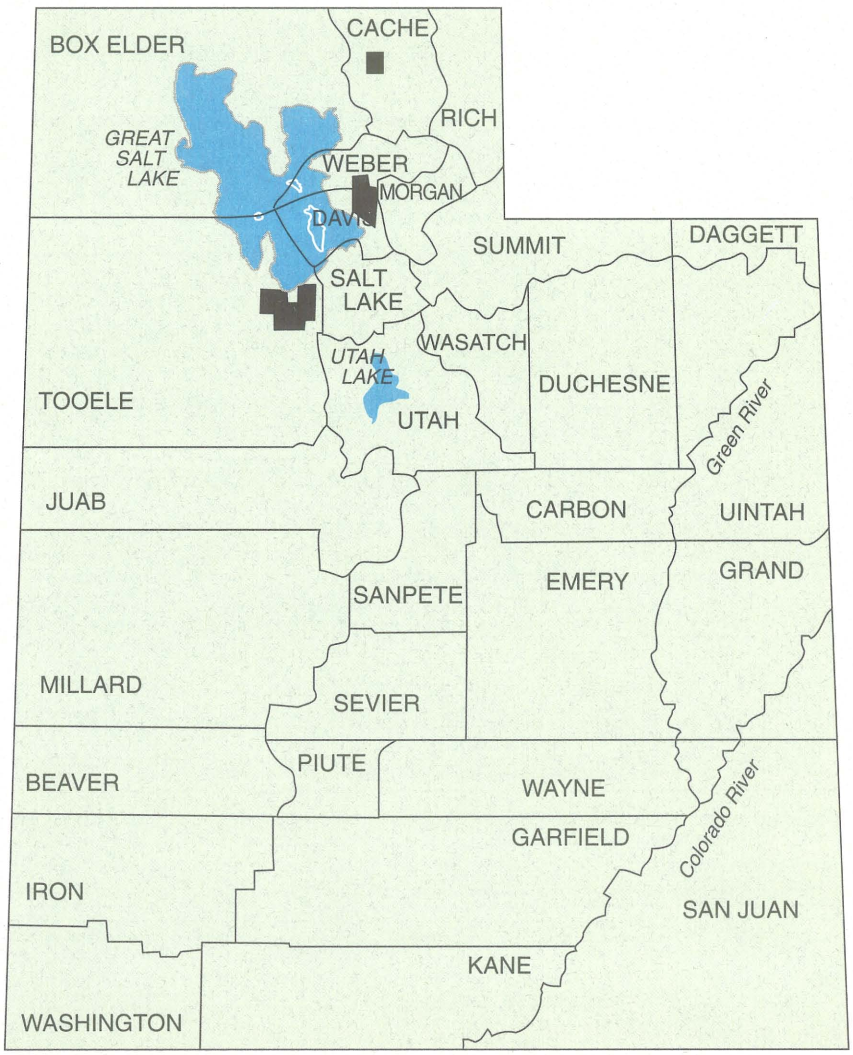
RADON-HAZARD POTENTIAL OF THE LOWER WEBER RIVER AREA, TOOELE VALLEY, AND SOUTHEASTERN CACHE VALLEY, CACHE, DAVIS, TOOELE, AND WEBER COUNTIES, UTAH

by
Bill D. Black and Barry J. Solomon



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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 three areas in northern Utah to indicate where indoor radon may be a hazard and radon-resistant techniques should be considered in new construction. The three areas include the lower Weber River area in Davis and Weber Counties, Tooele Valley in Tooele County, and southeastern Cache Valley in Cache County. These areas all lie in the depositional basin of Pleistocene Lake Bonneville, and display common geologic characteristics which affect their potential for radon hazards.

A primary factor affecting indoor-radon levels is the presence of uranium-enriched geologic materials. Uranium-238 levels are commonly highest in benches and piedmont slopes along the range fronts of the three areas, although higher levels (up to 5.0 parts per million [ppm]) are more common in the lower Weber River area. These benches and slopes are underlain by coarse-grained Bonneville shoreline and Holocene alluvial-fan deposits. Lowest uranium-238 concentrations (less than 2 ppm) are common in fine-grained lacustrine material underlying valleys.

Soil permeability and shallow ground water are factors which affect soil-gas migration and radon-hazard potential. Highly permeable soils and deep ground water facilitate radon migration in soil gas. Coarse-grained deposits on valley margins in the three study areas are typically highly permeable and well-drained. Impermeable clay-rich soils on fine-grained lake deposits, and shallow ground-water levels in valleys restrict radon migration.

A numerical rating system was used to assess and map the relative radon-hazard potential in the three study areas. A high-hazard potential was typically found along range fronts where uranium concentrations are higher, ground water is deep, and soils are permeable. 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 lower Weber River area, Tooele Valley, and southeastern Cache Valley (figure 1) were 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 the lower Weber River area and southeastern Cache Valley (Sprinkel and Solomon, 1990). In addition, Black (1993) shows there is a high potential for radon hazards in these areas, as well as in Tooele Valley. Based on this information, the UGS conducted investigations of geologic factors controlling radon levels in these areas. The investigations define the hazard potential in more detail, and designate areas where the need for additional indoor-radon testing is more urgent and 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 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.

Changes in building practices during the past 21 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, 1982).

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.

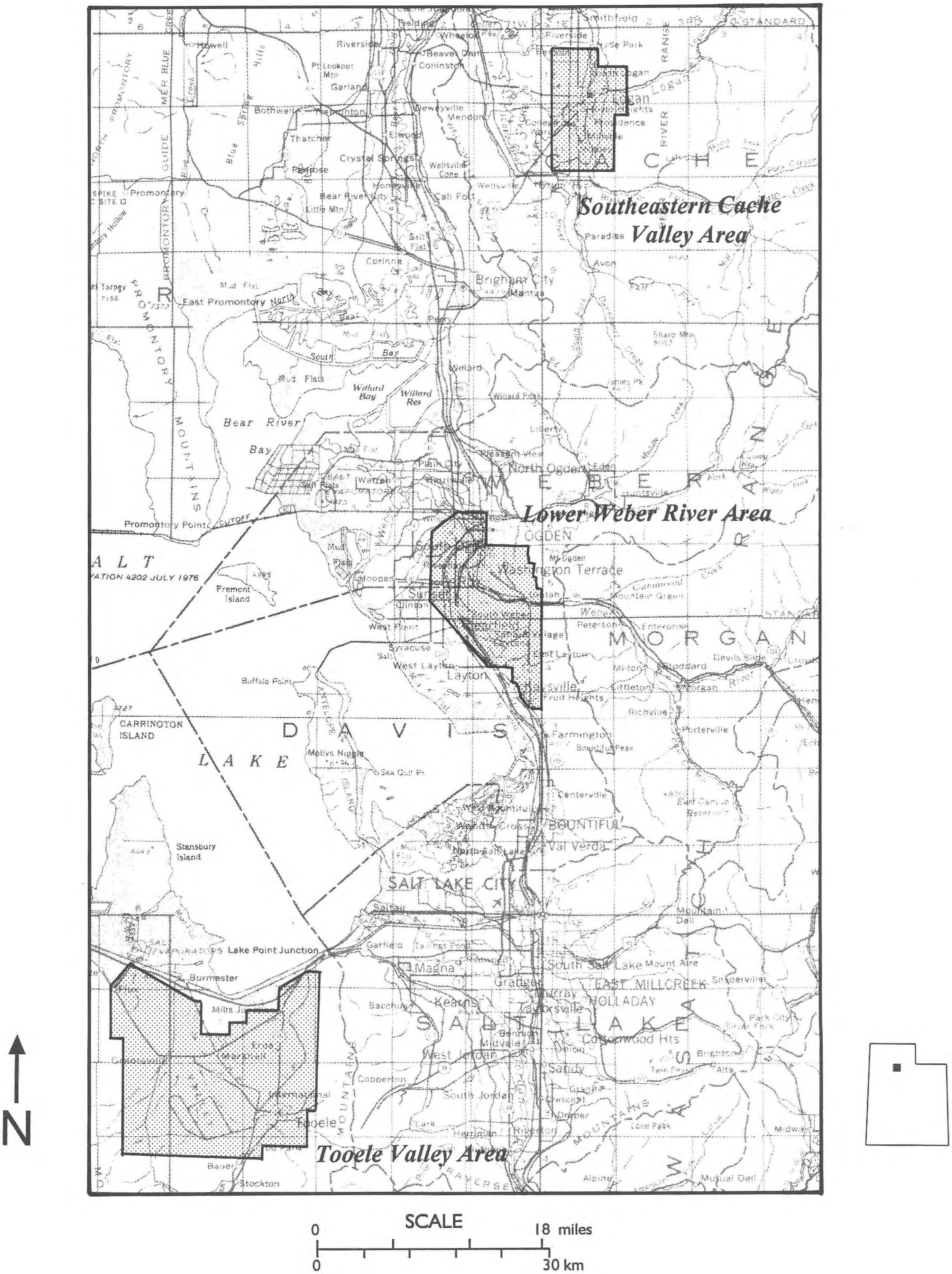

Figure 1. *Location of the lower Weber River area, Tooele Valley, and southeastern Cache Valley. Base map: U.S. Geological Survey.*

Table 1.
Uranium decay series showing the half-lives of isotopes. Radon's half-life is less than four days and the radon progeny combined half-life is about 90 minutes (Sprinkel and Solomon, 1990). a = alpha; b = beta; Mev = million electron 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	Tl-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	—	—

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 x 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 (Baretto, 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

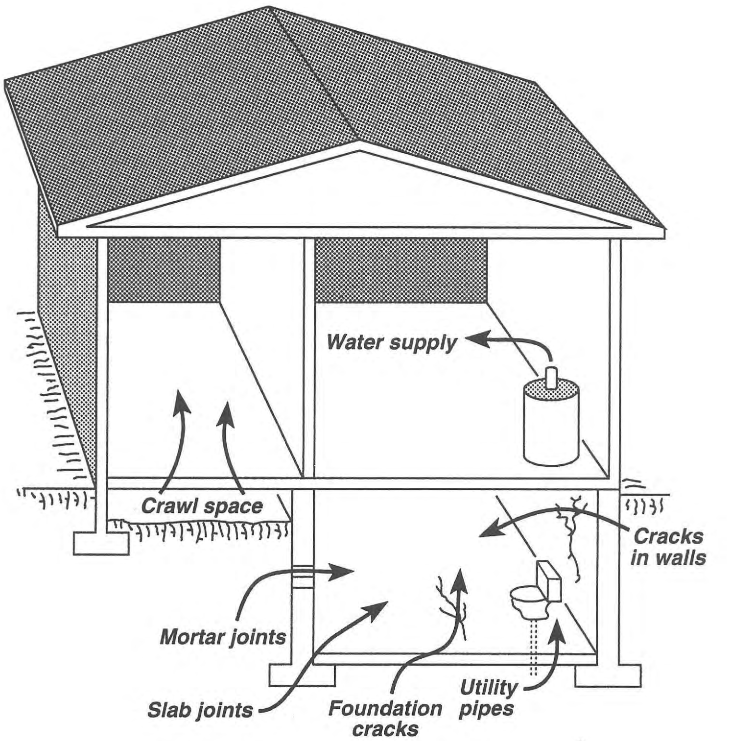

Figure 2. *Various pathways (shown by arrows) for radon to enter a home. Most entry routes are in the basement because this part of the house has the greatest surface area in contact with the surrounding soil (modified from U.S. Environmental Protection Agency, 1992).*

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 often 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. If a long-term follow-up test measures a level of 4 pCi/L (148 Bq/m^3) or higher, EPA recommends that the home be fixed to reduce indoor-radon levels. If the follow-up test is short term, EPA recommends that the home be fixed 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 radon levels in indoor air 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, and 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 miles (0.8 km) apart, depending on access, not including measurements collected in the town of Millville, Cache Valley. There, station spacing was about 0.1 mile (0.2 km) to determine the effect of denser spacing on hazard interpretation. 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 into 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 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 half of the spectrometer-measurement stations, but the spacing between soil-gas sample sites is irregular because of difficulties in penetrating dense and gravelly soils.

