, where low uranium levels, shallow ground water, or impermeable soils are found (see plate).

Table 5.
Summary of indoor-radon measurements in western Salt Lake Valley.

Testing Method	Total	Mean	Min.	Max.	Percentage of Measurements <2 pCi/L	2-4 pCi/L	>4 pCi/L
Short-term (charcoal canister)	60	3.1	0.3	10.8	35.0	41.7	23.3
Long-term (alpha track)	69	2.4	0.3	12.2	62.3	21.7	16.0
TOTAL	129	2.7	0.3	12.2	49.6	31.0	19.4

Table 6.
Long-term (alpha track) indoor-radon measurements in mapped radon-hazard-potential areas. Compare the average in each category to the probable indoor-radon concentrations predicted in table 4.

	HAZARD CATEGORY Low	Moderate	High
Sample Size	4	58	7
Minimum	1.0	0.3	0.5
Average	1.9	2.3	3.6
Maximum	2.8	12.2	7.9
% ±4 pCi/L	0	13.8	42.9
% of Total	5.8	84.1	10.1

Cautions When Using This Report

Because of the complex relationship between geologic and non-geologic factors controlling indoor-radon levels, this report should not be used to predict actual indoor-radon levels. Small localized areas of higher or lower radon-hazard potential may be found in the hazard areas depicted on the maps. Radon-hazard-potential categories are relative, and all map boundaries between hazard categories are approximate and gradational.

SUMMARY

Radon is a radioactive gas of geologic origin that can accumulate indoors in sufficient concentrations to pose a health hazard to building occupants. Indoor-radon levels depend on both geologic and non-geologic factors. The effects of geologic

factors can be estimated, whereas the effects of non-geologic factors, such as construction type, weather, and individual lifestyles, are difficult to quantify and characterize regionally.

The only way to determine the combined effects of both geologic and non-geologic factors is to measure indoor-radon levels in existing buildings. Indoor-radon levels may be easily and inexpensively measured, and various methods can be used to reduce high radon levels. However, the effects of non-geologic factors cannot be predicted prior to construction. Radon-hazard-potential maps based on geologic factors are particularly useful to indicate areas where radon-resistant construction techniques should be considered in new buildings. Radon-hazard-potential maps are also useful to prioritize testing in existing buildings when funds for testing are limited, or residents have been reluctant to test.

Geologic factors affecting radon levels include uranium concentration, depth to shallow ground water, and soil permeability. Radon is derived from the radioactive decay of uranium, and high uranium concentrations lead to elevated indoor-radon levels. Once radon is present, shallow ground water and soil permeability affect its ability to migrate to the surface and into structures. These geologic factors were used to map hazard potential in western Salt Lake Valley.

A qualitative assessment of the relative radon hazard was derived from the sum of numerical ratings assigned to each geologic factor. In areas of high-hazard potential, all factors contribute to elevated indoor-radon levels. In areas of moderate potential, some geologic factors contribute to elevated indoor-radon levels. In areas of low potential, no geologic factors contribute to elevated indoor-radon levels. Other geologic factors not considered, such as hydrothermal activity, fluctuations of the ground-water table, expansive soils, and active faults, may produce locally high indoor-radon levels.

The distinctive geology of western Salt Lake Valley affects the pattern of mapped hazard potential. Unconsolidated deposits in western Salt Lake Valley grade eastward from coarse-grained alluvial-fan and lake deposits along the Oquirrh Mountains to fine-grained lake deposits and alluvium in the valley interior. Bedrock sources high in uranium in the Oquirrh Mountains, particularly those in and around the Bingham stock, provide uranium-enriched sediment to these deposits. Deposits in the central and northern parts of the valley have a deep confined aquifer overlain by a shallow unconfined water-table aquifer. A deep unconfined aquifer is in piedmont slopes along the Oquirrh Mountains.