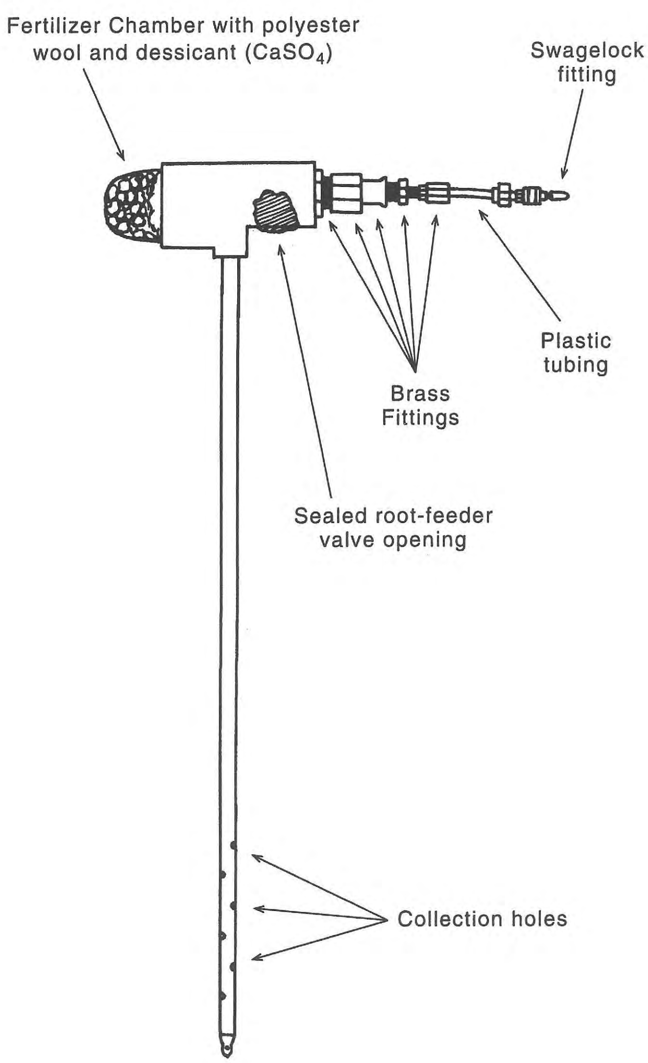

Figure 3. *Soil-gas probe modified from Ross Root Feeder Model 102 manufactured by Ross Daniels, Inc.*

DATA AND DISCUSSION

Characteristic geologic factors which influence indoor-radon levels (uranium concentration, ground-water depth, and soil permeability) were used to classify the relative hazard potential of the lower Weber River area, Tooele Valley, and southeastern Cache 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.

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.

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 between 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 and other radiometric data in the three study areas are statistically summarized in tables 2a-c. Radiometric data for each sample location in the study areas are listed in the appendix.

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

Table 2a. Statistical summary of radiometric data for the Weber River area.						
	Total Counts (ppm)	**K %**	**eU (ppm)**	**eTh (ppm)**	**eU/eTh**	**Soil-Gas Rn (pCi/L)**
Number of samples	159	159	159	159	159	90
Mean	11.0	1.4	2.5	9.2	0.30	280
Variance	21.4	0.3	0.9	26.1	0.01	89,949
Standard deviation	4.6	0.6	0.9	5.1	0.10	300
Skewness	139.1	0.2	0.6	245.2	0.00	96,000,000
Minimum	5.6	0.6	0.9	3.4	0.09	18
Median	9.5	1.3	2.3	7.3	0.30	196
Maximum	28.8	3.3	5.0	33.9	0.74	2,144

K = Potassium-40 *eU = equivalent Uranium-238*
eTh = equivalent Thorium-232 *Rn = Radon-222*
ppm = parts per million *pCi/L = picocuries per liter (1 pCi/l = 37 Bq/m³)*

Table 2b. Statistical summary of radiometric data for Tooele Valley.						
	Total Counts (ppm)	**K %**	**eU (ppm)**	**eTh (ppm)**	**eU/eTh**	**Soil-Gas Rn (pCi/L)**
Number of samples	211	211	211	211	211	112
Mean	10.1	1.5	2.2	7.7	0.30	220
Variance	6.8	0.2	0.4	6.8	0.03	21,758
Standard deviation	2.6	0.4	0.6	2.6	0.16	148
Skewness	0.1	0.0	0.2	3.3	0.01	5,700,000
Minimum	4.2	0.4	0.9	2.3	0.09	25
Median	9.8	1.5	2.2	7.5	0.28	176
Maximum	15.2	2.6	5.1	13.6	1.47	844

K = Potassium-40 *eU = equivalent Uranium-238*
eTh = equivalent Thorium-232 *Rn = Radon-222*
ppm = parts per million *pCi/L = picocuries per liter (1 pCi/l = 37 Bq/m³)*

Table 2c. Statistical summary of radiometric data for southeastern Cache Valley.						
	Total Counts (ppm)	**K %**	**eU (ppm)**	**eTh (ppm)**	**eU/eTh**	**Soil-Gas Rn (pCi/L)**
Number of samples	212	212	212	212	212	100
Mean	8.0	1.2	2.1	5.9	0.40	421
Variance	7.2	0.2	0.4	5.8	0.03	117,957
Standard deviation	2.7	0.4	0.6	2.4	0.18	343
Skewness	9.8	0.1	0.1	8.5	0.01	78,561,373
Minimum	3.5	0.3	0.8	1.6	0.12	42
Median	7.8	1.1	2.1	5.4	0.36	277
Maximum	14.9	2.7	3.9	12.6	1.30	1,864

K = Potassium-40 *eU = equivalent Uranium-238*
eTh = equivalent Thorium-232 *Rn = Radon-222*
ppm = parts per million *pCi/L = picocuries per liter (1 pCi/l = 37 Bq/m³)*

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) do 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).

Soil permeability also 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 the lower Weber River area (Erickson and Wilson, 1968), Tooele Valley (SCS, unpublished data), and southeastern Cache Valley (Erickson and Mortensen, 1974), and 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 x 10^{-5} cm/sec) to greater than 6.0 inches/hour (4.2 x 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 x 10^{-4} cm/sec), (2) moderately permeable soils, which have hydraulic conductivities ranging from 0.6 to 6.0 inches hour (4.2 x 10^{-4} to 4.2 x 10^{-3} cm/sec), and (3) highly permeable soils, which have hydraulic conductivities greater than 6.0 inches/hour (4.2 x 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.

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). However, some areas were not mapped due to a lack of data. Hill Air Force Base and Tooele Army Depot are unmapped because lack of access prohibited collection of radiometric data. Other unmapped areas lack soil-permeability data. 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 con- tribute to indoor-radon hazards.

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.

Table 3.
Hazard-potential ratings of geologic factors which affect levels of indoor radon. 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 value of factors in each category. Probable average indoor-radon concentrations for all homes in each category are also shown, but concentrations 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

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. This method was used to contour soil-gas data in the lower Weber River area and Tooele Valley, but was not needed in the southeastern Cache Valley because soil-gas measurements showed more consistent variations.

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). Average indoor-radon levels measured in the lower Weber River area, Tooele Valley, and southeastern Cache Valley by Sprinkel and Solomon (1990), Solomon and others (1993), and the UDRC (unpublished data) are within the range of expected values, but individual levels vary in each category (table 5).

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 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 hydrothermal activity in the lower Weber River area, Tooele Valley, and southeastern Cache Valley appears low (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 Wasatch fault zone at the base of the Wasatch Range in the Weber River area, the Oquirrh fault zone on the eastern side of Tooele Valley, and the East Cache fault zone on the eastern side of Cache Valley. 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 northwestern portion of the Weber River area, northern Tooele Valley, and central Cache Valley.

Table 5.
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. WR - Weber River area; TV - Tooele Valley; CV - southeastern Cache Valley. Measurements in unmapped areas or which could not be accurately located are not shown.

Hazard Area	Low			Moderate			High		
Study area	**WR**	**TV**	**CV**	**WR**	**TV**	**CV**	**WR**	**TV**	**CV**
Sample size	5	5	1	114	57	36	12	0	17
Minimum	0.7	1.5	2.2	0.0	0.2	0.7	0.9	—	2.8
Average	1.8	2.0	2.2	1.5	2.3	5.2	10.6	—	7.0
Maximum	2.6	2.5	2.2	15.0	8.0	23.6	68.2	—	14.3
% ≥4 pCi/L	0	0	0	4	23	53	50	¤	76
% of Total	5	8	2	86	92	67	9	0	31

Lower Weber River Area

The lower Weber River area is in Davis and Weber Counties, and extends roughly 9 miles (14 km) west from the Wasatch Range front and north from roughly Farmington to Ogden (figure 4). This area includes the communities of Clearfield, East Layton, Kaysville, Ogden, Riverdale, Roy, South Ogden, South Weber, Sunset, Uintah, and Washington Terrace. Total population of the Weber River area was approximately 96,500 in 1990, and is expected to be over 110,000 by the year 2000 (Utah Office of Planning and Budget, 1991).

Surficial geology of the lower Weber River area consists of unconsolidated deposits in the valley separated from bedrock in the Wasatch Range to the east by the active Wasatch fault zone. Unconsolidated deposits include latest Pleistocene to Holocene alluvial-fan deposits and Holocene stream alluvium, but are dominated by sediments deposited during various stages of latest Pleistocene Lake Bonneville (Nelson and Personius, 1993). The lake began to rise from levels close to those of the present Great Salt Lake about 28,000 years ago, reached its highest level (termed the Bonneville shoreline) between 16,400 and 15,000 years ago, and abruptly receded below the level of Great Salt Lake by about 13,000 years ago (Oviatt and others, 1992). Foothills underlain by Lake Bonneville sediments form broad terraces and linear hill-and-valley topography in the southern and eastern portions of the study area (figure 5). The Weber delta, a large plain of low surface relief formed by the Weber River during the waning stages of Lake Bonneville (Feth and others, 1966), is present in the north-central portion of the study area (figure 6). Bedrock units in the Wasatch Range include the Precambrian Farmington Canyon Complex, and the Cambrian Maxfield Limestone, Ophir Formation, and Tintic Quartzite (Bryant, 1984; Nelson and Personius, 1993).

Uranium Concentration

Uranium concentrations measured at 159 sample sites in the lower Weber River area range from 0.9 to 5.0 ppm; mean concentration is 2.5 ppm and the standard deviation is 0.9 (table 2a). Distribution of eU concentrations is approximately lognormal (figure 7) and has a positive skewness of 0.6. Median concentration is 2.3 ppm (table 2a).

The highest uranium concentrations are in alluvial fans deposited by streams issuing from the Wasatch Range (figure 8). The Precambrian Farmington Canyon Complex crops out nearby, and is a potential bedrock source of uranium to locally derived alluvial deposits. The Farmington Canyon Complex consists of gneiss, schist, and metamorphosed silicic igneous rocks (granite, pegmatite, and quartz monzonite) (Mullens and Laraway, 1973). Although there has been no economic production of uranium from the Farmington Canyon Complex, rock assays of mineralized deposits in this unit have a mean concentration of 12 ppm U_3O_8 (Madson and Reinhart, 1982). The mean eU concentration of the unit in the Ogden 1^{o} x 2^{o} quadrangle, determined by an aerial radiometric survey, is 3.1 ppm; this is well above the average eU concentration of all geologic material in the quadrangle, which is 2.2 ppm (EG&G Geometrics, 1979).

Locally high uranium concentrations in the Weber River floodplain near Uintah (figure 8) may result from preferential leaching of uranium from the Farmington Canyon Complex. Several factors influence the mobility and concentration of uranium leached from rock or sediment: (1) uranium content of the source material; (2) proximity of water to the uranium source; (3) the degree of isolation of solutions from fresher surface or ground waters; and (4) other factors such as climatic effects, the pH and oxidation state of the water, the presence of agents which can increase the solubility of uranium, and the presence of sorptive material such as organic matter and clays (Durrance, 1986). The Farmington Canyon Complex has a high uranium content and crops out in ground-water recharge areas along the range front. Uranium in this unit could be leached by ground water and transported into the Weber River hydrologic regime, where a combination of factors cause it to be deposited.

Lowest uranium concentrations are in bluffs along the modern floodplain of the Weber River (figure 8). These areas are underlain by sediment transported to the Weber delta of Lake Bonneville by longshore currents and inflow from the Weber River, and by younger alluvium deposited in the Weber River floodplain since the lake receded (Davis, 1985; Nelson and Personius, 1993). Uranium-deficient stratigraphic units are common along the Lake Bonneville shoreline and in the Weber River drainage area to the east. However, sediment in the lower Weber River area could come from a variety of sources, due to complex sedimentation patterns (such as longshore transport). Analysis and explanation of these sedimentation patterns is beyond the scope of this study.

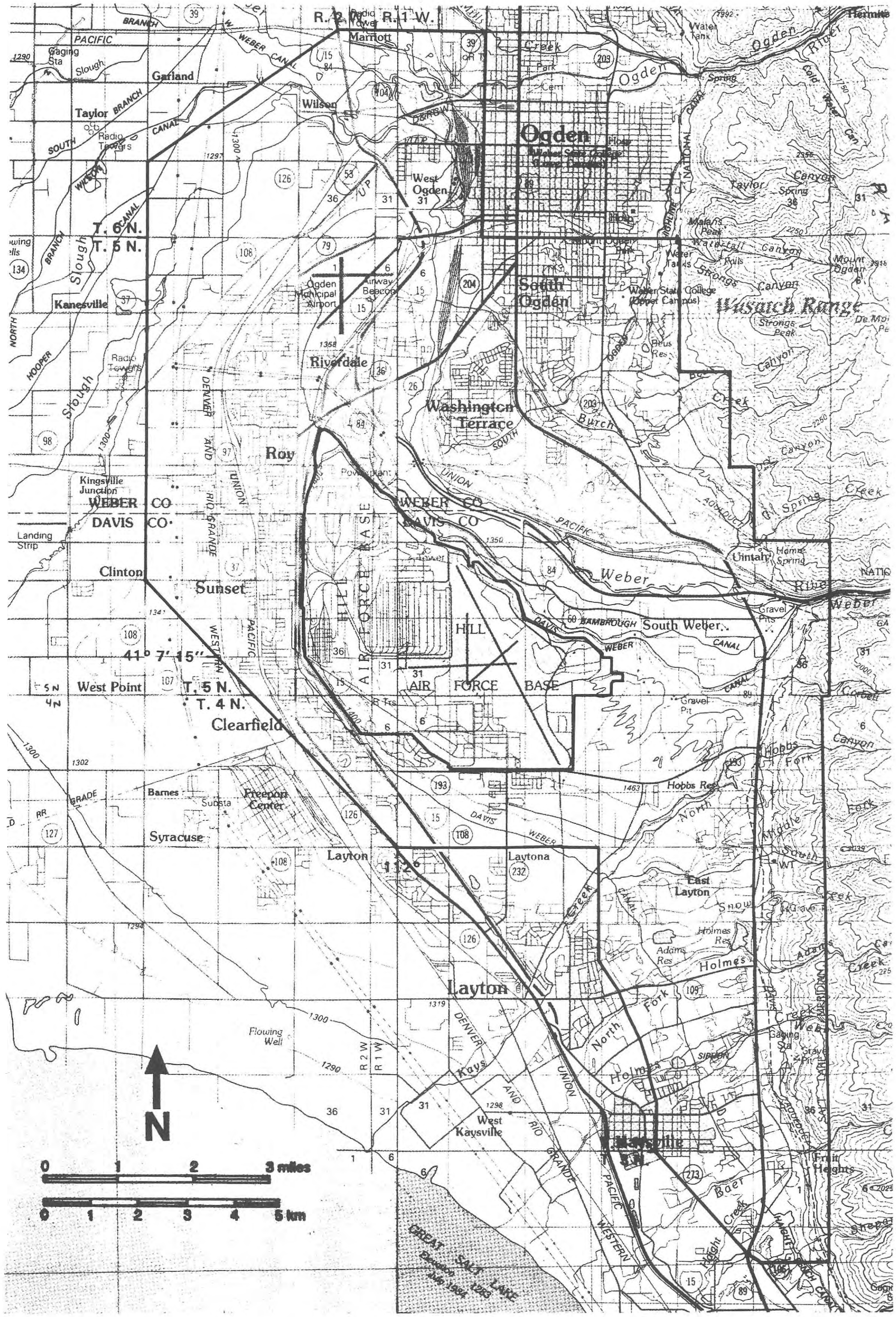

Figure 4. *Lower Weber River study area. Base map from Ogden and Promontory Point U.S. Geological Survey 30 x 60 minute topographic quadrangles. Contour interval is 20 meters (66 ft) and 50 meters (164 ft).*

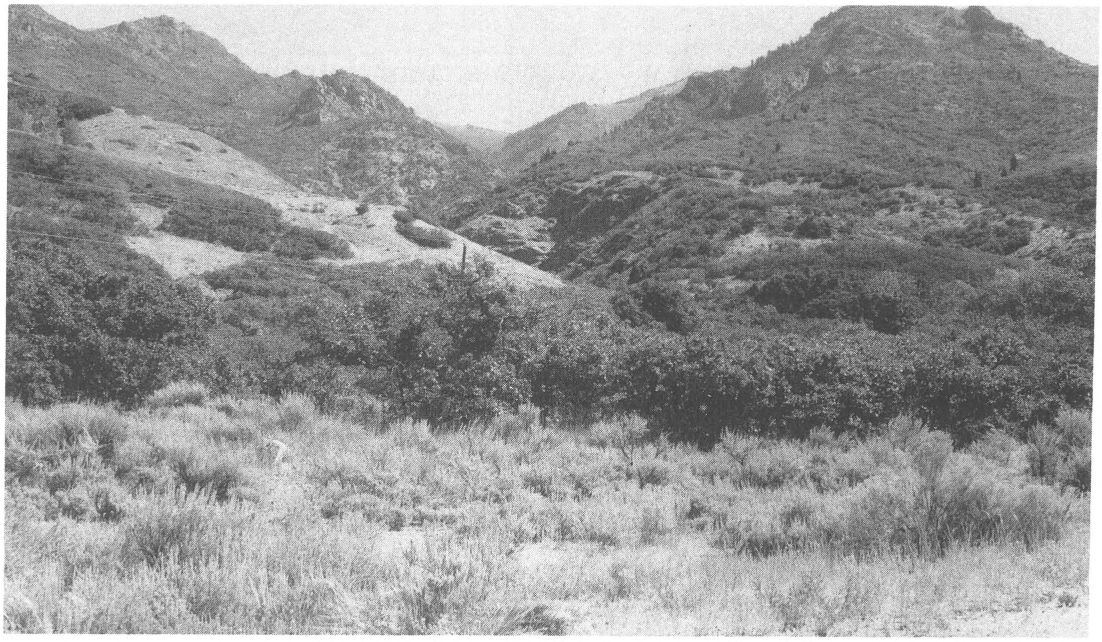

Figure 5. *East view of foothills along the western side of the Wasatch Range in the lower Weber River area.*

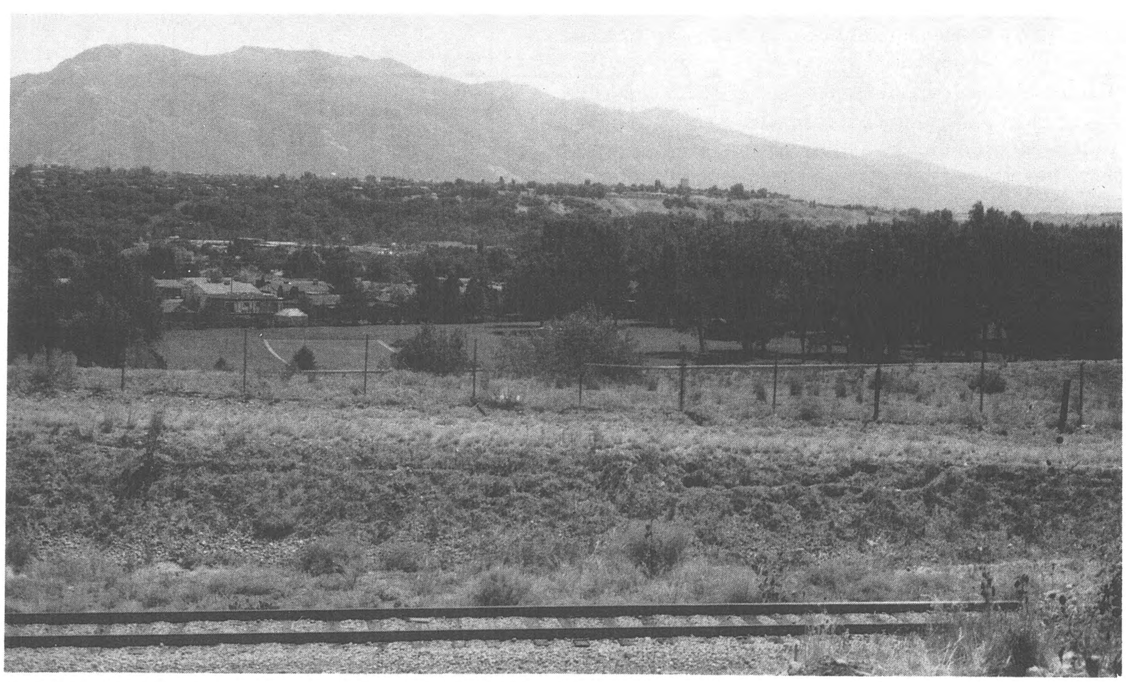

Figure 6. *Southeast view of the Weber delta in Weber County, Utah.*

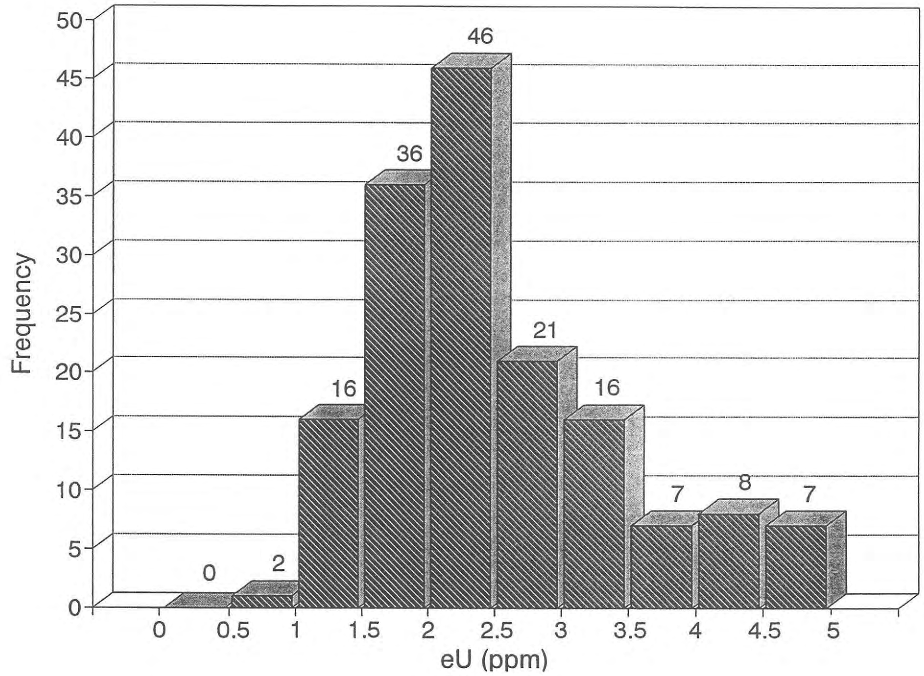

Figure 7. *Histogram of uranium concentrations in the lower Weber River area.*

Ground-Water Depth

Ground water in the lower Weber River area is in unconsolidated sediments that grade westward from coarse-grained deltaic, alluvial-fan, and slope-wash deposits to fine-grained lake deposits (Clark and others, 1990). Ground water is under both confined (artesian) and unconfined (water table and perched) conditions.

Feth and others (1966) delineate two major confined aquifers in the lower Weber River area: (1) the Delta aquifer, which is 500 to 700 feet (152-213 m) below the surface and from 50 to 150 feet (15-46 m) thick; and (2) the Sunset aquifer, which is 250 to 400 feet (76-122 m) below the surface and from 50 to 250 feet (15-76 m) thick. Water in these aquifers generally does not affect radon migration because it is deeper than 30 feet (9 m).