Uranium concentration and ground-water depth are the dominant factors governing the radon-hazard potential of western Salt Lake Valley. Permeability of soils in the study area is generally moderate to low. High uranium levels and deep ground water are common in piedmont slopes along the Oquirrh Mountains, whereas low uranium levels and shallow ground water are found along the Jordan River and in low-lying areas in the northern part of the study area. The hazard potential shows a similar pattern of distribution: generally high on the valley margin in the piedmont slopes, and low in the valley interior in the low-lying areas. Soil-gas measurements in the study area generally correlate well with the mapped hazard potential, but variations exist due to possible inaccuracies introduced by sampling techniques. Average indoor-radon levels measured in western Salt Lake Valley are within the expected range of concentrations in the hazard categories, but locally anomalous indoor levels may occur because of the local influence of unmeasured factors or the influence of measured factors beyond the map-scale resolution.

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Appendix

Radiometric Data
Western Salt Lake Valley

K = potassium
eTh = equivalent thorium (thallium-208)
% = percent

eU = equivalent uranium (bismuth-214)
ppm = parts per million
pCi/L = picocuries per liter

- = not measured

No.	T.	R.	Section	Total Gamma ppm	K %	eU ppm	eTh ppm	eU/eTh	Soil-gas radon pCi/L
1	1S	2W	NW1/4SE1/4 section 19	12.6	1.8	4.0	10.7	0.4	203
2	1S	2W	NW1/4NE1/4 section 30	9.8	1.4	3.2	8.1	0.4	-
3	1S	2W	SW1/4SE1/4 section 30	7.4	0.9	2.9	4.6	0.6	-
4	1S	2W	SE1/4NW1/4 section 29	9.7	1.4	2.9	8.7	0.3	212
5	1S	2W	NW1/4SE1/4 section 20	10.2	1.3	3.2	8.4	0.4	181
6	1S	2W	NW1/4NW1/4 section 28	9.7	1.4	3.1	8.2	0.4	-
7	1S	2W	SE1/4SE1/4 section 29	11.7	1.7	3.3	9.5	0.3	431
8	1S	2W	NE1/4SW1/4 section 32	8.9	1.2	3.4	7.2	0.5	-
9	2S	2W	NE1/4NW1/4 section 5	10.8	1.8	3.3	7.7	0.4	-
10	2S	2W	SE1/4SW1/4 section 5	10.2	1.4	3.7	6.0	0.6	-
11	2S	2W	SW1/4NE1/4 section 8	8.3	1.0	3.8	6.9	0.6	-
12	2S	2W	SW1/4SW1/4 section 9	12.9	1.3	4.9	13.3	0.4	-
13	2S	2W	NE1/4NE1/4 section 16	11.1	1.5	3.2	9.1	0.4	357
14	2S	2W	NW1/4NE1/4 section 15	9.6	1.4	3.7	6.9	0.5	-