An unconfined aquifer is found locally in the Weber delta and along the front of the Wasatch Range (Bolke and Waddell, 1972). Unconfined ground-water levels were mapped in Davis County (Anderson and others, 1994) and Weber County (unpublished data compiled by Loren Anderson, Department of Civil and Environmental Engineering, Utah State University) 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 the Weber River floodplain, terraces around South Ogden, low-lying areas around the Weber delta, and the southeastern part of the study area in drainages issuing from the Wasatch Range (figure 9). Unconfined ground water is deeper than 30 feet (9 m) primarily in localized areas of the Weber delta.

Soil Permeability

Soil permeability in the lower Weber River area is generally moderate to high. Highly permeable soils are commonly coarse-grained deposits of eolian sand, lacustrine sand and gravel, and stream and fan alluvium (Erickson and Wilson, 1968). These soils are generally found along the Wasatch Range front and in the Weber River floodplain (figure 10). Soils having low permeability are fine-grained deposits of reworked lacustrine silt and clay that commonly have an indurated hardpan ranging up to 40 inches (102 cm) thick (Erickson and Wilson, 1968). These soils are found in low-lying areas of the northwestern portion of the study area (figure 10).

Hazard Potential

The radon-hazard potential of the lower Weber River area is generally highest in benches along the Wasatch Range front, and decreases to the west as distance from the mountains increases (plate 1A). The hazard potential is high in benches underlain by well-drained and highly permeable Lake Bonneville shoreline sand and gravel having moderate uranium concentrations, and post-lake alluvial-fan deposits having high uranium concentrations. The hazard potential is moderate west of the benches on the Weber delta underlain by deposits that have lower uranium concentrations. However, local uranium concentrations in the Weber delta are sufficiently high to result in a high-hazard potential in several scattered areas where ground water is deep and soils are highly permeable (plate 1A). The hazard potential of the Weber River floodplain, incised into the Weber delta, is also moderate. However, the hazard potential of the floodplain is locally high where soils are highly permeable and uranium levels are elevated near South Weber, and low where uranium levels are low and ground water is shallow near Washington Terrace and West Ogden (plate 1A). The hazard potential is commonly low in low-lying areas on the margin of the Weber delta, where fine-grained soils derived from Lake Bonneville

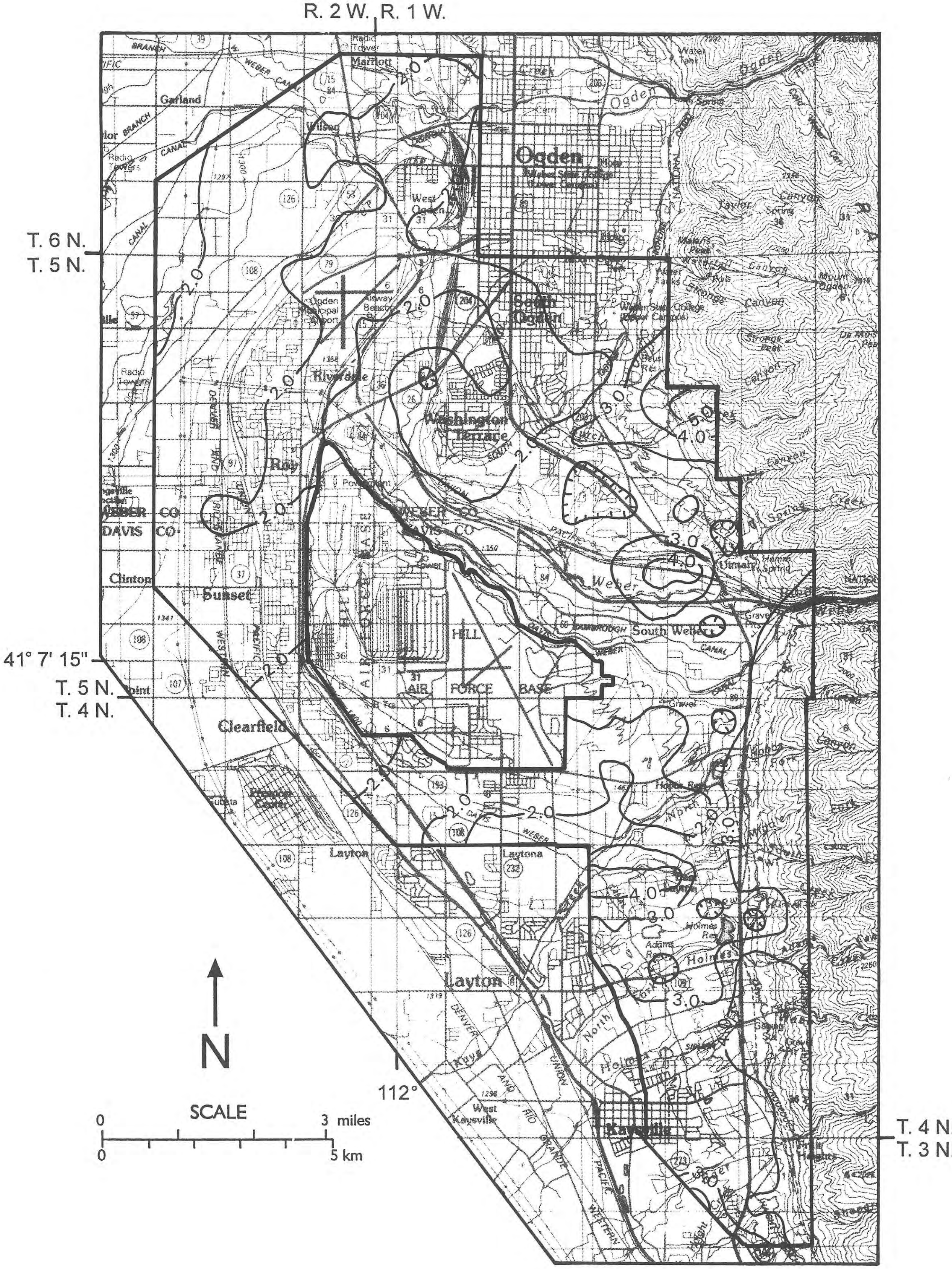

Figure 8. Contour map of uranium (eU) concentrations in the lower Weber River area. Contour interval is 1 ppm.

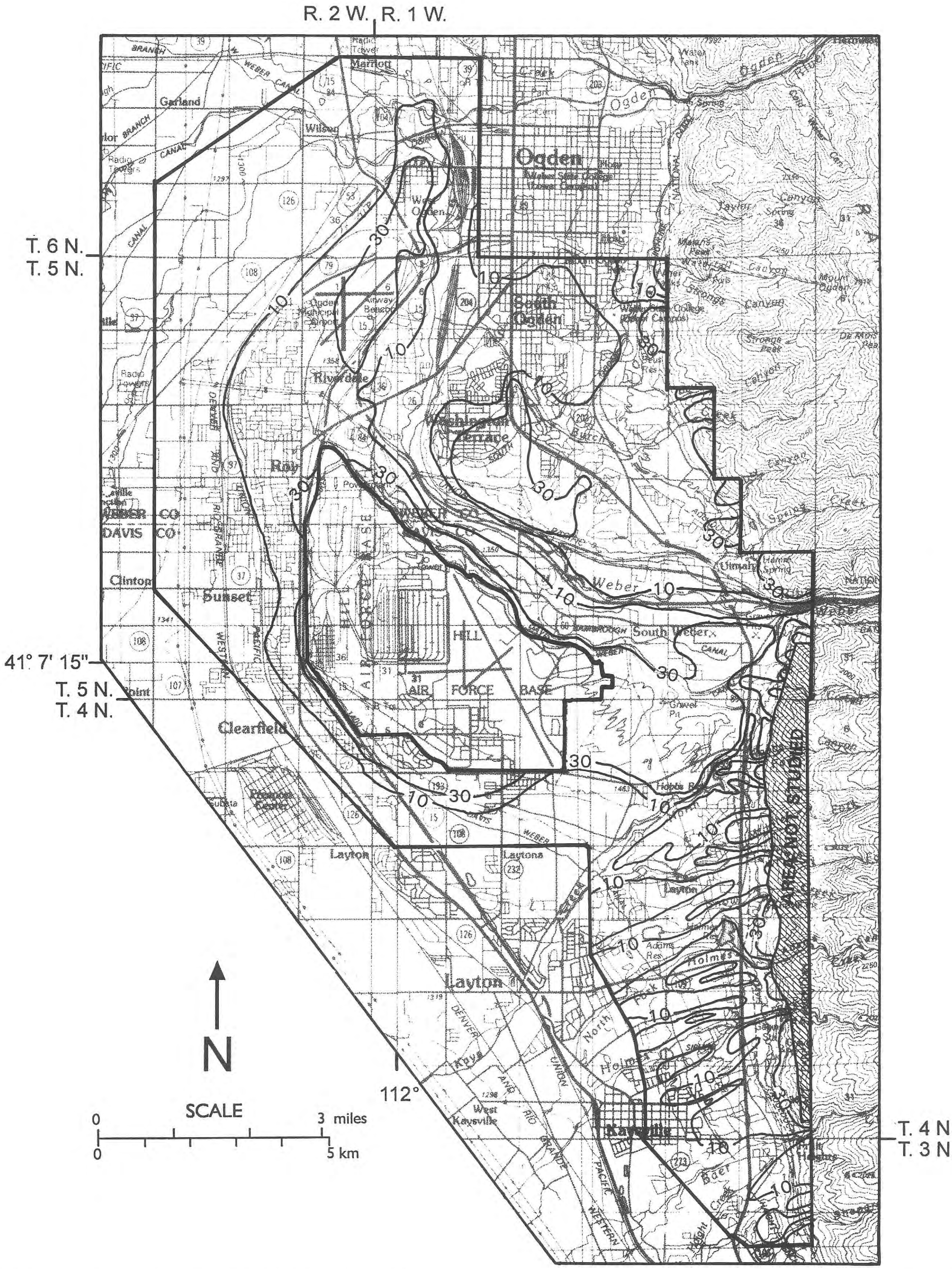

Figure 9. Depth to shallow ground water in the lower Weber River area (modified from Anderson and others, 1994, and Anderson, unpublished data). Contours show depths of 10 feet (3 m) and 30 feet (9 m).

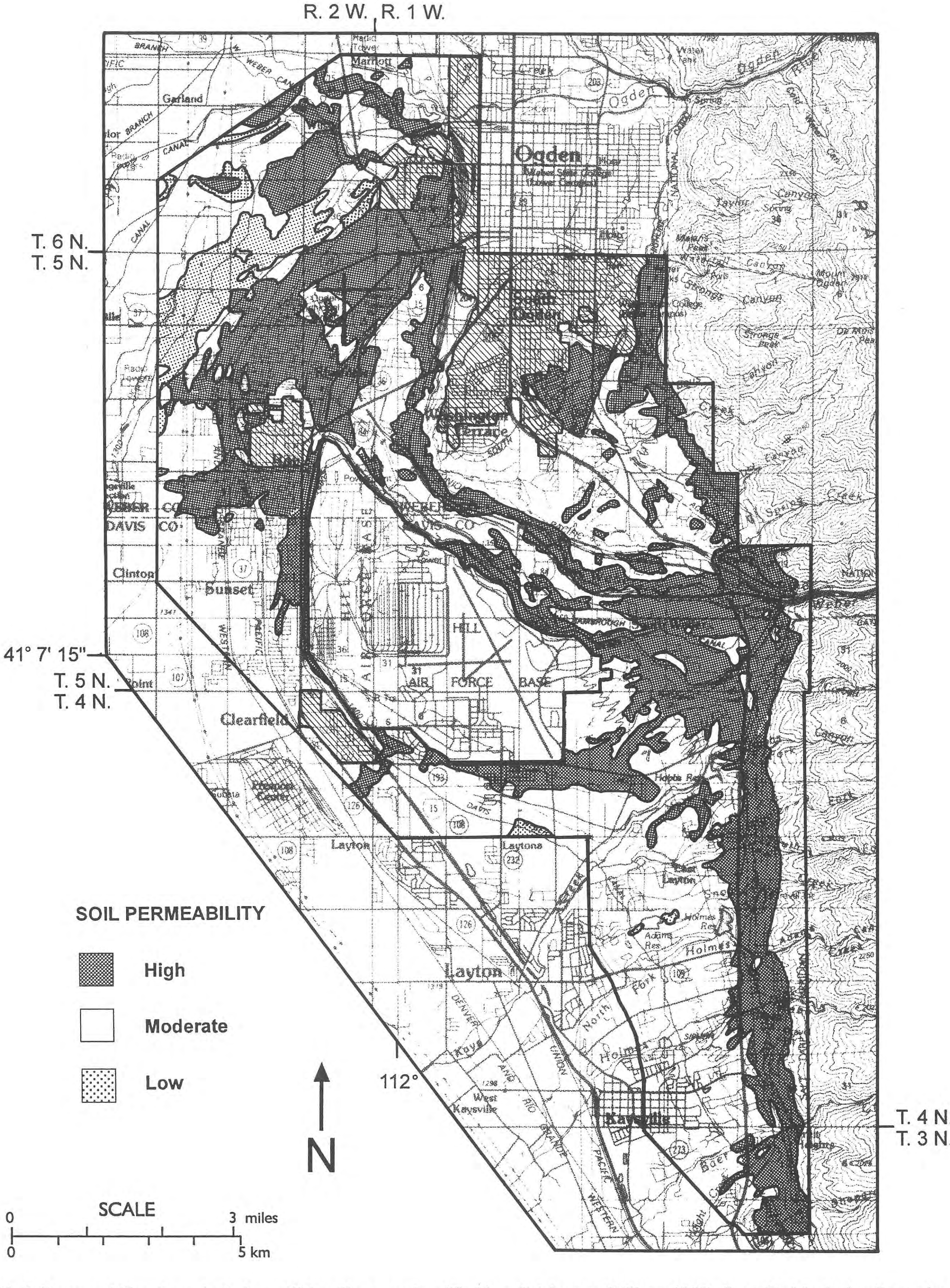

Figure 10. Soil-permeability classes in the lower Weber River area (modified from Erickson and Wilson, 1968). See table 3 for hydraulic conductivities associated with each class.

offshore deposits are impermeable and ground water is shallow. These low-lying areas are in the northwestern part of the study area, and in the southwestern part near Clearfield and Layton (plate 1A).

Soil-Gas Radon

Soil-gas-radon concentrations measured at 90 sample sites in the lower Weber River area ranges from 18 to 2,144 pCi/L (6.66×10^2-7.93×10^4 Bq/m^3); mean concentration is 280 pCi/L (1.04×10^4 Bq/m^3) and the standard deviation is 300 (table 2a). Distribution of soil-gas data is lognormal (figure 11) and has a positive skewness of 9.6×10^7. Median concentration is 196 pCi/L (7.25×10^3 Bq/m^3) (table 2a).

Soil-gas radon does not correspond well to the hazard potential. Highest soil-gas levels are in the southwestern part of the study area, near Clearfield, Layton, and South Weber (figure 12). Soils in this area are Lake Bonneville sand and silt on the Weber delta, and post-Lake Bonneville alluvium in the Weber River floodplain. Although soil-gas levels of the delta and floodplain are high, the hazard potential is moderate. Lowest soil-gas levels are in the eastern part of the study area along the Wasatch Range front, and in the northwestern part of the study area north and west of West Ogden. Soils along the range front are coarse-grained Lake Bonneville shoreline deposits and post-lake alluvial-fan deposits; soils in the northwestern part of the study area are fine-grained, clay-rich Lake Bonneville offshore deposits (figure 12). The hazard potential of the range front is commonly high, and is low to moderate in the northwestern part of the study area.

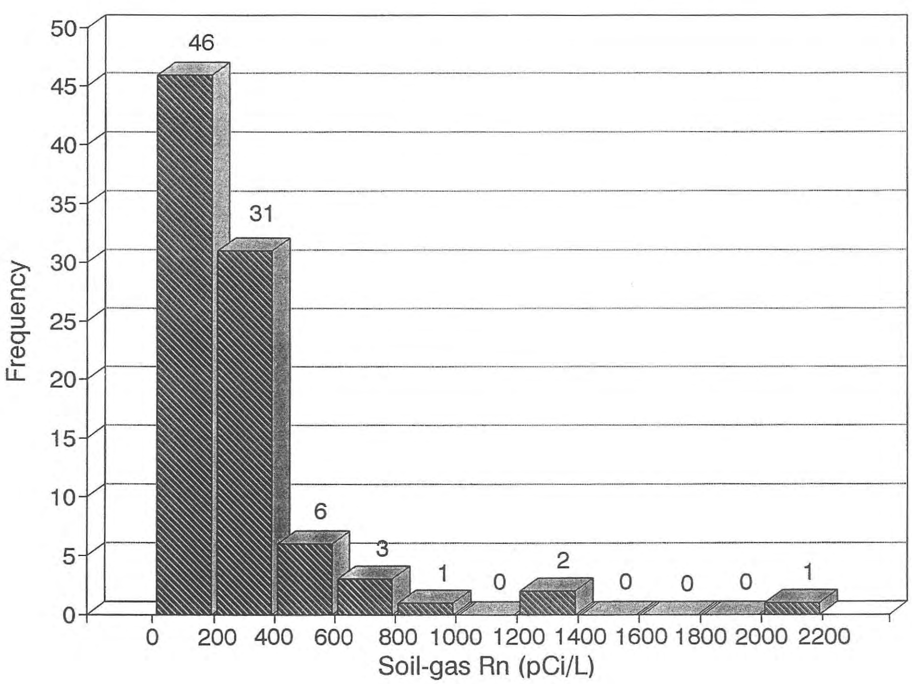

Figure 11. *Histogram of soil-gas-radon concentrations in the lower Weber River area.*

Several factors contribute to the lack of correlation between soil-gas radon and hazard potential, but contamination of soil-gas samples by atmospheric air is of particular significance. Gravelly deposits, such as those commonly found in the lower Weber River area, are difficult to sample without atmospheric contamination because the gravel prevents a good seal between the soil and the outer probe wall. This contamination is suggested by the scatter plot of uranium and soil-gas concentrations from samples measured at the same site (figure 13). Uranium concentrations of data pairs vary widely from 1 to 5 ppm, but most soil-gas concentrations are clustered in a narrow range between 0 and 500 pCi/L (0 and 1.85×10^3 Bq/m^3). If contamination were not significant, radon concentrations should increase as uranium concentration increases.

Linear regression of uranium-radon data pairs in the lower Weber River area shows they are related by the formula:

$$Rn = 270.2 + 3.7eU$$

where Rn is the soil-gas concentration in pCi/L, and eU is the uranium concentration in ppm. At the 90 percent confidence level for 90 samples, the Spearman correlation coefficient of 0.172 exceeds the threshold value of 0.136, indicating that the regression correlation is statistically significant. Although average soil-gas concentrations determined by this formula at low uranium levels compare favorably to those derived from other studies in Utah (Solomon and others, 1993), the lack of a corresponding increase in soil-gas concentrations at high uranium levels results in a poorer correlation than in most other areas (Solomon, 1995, 1996; Solomon and others, 1991, 1994). In the lower Weber River area, high uranium concentrations are common in gravelly lacustrine-shoreline and alluvial-fan deposits along the mountain front that are difficult to sample without atmospheric contamination.

Indoor Radon

Mean concentration of 169 indoor-radon samples measured in the lower Weber River area is 2.1 pCi/L (78 Bq/m^3); 6.5 percent are greater than or equal to 4 pCi/L (148 Bq/m^3) (table 6). Ten of 11 elevated indoor-radon levels (greater than or equal to 4 pCi/L [148 Bq/m^3]) are in areas of moderate- and high-hazard potential (plate 1A); the remaining high measurement is in an area of no data. Five of these measurements, including the highest value of 68.2 pCi/L (2,523 Bq/m^3) near Uintah (plate 1A), are in areas of high-hazard potential (table 5). Thirty-one indoor-radon levels from 2 to 4 pCi/L (74-148 Bq/m^3) were also measured, most in areas of moderate-hazard potential (table 5). Measurements less than 2 pCi/L (74 Bq/m^3) are generally in areas of moderate- and low-hazard potential (table 5).

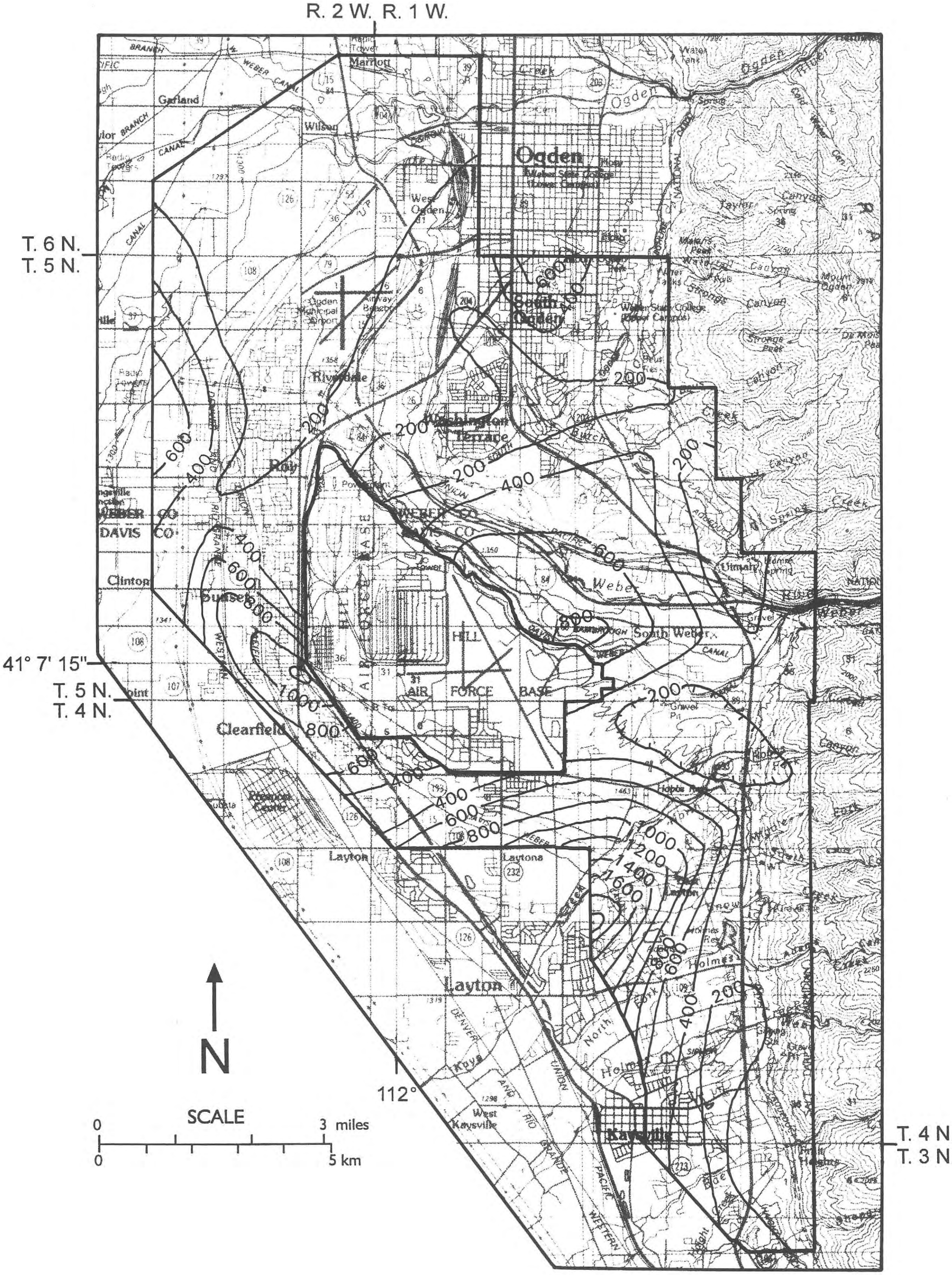

Figure 12. Exclusion isoline map of soil-gas-radon concentrations in the lower Weber River area. Contour interval is 200 pCi/L (7.4 x 10^3 Bq/m^3).