15	1S	2W	NE1/4SE1/4 section 21	9.7	1.2	3.2	8.2	0.4	288
16	1S	2W	SW1/4NE1/4 section 22	10.7	1.6	3.3	8.6	0.4	-
17	1S	2W	NE1/4NE1/4 section 23	10.6	1.6	3.5	8.2	0.4	-
18	1S	2W	NW1/4NW1/4 section 23	10.9	1.7	3.0	10.3	0.3	353
19	1S	2W	SE1/4SE1/4 section 23	10.7	1.5	3.6	7.6	0.5	232
20	1S	2W	SE1/4SW1/4 section 23	7.3	1.0	3.1	3.9	0.8	-
21	1S	2W	NW1/4NE1/4 section 27	6.4	0.7	3.0	4.5	0.7	-
22	1S	2W	NE1/4NE1/4 section 28	5.8	0.8	2.2	3.7	0.6	-
23	1S	2W	SE1/4SE1/4 section 28	8.8	1.1	2.6	9.0	0.3	122
24	1S	2W	SW1/4NW1/4 section 33	10.7	1.4	3.8	8.7	0.4	-
25	1S	2W	SE1/4SW1/4 section 33	10.7	1.6	2.8	9.5	0.3	226
26	1S	2W	NE1/4SE1/4 section 33	8.0	1.2	3.0	5.0	0.6	-
27	2S	2W	NW1/4NE1/4 section 3	10.7	1.5	2.8	11.1	0.3	280
28	1S	2W	NW1/4NE1/4 section 24	13.6	1.9	4.2	11.6	0.4	-
29	1S	2W	SE1/4SE1/4 section 26	10.3	1.4	3.1	10.2	0.3	253
30	1S	2W	NE1/4NW1/4 section 35	11.2	1.8	3.0	11.0	0.3	-
31	1S	2W	SE1/4SE1/4 section 27	11.1	1.7	2.9	9.8	0.3	294
32	1S	2W	NE1/4SE1/4 section 34	10.4	1.4	3.4	11.0	0.3	-
33	2S	2W	SE1/4SE1/4 section 3	8.4	1.0	4.0	5.4	0.7	-
34	2S	2W	NW1/4SW1/4 section 11	7.5	1.0	3.1	6.4	0.5	-
35	2S	2W	SW1/4SE1/4 section 11	9.7	1.5	2.4	9.5	0.3	250
36	2S	2W	NE1/4NE1/4 section 11	7.9	1.1	2.0	7.5	0.3	-
37	2S	2W	NW1/4SW1/4 section 1	10.4	1.5	3.2	7.5	0.4	244
38	2S	2W	NW1/4NE1/4 section 2	9.4	1.4	2.6	9.1	0.3	-
39	1S	2W	NE1/4NE1/4 section 36	12.9	2.1	4.0	10.5	0.4	180
40	2S	2W	NE1/4NE1/4 section 1	10.6	1.5	3.2	9.1	0.4	-
41	2S	1W	NW1/4SW1/4 section 6	10.9	1.4	4.1	8.5	0.5	254
42	2S	1W	SW1/4NW1/4 section 7	11.6	1.6	3.9	10.4	0.4	245
43	2S	2W	SE1/4NE1/4 section 13	8.8	1.1	2.8	7.7	0.4	-
44	2S	1W	SW1/4SW1/4 section 18	12.8	1.8	2.8	14.0	0.2	143
45	2S	2W	SE1/4SE1/4 section 24	12.4	1.8	4.1	10.8	0.4	182
46	2S	2W	SE1/4SE1/4 section 23	11.0	1.3	3.8	9.9	0.4	-
47	2S	2W	NE1/4NW1/4 section 24	8.8	1.2	2.9	7.7	0.4	-
48	2S	2W	NW1/4NE1/4 section 23	9.2	1.1	3.4	6.9	0.5	190
49	2S	2W	NW1/4NW1/4 section 23	11.1	1.6	3.3	11.1	0.3	-
50	2S	2W	NE1/4SE1/4 section 16	8.0	0.9	2.5	6.1	0.4	-
51	2S	2W	NW1/4NW1/4 section 22	11.1	1.4	3.4	7.7	0.4	199
52	2S	2W	NE1/4SW1/4 section 22	9.5	1.1	4.5	7.7	0.6	-
53	2S	2W	NW1/4SE1/4 section 12	7.0	0.9	1.8	8.6	0.2	-
54	1S	1W	NW1/4NE1/4 section 20	9.9	1.2	3.4	8.3	0.4	-
55	1S	1W	NE1/4NW1/4 section 21	12.4	1.8	4.2	10.4	0.4	-
56	1S	1W	NE1/4SW1/4 section 21	7.4	1.0	2.4	5.1	0.5	488