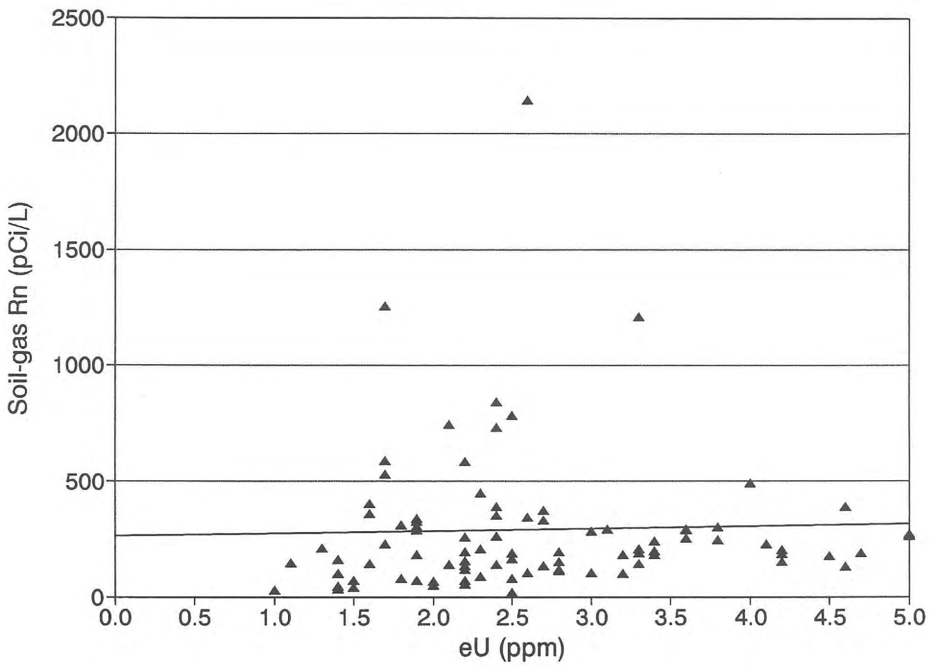

***Figure 13.** Scatter plot and linear regression of uranium (eU) and soil-gas-radon (Rn) data pairs in the lower Weber River area.*

Table 6.
Summary of indoor-radon measurements in the Weber River area.

Indoor-Radon Level (pCi/L)	Number of Measurements	Percent of Total
≥20	1	0.6
10 - 20	3	1.8
4 - 10	7	4.1
2 - 4	31	18.3
<2	127	75.2
TOTAL	169	100

Tooele Valley

Tooele Valley is in eastern Tooele County, extending north from South Mountain to Great Salt Lake and west from the Oquirrh Mountains to the Stansbury Mountains (figure 14). The valley includes the communities of Erda, Grantsville, Mills Junction, and Tooele. Total population of Tooele Valley was approximately 24,500 in 1990 and is expected to remain roughly the same or increase slightly by the year 2000 (Utah Office of Planning and Budget, 1991).

Surficial geology of the area consists of unconsolidated deposits in the valley and bedrock in the adjacent mountains. The active Oquirrh fault zone bounds the eastern valley margin at the foot of the Oquirrh Mountains. Unconsolidated units include Pliocene to Pleistocene pre-Lake Bonneville alluvial-fan and terrace deposits on valley margins above the Bonneville shoreline, and post-lake alluvial, eolian, mass-wasting, playa, and spring deposits on the valley floor. Valley sediments are dominated by latest Pleistocene Lake Bonneville deposits (Solomon, 1993; figure 15). Bedrock units in the mountains surrounding Tooele Valley are Cambrian to Tertiary in age, and include: (1) the Cambrian Tintic Quartzite, (2) the Mississippian Great Blue Limestone, (3) the Pennsylvanian to Permian Oquirrh Formation, and (4) Tertiary andesite, dacite, and quartz-latite flows and breccias (Moore and Sorensen, 1979; Stokes, 1986).

Uranium Concentration

Uranium concentrations measured at 211 sample sites in Tooele Valley range from 0.9 to 5.1 ppm; mean concentration is 2.2 ppm and the standard deviation is 0.6 (table 2b). Distribution of eU concentrations is approximately lognormal (figure 16) and has a positive skewness of 0.2. Median concentration is 2.2 ppm (table 2b).

Highest uranium concentrations are in lacustrine sediments comprised of silt and clay, wind-blown deposits derived from lake-bed remnants, and older, inactive alluvial fans above the Bonneville shoreline. The highest measured value of 5.1 ppm is east of Grantsville in the north-central part of the valley (figure 17). The source of uranium for these deposits is unclear, because uranium assays do not indicate a significant source potential for most rock in the mountains surrounding Tooele Valley (Black, 1993). However, a localized source of uranium may be Tertiary volcanic rock along the eastern side of the Stansbury Mountains and the northeastern side of South Mountain (Moore and Sorensen, 1979). Similar rocks are significant producers of uranium in other areas of Utah (Black, 1993; Solomon, 1996). More distant sources may include uranium-enriched rock or lacustrine sediment in the Bonneville basin; sediment from these sources could be transported to Tooele Valley by wind and Lake Bonneville currents. High uranium levels in lacustrine sediments may also result from adsorption of uranium in ground or surface water by clay and organic matter (Durrance, 1986).

Lowest uranium concentrations, including the lowest measured value of 0.9 ppm, are in Lake Bonneville shoreline gravel, post-lake alluvium, and undifferentiated lacustrine and alluvial sediments. These deposits are likely derived from uranium-deficient rock in the mountains surrounding Tooele Valley, and underlie Erda, Tooele, Grantsville, and areas in the eastern part of the valley (figure 17).

Ground-Water Depth

Ground water in Tooele Valley is in coarse-grained, unconsolidated alluvial-fan deposits and Lake Bonneville sediments, under both confined and unconfined conditions. Ground water

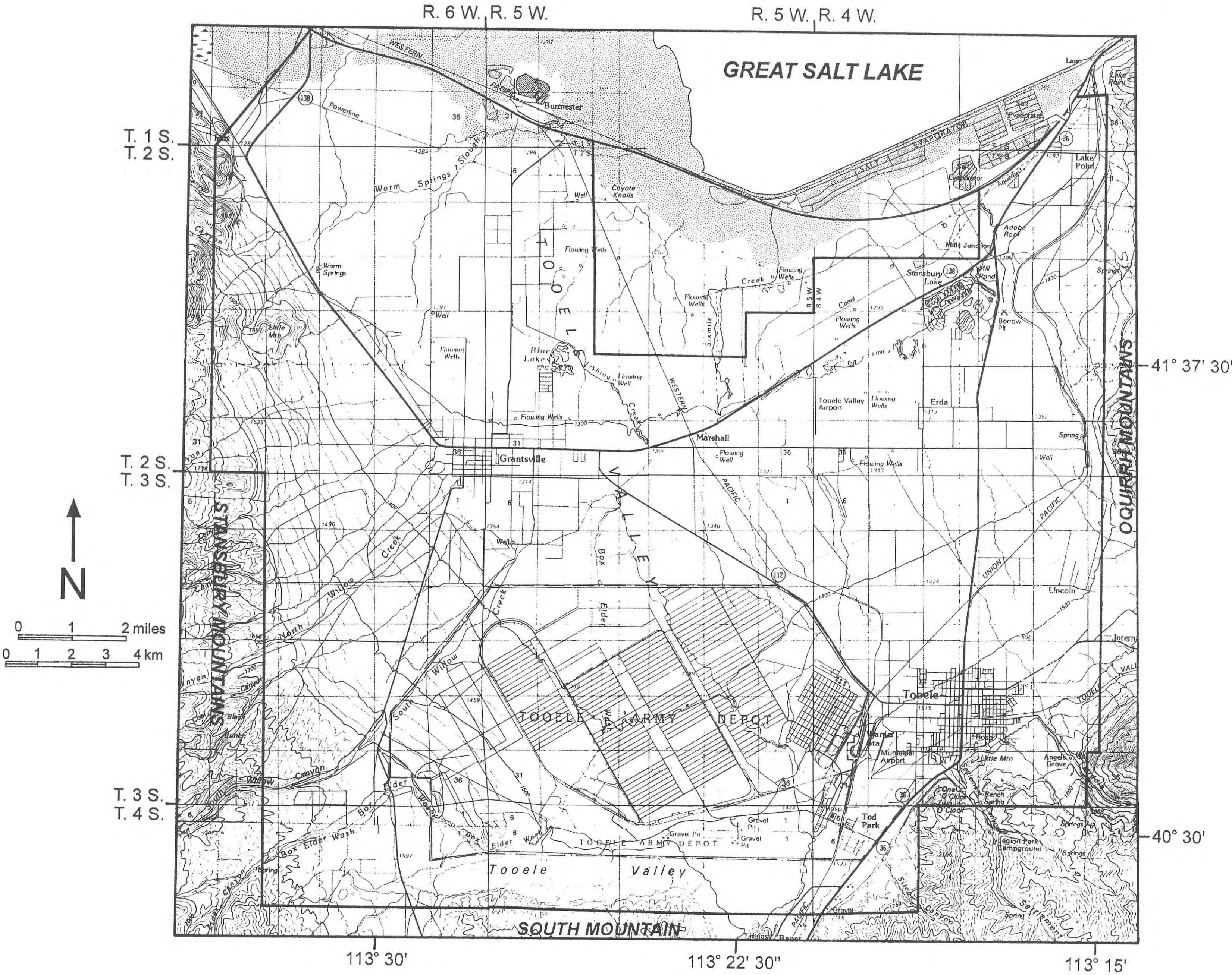

Figure 14. Tooele Valley study area. Base map from Tooele and Rush Valley U.S. Geological Survey 30 x 60 minute topographic quadrangles. Contour interval is 20 meters (66 ft) and 50 meters (164 ft).