No.	T.	R.	Section	Total Gamma ppm	K %	eU ppm	eTh ppm	eU/eTh	Soil-gas radon pCi/L
57	1S	1W	SE1/4NW1/4 section 28	9.1	1.2	2.3	7.3	0.3	-
58	1S	1W	NE1/4SE1/4 section 29	11.2	1.6	3.1	11.5	0.3	183
59	1S	1W	SE1/4SW1/4 section 20	8.8	1.3	2.8	9.7	0.3	-
60	1S	1W	SE1/4NW1/4 section 20	13.8	2.0	4.7	10.7	0.4	-
61	1S	1W	SE1/4NW1/4 section 30	6.4	0.9	2.2	5.6	0.4	-
62	1S	1W	SW1/4SW1/4 section 29	11.9	1.7	3.2	9.0	0.4	256
63	1S	1W	NE1/4SE1/4 section 31	10.8	1.6	3.5	8.0	0.4	-
64	1S	1W	NE1/4NW1/4 section 32	7.5	0.9	2.0	6.8	0.3	-
65	2S	1W	SE1/4SW1/4 section 6	8.8	1.0	3.2	7.6	0.4	490
66	2S	1W	SW1/4NW1/4 section 5	10.0	1.4	2.4	10.5	0.2	-
67	2S	1W	NW1/4NE1/4 section 7	9.9	1.6	3.5	6.3	0.6	-
68	2S	1W	SW1/4SW1/4 section 8	7.3	0.9	2.1	8.2	0.3	-
69	2S	1W	SW1/4NE1/4 section 18	12.0	1.5	4.6	10.0	0.5	-
70	2S	1W	NE1/4NE1/4 section 19	8.9	1.1	3.0	8.5	0.4	-
71	2S	1W	SE1/4SW1/4 section 17	6.6	0.7	2.8	4.6	0.6	426
72	2S	1W	SE1/4SE1/4 section 17	9.4	1.4	3.5	7.4	0.5	-
73	2S	1W	SE1/4NE1/4 section 17	7.0	0.8	2.5	5.6	0.4	-
74	2S	1W	SW1/4SE1/4 section 8	6.9	1.0	2.8	5.5	0.5	98
75	2S	1W	SW1/4NE1/4 section 8	11.8	1.8	3.4	12.6	0.3	-
76	2S	1W	SW1/4SW1/4 section 4	8.7	1.2	3.7	6.8	0.5	625
77	2S	1W	SW1/4NE1/4 section 5	8.7	1.1	2.6	7.9	0.3	-
78	2S	1W	NW1/4NW1/4 section 4	9.2	1.2	3.0	8.5	0.4	-
79	2S	1W	NE1/4NW1/4 section 4	6.3	1.0	2.4	3.9	0.6	-
80	2S	1W	NW1/4SW1/4 section 3	9.2	1.3	2.9	6.6	0.4	-
81	2S	1W	NE1/4SE1/4 section 7	9.2	1.3	2.3	8.6	0.3	226
82	2S	1W	SW1/4NE1/4 section 15	12.6	1.9	3.9	9.2	0.4	-
83	2S	1W	NE1/4NE1/4 section 22	8.8	1.2	3.4	6.7	0.5	-
84	2S	1W	NW1/4SW1/4 section 23	10.4	1.3	3.5	9.8	0.4	-
85	2S	1W	NW1/4SE1/4 section 22	8.4	1.1	2.7	7.5	0.4	-
86	2S	1W	SW1/4SW1/4 section 15	10.4	1.6	3.0	8.6	0.3	-
87	2S	1W	NW1/4SE1/4 section 16	7.3	0.9	2.7	7.4	0.4	-
88	2S	1W	SE1/4SW1/4 section 21	9.0	1.2	3.3	6.4	0.5	376
89	2S	1W	SE1/4SE1/4 section 9	11.5	1.7	3.4	10.2	0.3	-
90	2S	1W	SW1/4SE1/4 section 4	8.0	1.2	2.6	6.5	0.4	-
91	2S	1W	NW1/4NE1/4 section 10	12.8	1.8	4.4	8.6	0.5	290
92	2S	1W	SW1/4SW1/4 section 2	9.7	1.3	3.1	6.1	0.5	-
93	2S	1W	SE1/4SE1/4 section 10	9.1	1.1	2.7	7.1	0.4	212
94	1S	1W	NE1/4SW1/4 section 33	10.2	1.4	3.3	6.4	0.5	960
95	1S	1W	SW1/4NW1/4 section 27	9.5	1.5	3.5	8.4	0.4	-
96	1S	1W	SE1/4SW1/4 section 22	11.2	1.7	4.1	6.6	0.6	-
97	1S	1W	SE1/4NW1/4 section 22	9.4	1.3	2.9	6.9	0.4	-
98	1S	1W	NW1/4NW1/4 section 23	9.6	1.2	3.5	8.0	0.4	1,063
99	1S	1W	SW1/4SW1/4 section 23	9.8	1.4	2.9	7.0	0.4	-
100	1S	1W	SW1/4NE1/4 section 27	7.3	1.0	3.0	5.9	0.5	381
101	1S	1W	SE1/4SE1/4 section 27	7.5	0.9	3.2	5.9	0.5	-
102	1S	1W	SW1/4NE1/4 section 34	8.1	1.0	2.4	8.4	0.3	-
103	1S	1W	SE1/4NE1/4 section 33	9.2	1.3	2.6	6.9	0.4	-
104	2S	1W	SW1/4SW1/4 section 5	8.4	1.1	2.8	7.5	0.4	-
105	2S	1W	NW1/4SW1/4 section 17	8.6	1.3	2.7	6.4	0.4	-
106	2S	1W	NE1/4SW1/4 section 20	8.6	1.2	2.1	8.2	0.3	-
107	2S	1W	SW1/4NW1/4 section 21	9.6	1.5	3.1	7.2	0.4	-
108	2S	1W	NE1/4NE1/4 section 17	10.9	1.4	3.4	10.1	0.3	-
109	2S	1W	SW1/4SE1/4 section 9	8.3	1.1	2.9	6.4	0.5	-
110	2S	1W	SE1/4NW1/4 section 9	10.6	1.4	3.0	10.1	0.3	-
111	2S	1W	NE1/4SE1/4 section 2	10.2	1.3	3.8	6.5	0.6	-
112	2S	1W	SE1/4NE1/4 section 27	10.4	1.7	2.5	9.4	0.3	-
113	2S	1W	NW1/4NW1/4 section 35	12.7	1.6	4.0	12.7	0.3	-
114	2S	1W	NE1/4NW1/4 section 34	12.4	1.7	4.0	8.7	0.5	1,115
115	2S	1W	NE1/4SE1/4 section 28	12.4	1.8	3.3	12.8	0.3	-
116	2S	1W	NE1/4NW1/4 section 27	8.1	1.2	2.3	6.9	0.3	-
117	2S	1W	SW1/4SE1/4 section 28	11.3	1.7	3.0	9.8	0.3	-
118	2S	1W	NW1/4NW1/4 section 28	13.0	2.0	4.5	10.0	0.5	320
119	2S	1W	NE1/4NW1/4 section 29	11.1	1.7	3.1	10.2	0.3	-
120	2S	1W	SW1/4SW1/4 section 28	13.6	1.9	4.4	10.3	0.4	-
121	2S	1W	NW1/4NE1/4 section 32	10.4	1.4	3.2	8.0	0.4	210
122	2S	1W	NE1/4NE1/4 section 31	12.8	1.8	3.4	10.3	0.3	2,149
123	2S	1W	SE1/4NW1/4 section 30	9.0	1.1	3.4	8.8	0.4	-
124	3S	1W	SW1/4NE1/4 section 2	10.2	1.5	3.9	8.9	0.4	-