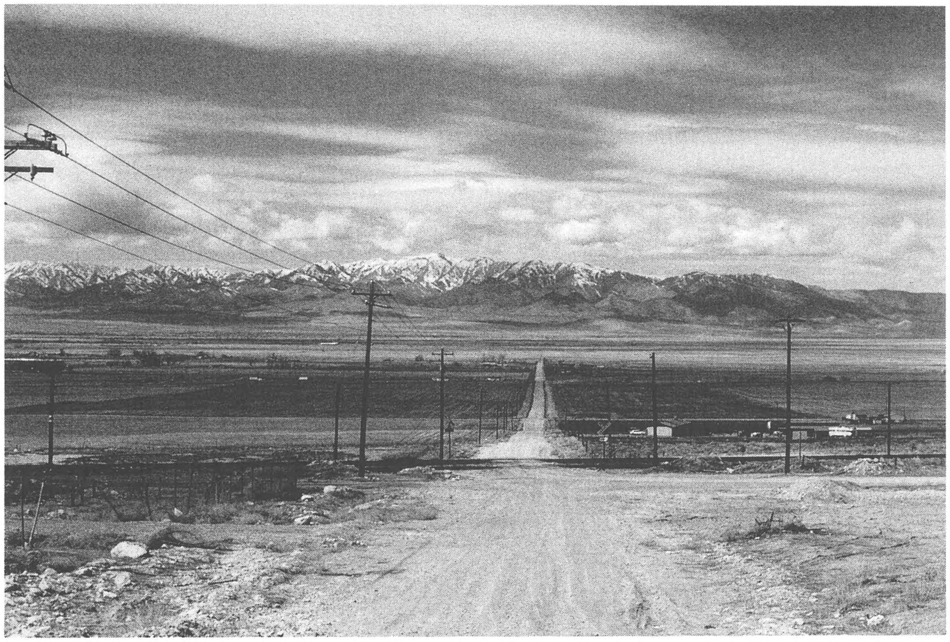

Figure 15. *West view of northern Tooele Valley.*

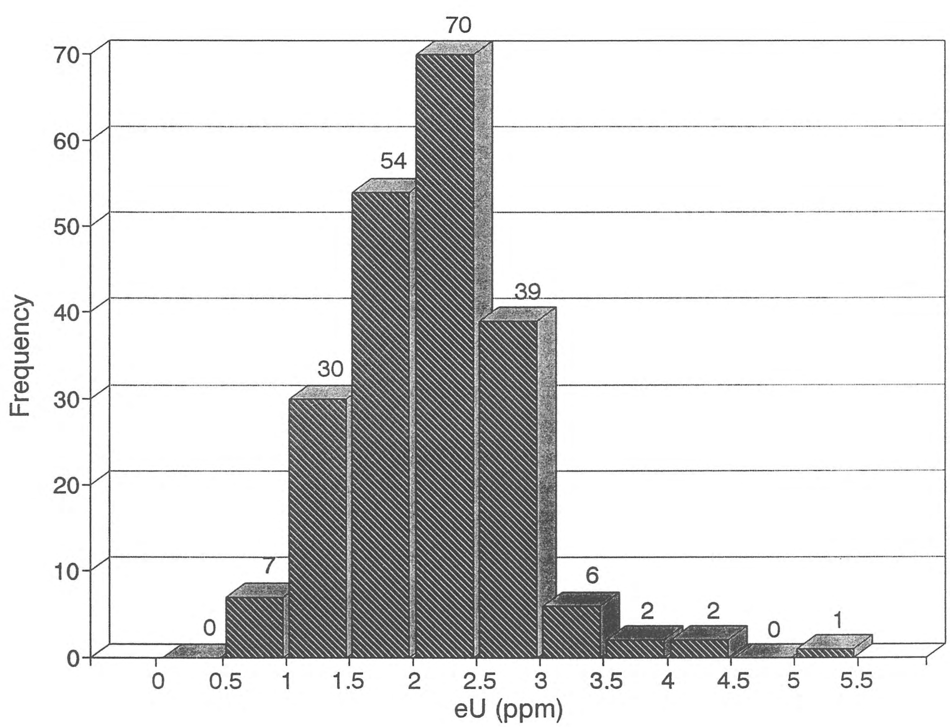

Figure 16. *Histogram of uranium concentrations in Tooele Valley.*

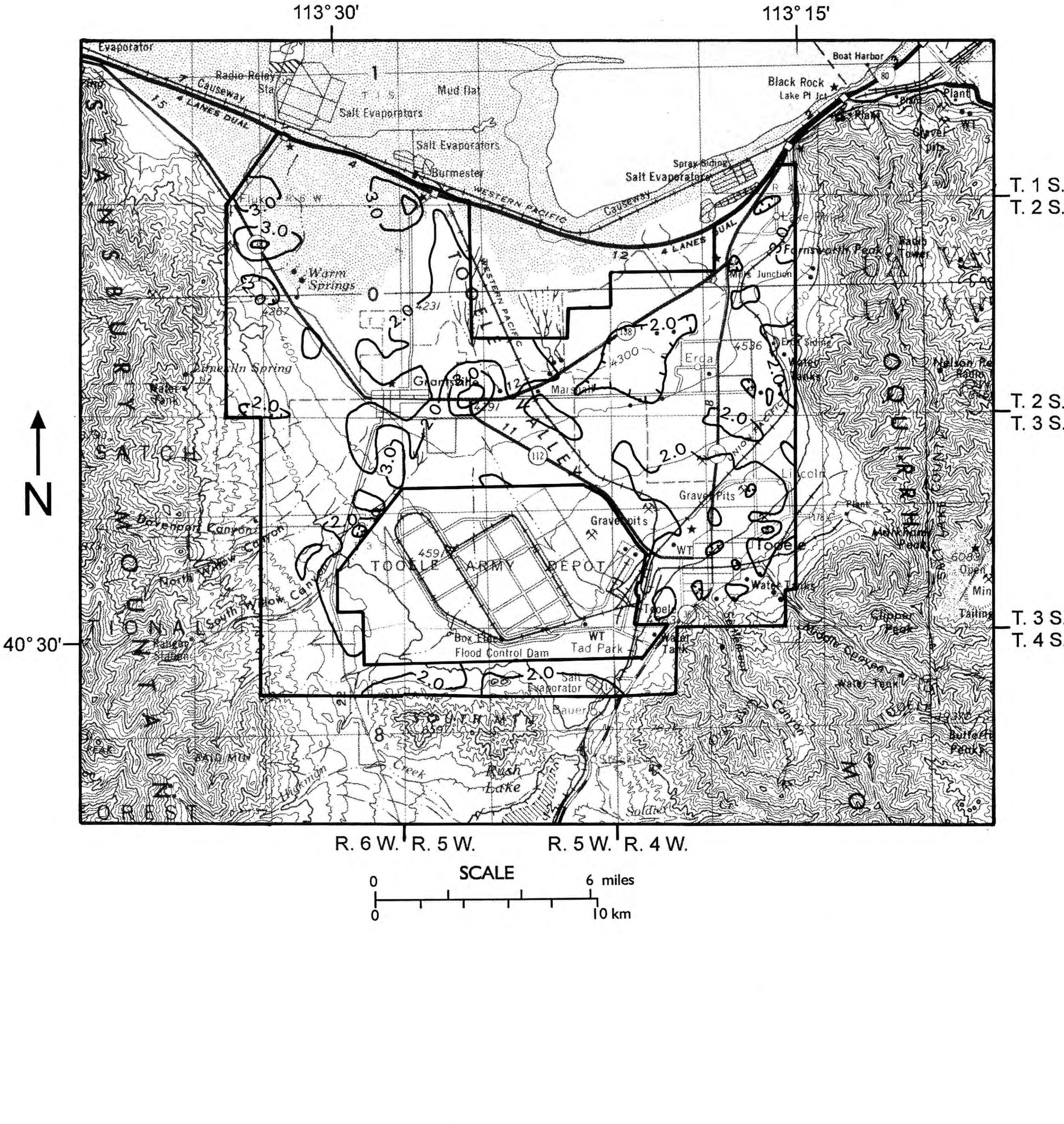

Figure 17. Contour map of uranium (eU) concentrations in Tooele Valley. Contour interval is 1 ppm.

under confined conditions is found central Tooele Valley. Early studies (Thomas, 1946; Gates, 1965) divided the artesian aquifer in Tooele Valley into districts based on hydrologic factors. However, the district boundaries are not barriers to ground-water movement and the aquifer in Tooele Valley is a single unit (Razem and Steiger, 1981). As in the lower Weber River area, water in the artesian aquifer generally does not affect radon migration because it is deeper than 30 feet (9 m). Ground water is unconfined near the mountains and above confined aquifers in the northern part of the valley (Razem and Steiger, 1981). Water-table aquifers near the mountains are several hundred feet deep and merge with artesian aquifers toward the center of the valley. A shallow water-table aquifer is present in the northern part of the valley, mainly recharged by upward leakage from underlying artesian aquifers (Razem and Steiger, 1981). Black (1995) shows ground water is commonly less than 10 feet (3 m) deep near the shoreline of Great Salt Lake, and more than 30 feet (9 m) deep in the southern half of the valley (figure 18).

Soil Permeability

Soil permeability in Tooele Valley is generally low to moderate (U.S. Soil Conservation Service, unpublished data), and lower overall than in the lower Weber River area. Highly permeable soils are not extensive and are found in only two areas in southeastern Tooele Valley (figure 19): (1) east of Tooele, associated with coarse tailings and slag from the inactive International Smelter, and (2) southwest of Tooele, underlain by lacustrine gravel. Moderate-permeability soils are common on benches and piedmont slopes along the Oquirrh and Stansbury Mountains (figure 19), and are generally associated with alluvial-fan deposits or lacustrine shoreline sand and gravel. Low-permeability soils are common in central and northern Tooele Valley (figure 19), and are generally associated with lacustrine lake-bottom silt and clay.

Hazard Potential

The radon-hazard potential of Tooele Valley is generally moderate, but is highest along the valley margins and decreases northward to Great Salt Lake (plate 1B). The hazard potential is locally high near the base of the Stansbury Mountains and the Oquirrh Mountains in well-drained, uranium-enriched Holocene alluvial-fan deposits. The hazard potential is commonly low in the northern portion of the valley underlain by poorly drained, fine-grained Pleistocene to Holocene lacustrine deposits. The hazard potential is moderate elsewhere in the valley where well-drained, unconsolidated valley fill having low to moderate uranium concentrations are found.

Soil-Gas Radon

Soil-gas radon measured at 112 sample sites in Tooele Valley ranges in concentration from 25 to 844 pCi/L (9.25×10^2-3.12×10^4 Bq/m^3); mean concentration is 220 pCi/L (8.14×10^3 Bq/m^3) and the standard deviation is 148 (table 2b). Distribution of soil-gas data is lognormal (figure 20) and has a positive skewness of 5.7×10^6. Median concentration is 176 pCi/L (6.51×10^3 Bq/m^3) (table 2b).

Soil-gas radon and hazard potential more closely correspond in Tooele Valley than in the lower Weber River area. Highest soil-gas levels in Tooele Valley are primarily in areas underlain by a thin veneer of Lake Bonneville sediment deposited on pre-lake alluvial fans (Solomon, 1993). Areas underlain by lacustrine deposits that have both high soil-gas levels and moderate to high hazard potential include those east of Mills Junction, where the highest soil-gas level of 844.4 pCi/L (3.12×10^4 Bq/m^3) was measured, east of Tooele, and south of Grantsville near the northern boundary of Tooele Army Depot (figure 21). Soil-gas levels are also high in smaller areas underlain by pre-Lake Bonneville alluvial-fan deposits along the northwestern side of South Mountain, eolian deposits north of Grantsville, and stream alluvium near the mouth of Middle Canyon east of Tooele (figure 21). These local areas of high soil-gas levels have a low to moderate hazard potential. Lowest soil-gas levels are common in areas underlain by clay-rich lake deposits, such as northern Tooele Valley, and on piedmont slopes of both the Oquirrh and Stansbury Mountains underlain by coarser lacustrine and alluvial-fan deposits (figure 21). The hazard potential in northern Tooele Valley is low.

Linear regression of uranium-radon data pairs in Tooele Valley (figure 22) shows they are related by the formula:

$$Rn = 94.7 + 58.2eU$$

At the 99 percent confidence level for 112 samples, the Spearman correlation coefficient of 0.339 exceeds the threshold value of 0.221, indicating that the regression correlation is statistically significant. The confidence level for the correlation is higher in Tooele Valley (99 percent) than in the lower Weber River area (90 percent). This suggests a more consistent relationship between eU and soil-gas radon in Tooele Valley, particularly for data pairs having higher eU concentrations, and implies that the effects of atmospheric contamination of soil-gas samples is less pronounced in Tooele Valley. This is consistent with the occurrence of higher eU concentrations in deposits that have generally finer grain size in Tooele Valley than in the lower Weber River area, and the potential for greater atmospheric contamination in coarse-grained deposits. Average soil-gas concentrations determined by the formula for Tooele Valley are slightly lower than the lower Weber River area for low eU concentration, but are increasingly higher for eU concentrations greater than about 3.5 ppm. The relation between eU and radon is comparable to those derived from other studies in Utah (Solomon, 1995, 1996; Solomon and others, 1991, 1994).

Indoor Radon

Mean concentration of 70 indoor-radon samples measured in Tooele Valley is 2.2 pCi/L (81 Bq/m^3); 18.6 percent are greater than or equal to 4 pCi/L (148 Bq/m^3) (table 7). Measurements are chiefly in areas of moderate-hazard potential (table 5). Most of the 13 elevated indoor-radon levels (greater than or equal to 4 pCi/L [148 Bq/m^3]), including the highest measured value of 8.0 pCi/L (296 Bq/m^3), were in a roughly 1 square mile (2.6 km^2) area in Tooele west of the mouth of Settlement Canyon (plate 1B). This area has a moderate-hazard potential due to the com-