No.	T.	R.	Section	Total Gamma ppm	K %	eU ppm	eTh ppm	eU/eTh	Soil-gas radon pCi/L
125	2S	1W	NW1/4SW1/4 section 35	11.1	1.6	3.5	10.2	0.3	246
126	3S	1W	NE1/4NE1/4 section 3	14.3	2.5	3.4	11.4	0.3	-
127	3S	1W	NE1/4NE1/4 section 10	12.7	2.0	3.5	11.1	0.3	-
128	3S	1W	NE1/4NE1/4 section 15	10.7	1.5	3.0	9.5	0.3	176
129	3S	1W	NW1/4SE1/4 section 11	12.5	1.9	3.4	10.3	0.3	-
130	3S	1W	NW1/4NW1/4 section 15	9.3	1.3	2.9	7.7	0.4	138
131	3S	1W	SE1/4SW1/4 section 10	9.5	1.3	2.4	9.6	0.3	-
132	3S	1W	NE1/4NE1/4 section 9	13.0	1.8	4.0	10.8	0.4	-
133	2S	1W	NE1/4SW1/4 section 34	12.0	1.8	2.5	11.2	0.2	-
134	3S	1W	NE1/4NE1/4 section 4	10.2	1.3	2.7	9.3	0.3	500
135	2S	1W	SE1/4SW1/4 section 33	15.6	2.2	5.2	11.1	0.5	-
136	3S	1W	SW1/4NW1/4 section 4	10.7	1.5	3.4	8.2	0.4	-
137	3S	1W	NW1/4SE1/4 section 5	7.2	1.0	2.3	4.6	0.5	-
138	3S	1W	SW1/4NW1/4 section 5	10.8	1.7	3.1	10.2	0.3	219
139	3S	1W	SW1/4NW1/4 section 5	10.5	1.6	2.9	8.5	0.3	-
140	2S	1W	SE1/4SE1/4 section 31	8.3	1.3	3.1	6.2	0.5	-
141	3S	1W	SE1/4SW1/4 section 15	9.7	1.2	3.9	6.3	0.6	2,101
142	3S	1W	SE1/4SW1/4 section 22	9.6	1.5	3.0	8.2	0.4	-
143	3S	1W	SW1/4SE1/4 section 21	12.0	1.8	3.4	10.2	0.3	-
144	3S	1W	NE1/4SW1/4 section 28	13.0	1.6	3.8	10.8	0.4	156
145	3S	1W	SE1/4SE1/4 section 29	12.4	2.0	4.0	9.8	0.4	-
146	3S	1W	NW1/4SE1/4 section 32	13.4	2.0	3.5	12.1	0.3	-
147	3S	1W	SE1/4SE1/4 section 30	10.6	1.4	3.0	9.3	0.3	885
148	3S	1W	NW1/4NW1/4 section 29	13.2	2.0	3.6	10.7	0.3	-
149	3S	1W	SE1/4NE1/4 section 19	13.6	2.2	4.1	10.1	0.4	-
150	3S	1W	NW1/4NW1/4 section 20	9.6	1.8	3.1	7.5	0.4	-
151	3S	1W	NW1/4NW1/4 section 28	15.6	2.2	4.4	14.1	0.3	-
152	3S	1W	SE1/4NW1/4 section 21	11.8	1.8	4.0	9.8	0.4	-
153	3S	1W	SW1/4SE1/4 section 16	11.2	1.5	4.2	8.6	0.5	-
154	3S	1W	SE1/4NE1/4 section 17	9.0	1.4	3.3	6.3	0.5	-
155	3S	1W	SE1/4SE1/4 section 5	11.3	1.8	2.8	10.4	0.3	240
156	3S	1W	SW1/4NE1/4 section 8	9.0	1.4	3.6	4.9	0.7	-
157	3S	1W	SE1/4SW1/4 section 8	9.3	1.3	2.8	8.0	0.4	170
158	3S	1W	NW1/4NW1/4 section 8	8.7	1.3	2.9	7.0	0.4	-
159	3S	1W	SW1/4SE1/4 section 7	8.5	1.4	2.4	7.2	0.3	-
160	3S	1W	SE1/4SW1/4 section 9	12.3	1.7	3.8	9.7	0.4	-
161	3S	1W	NW1/4NE1/4 section 33	11.7	1.6	3.6	11.4	0.3	1,072
162	3S	1W	SW1/4SW1/4 section 27	7.5	1.2	2.0	6.8	0.3	-
163	3S	1W	SE1/4SW1/4 section 34	8.8	1.5	2.7	5.4	0.5	-
164	3S	1W	SW1/4SW1/4 section 35	11.2	1.6	3.7	9.1	0.4	-
165	3S	1W	NW1/4NW1/4 section 35	11.5	1.6	2.7	10.7	0.3	-
166	3S	1W	NW1/4SW1/4 section 26	9.0	1.6	1.6	9.8	0.2	-
167	3S	1W	SW1/4SW1/4 section 23	10.1	1.4	3.0	9.4	0.3	-
168	3S	1W	NE1/4NW1/4 section 23	10.8	1.6	2.9	9.9	0.3	530
169	2S	2W	NW1/4NE1/4 section 36	14.3	2.2	3.4	14.6	0.2	511
170	2S	2W	SW1/4NW1/4 section 25	8.8	1.2	3.2	5.7	0.6	-
171	2S	2W	NW1/4NE1/4 section 35	13.9	1.9	4.0	12.4	0.3	488
172	2S	2W	SE1/4SE1/4 section 27	7.7	1.0	2.8	6.8	0.4	-
173	2S	2W	SE1/4NW1/4 section 27	7.7	1.0	2.4	7.2	0.3	-
174	2S	2W	SE1/4NW1/4 section 34	8.3	0.9	3.2	7.3	0.4	167
175	3S	2W	NW1/4NW1/4 section 3	12.1	1.7	3.1	10.5	0.3	-
176	3S	2W	SW1/4NE1/4 section 4	10.3	1.5	2.7	10.8	0.3	-
177	3S	2W	NW1/4SW1/4 section 3	9.7	1.1	3.2	8.7	0.4	-
178	3S	2W	NW1/4NW1/4 section 10	11.8	1.8	2.9	9.2	0.3	892
179	3S	2W	SE1/4SE1/4 section 3	10.1	1.5	3.0	9.4	0.3	-
180	3S	2W	SE1/4SE1/4 section 3	8.4	1.2	2.7	6.5	0.4	110
181	2S	2W	NW1/4SW1/4 section 30	9.2	1.2	3.0	9.8	0.3	-
182	2S	2W	SE1/4NE1/4 section 36	8.2	1.3	2.4	7.4	0.3	-
183	3S	1W	NW1/4NW1/4 section 6	10.7	1.5	3.1	9.2	0.3	889
184	3S	2W	NW1/4NW1/4 section 17	14.9	1.9	4.3	13.8	0.3	548
185	3S	2W	SW1/4SW1/4 section 9	13.3	2.1	4.1	11.4	0.4	-
186	3S	2W	SE1/4SW1/4 section 9	12.8	1.7	4.0	8.9	0.4	606
187	3S	2W	SE1/4SW1/4 section 8	14.0	2.3	3.7	11.9	0.3	-
188	3S	2W	NW1/4SE1/4 section 9	10.0	1.4	3.2	8.4	0.4	-
189	3S	2W	NW1/4NW1/4 section 15	8.8	1.3	2.4	7.8	0.3	-
190	3S	2W	SW1/4SE1/4 section 10	12.9	1.8	2.8	12.3	0.2	105
191	3S	2W	SE1/4SW1/4 section 11	8.6	1.2	2.7	7.0	0.4	-
192	3S	2W	NE1/4NW1/4 section 11	10.6	1.4	2.8	9.2	0.3	407

No.	T.	R.	Section	Total Gamma ppm	K %	eU ppm	eTh ppm	eU/eTh	Soil-gas radon pCi/L
193	3S	2W	SW1/4NW1/4 section 12	11.7	1.7	3.9	9.8	0.4	-
194	3S	2W	SE1/4SE1/4 section 1	8.1	1.2	2.4	7.4	0.3	-
195	3S	1W	SW1/4NW1/4 section 7	11.7	1.8	3.1	10.2	0.3	224
196	3S	2W	SW1/4SW1/4 section 15	9.8	1.4	2.3	9.7	0.2	534
197	3S	2W	NE1/4SE1/4 section 21	11.1	1.6	3.7	9.1	0.4	-
198	3S	2W	NW1/4NW1/4 section 28	10.4	1.3	3.6	8.5	0.4	-
199	3S	2W	NE1/4SW1/4 section 32	12.8	1.8	3.4	12.7	0.3	-
200	3S	2W	SE1/4SW1/4 section 29	9.3	1.3	2.4	8.8	0.3	-
201	3S	2W	NE1/4SE1/4 section 29	12.3	1.7	2.9	11.7	0.2	176
202	3S	2W	NW1/4NW1/4 section 27	8.1	1.3	2.7	6.1	0.4	-
203	3S	1W	NE1/4NE1/4 section 27	12.5	1.9	4.7	8.3	0.6	-
204	3S	2W	SE1/4NE1/4 section 22	12.3	1.9	3.5	10.8	0.3	-
205	3S	2W	NW1/4NE1/4 section 26	13.1	1.7	3.8	14.0	0.3	-
206	3S	2W	SW1/4NW1/4 section 24	12.1	1.9	3.2	10.7	0.3	-
207	3S	2W	NW1/4SW1/4 section 13	8.2	1.2	2.3	7.6	0.3	-
208	3S	2W	SW1/4SE1/4 section 26	12.6	2.0	3.3	12.0	0.3	182
209	3S	2W	NW1/4SW1/4 section 33	9.2	1.3	2.4	7.1	0.3	-
210	3S	2W	SE1/4SE1/4 section 33	12.7	1.7	3.2	11.7	0.3	166
211	3S	2W	SE1/4SW1/4 section 34	10.8	1.3	3.3	10.3	0.3	-
212	3S	2W	NE1/4SE1/4 section 34	17.3	2.3	4.0	20.6	0.2	-
213	3S	2W	NW1/4SE1/4 section 35	11.4	1.7	3.1	12.5	0.2	148
214	3S	2W	SE1/4NW1/4 section 36	9.3	1.5	3.0	8.8	0.3	-
215	3S	1W	NW1/4NW1/4 section 31	14.0	2.1	3.6	12.7	0.3	389
216	3S	1W	NW1/4NE1/4 section 25	11.3	1.8	2.6	10.7	0.2	423
217	3S	1W	NW1/4NW1/4 section 30	13.9	1.9	4.2	11.7	0.4	-

R. 2 W. R. 1 W.

T. 1 S.
T. 2 S.
T. 2 S.
T. 3 S.
T. 3 S.
T. 4 S.

40°37′30″

112°

SCALE 1:50,000

1 0.5 0 1 2 3 4 5 Kilometers

1 0.5 0 1 2 Miles

EXPLANATION

H — High radon-hazard potential. Areas in which all geologic factors contribute to indoor-radon hazards.

M — Moderate radon-hazard potential. Areas in which some geologic factors contribute to indoor-radon hazards.

L — Low radon-hazard potential. Areas in which no geologic factors contribute to indoor-radon hazards.

4.9 — Indoor radon sample location and concentration in picocuries per liter (pCi/L).

——— Outline of study area.

UTAH

NORTH

RADON-HAZARD-POTENTIAL MAP OF WESTERN SALT LAKE VALLEY, SALT LAKE COUNTY, UTAH.

1996

Special Study 91

UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES
in cooperation with
U.S. ENVIRONMENTAL PROTECTION AGENCY