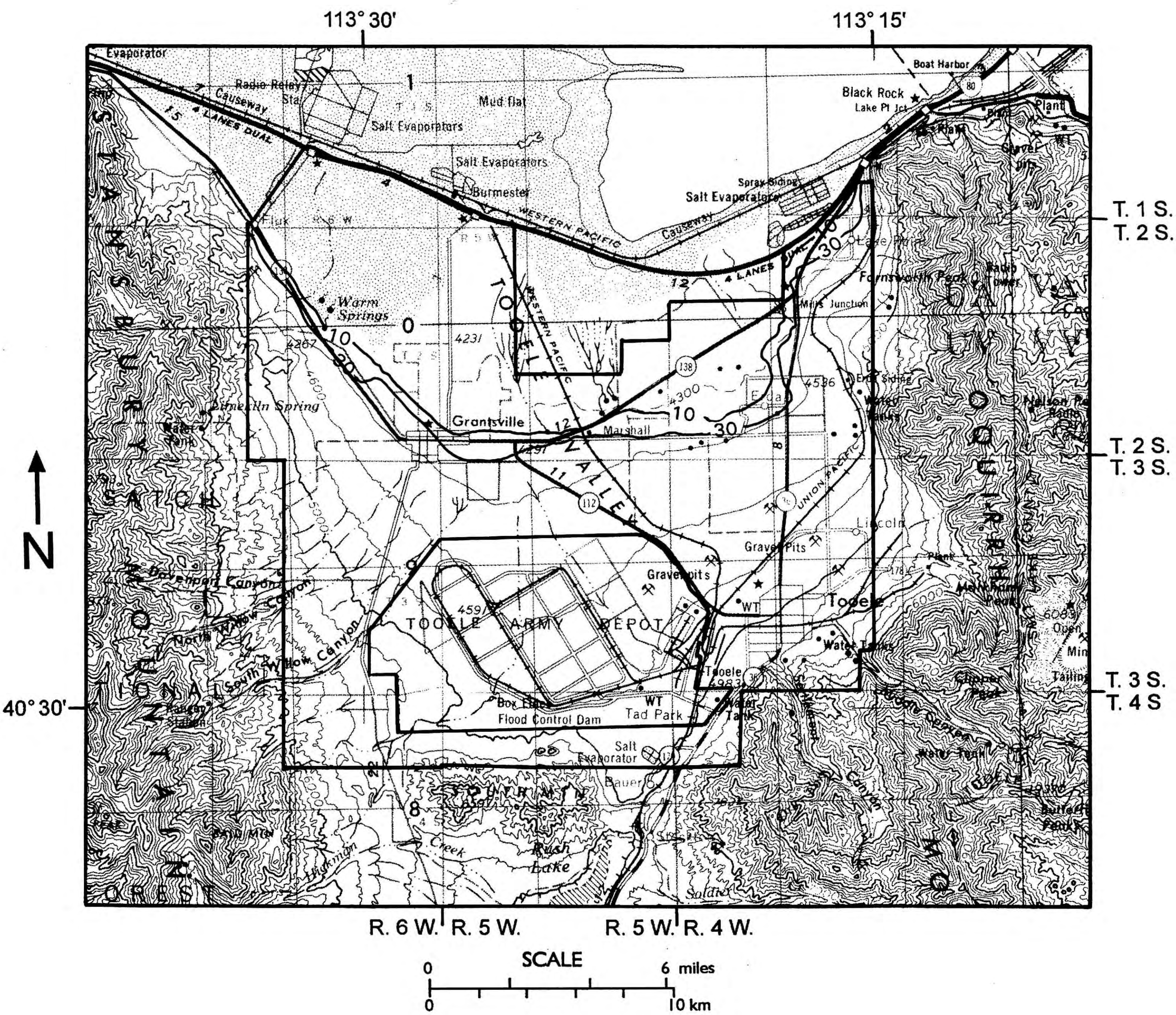

Figure 18. Depth to shallow ground water in Tooele Valley (modified from Black, 1995). Contours show depths of 10 feet (3 m) and 30 feet (9 m).

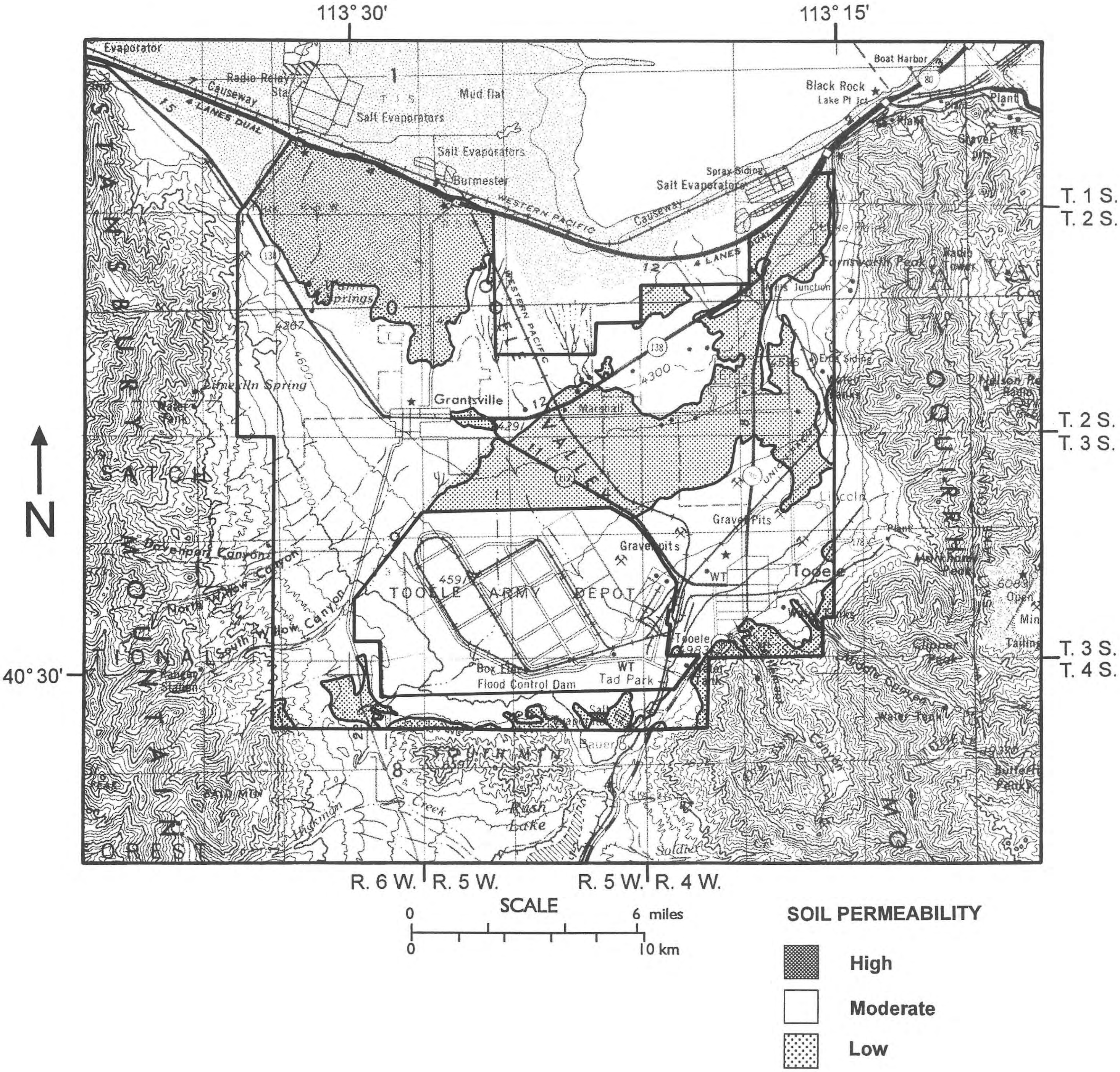

Figure 19. Soil-permeability classes in Tooele Valley (modified from U.S. Soil Conservation Service, unpublished data). See table 3 for hydraulic conductivities associated with each class.

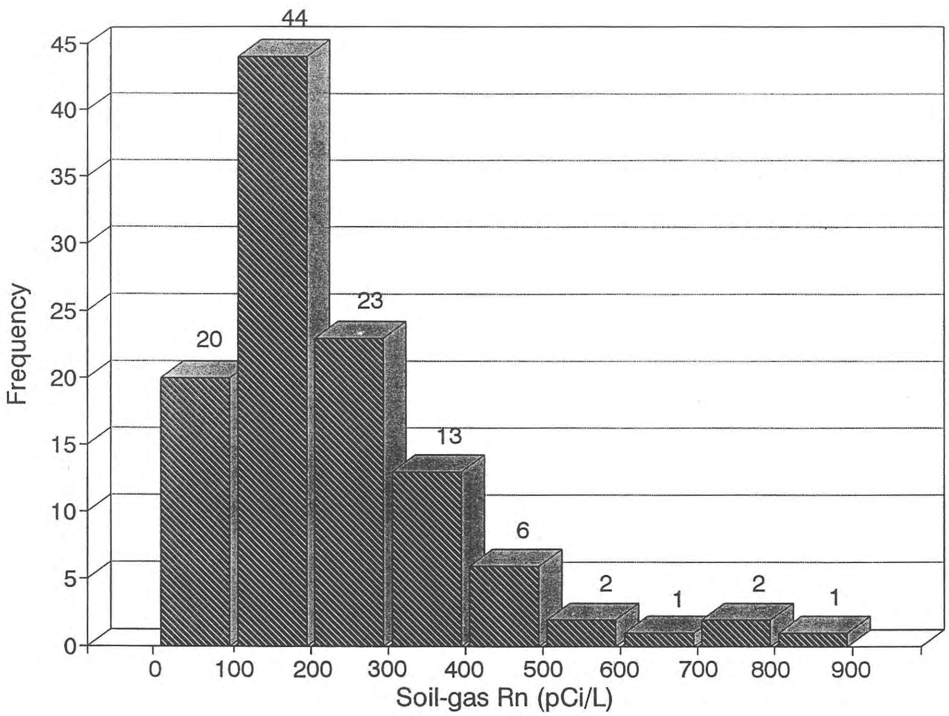

Figure 20. *Histogram of soil-gas-radon concentrations in Tooele Valley.*

Table 7. *Summary of indoor-radon measurements in Tooele Valley.*		
Indoor-Radon Level (pCi/L)	**Number of Measurements**	**Percent of Total**
≥20	0	0
10 - 20	0	0
4 - 10	13	18.6
2 - 4	13	18.6
<2	44	62.8
TOTAL	70	100

bination of moderately permeable soils, deep ground water, and moderate uranium concentrations. Although uranium concentrations are not high, they are slightly higher (ranging from 2 to 2.5 ppm eU) than in surrounding areas of Tooele (figure 17). The cluster of elevated indoor-radon levels may result from a locally high concentration of uranium that was not detected because of the sample density. Denser sampling of uranium could result in reclassification of the area's hazard potential to high if higher uranium levels are found.

Southeastern Cache Valley

Southeastern Cache Valley is in west-central Cache County, and extends west from the Bear River Range to the Little Bear River, and north from Harem to Hyde Park (figure 23). This area includes the communities of Logan, Millville, Nibley, North Logan, Providence, and River Heights. Total population of southeastern Cache Valley was approximately 43,500 in 1990; the population is expected to be over 53,000 by the year 2000 (Utah Office of Planning and Budget, 1991).

Surficial geology of the area consists of unconsolidated deposits in the valley separated from bedrock in the Bear River Range to the east by the active East Cache fault zone. Unconsolidated units include middle Pleistocene to Holocene alluvial-fan deposits and stream alluvium but, as in the lower Weber River area and Tooele Valley, are primarily deposits from various stages of latest Pleistocene Lake Bonneville (McCalpin, 1989) (figure 24). Compound deltas formed at both the Bonneville and Provo shoreline levels of the lake are present at the mouths of Logan, Providence, and Millville Canyons on the eastern valley margin (figure 25). Bedrock in the Bear River Range consists predominantly of sedimentary rocks of Mississippian through Cambrian age (Evans and others, 1991; Lowe and Galloway, 1993). Overall lithology of these Paleozoic rocks is approximately 60 percent dolomite, 15 percent limestone, 25 percent sandstone and quartzite, and minor conglomerate and black shale. Sedimentary rocks of the Miocene and Pliocene Salt Lake Formation, in part tuffaceous, are present in outcrops about 1 mile (1.6 km) north (Lowe and Galloway, 1993) and 2 miles (3.2 km) south (Mullens and Izett, 1964) of the study area. This unit may be present at shallow depth beneath piedmont slopes overlain by Quaternary deposits.

Uranium Concentration

Uranium concentrations measured at 212 sample sites in southeastern Cache Valley range from 0.8 to 3.9 ppm; mean concentration is 2.1 ppm and the standard deviation is 0.6 (table 2c). Distribution of eU concentrations is approximately lognormal (figure 26) and has a positive skewness of 0.1. Median concentration is 2.1 ppm (table 2c).

Highest uranium concentrations (greater than 3 ppm) are in deltaic deposits related to the Provo and younger shorelines of Lake Bonneville, lacustrine sand and silt related to the Provo and younger shorelines, and undivided Bonneville-lake-cycle deposits. High uranium concentrations are found near the mouths of Logan and Providence Canyons, and north of the mouth of Blacksmith Fork (figure 27), likely due to deposition of sediment derived from uraniferous bedrock upslope. High uranium concentrations are also found in the southwestern corner of the study area (figure 27), possibly due to adsorption of uranium in ground or surface water by clay and organic matter (Durrance, 1986) in fine-grained lacustrine deposits underlying these areas. Ura-

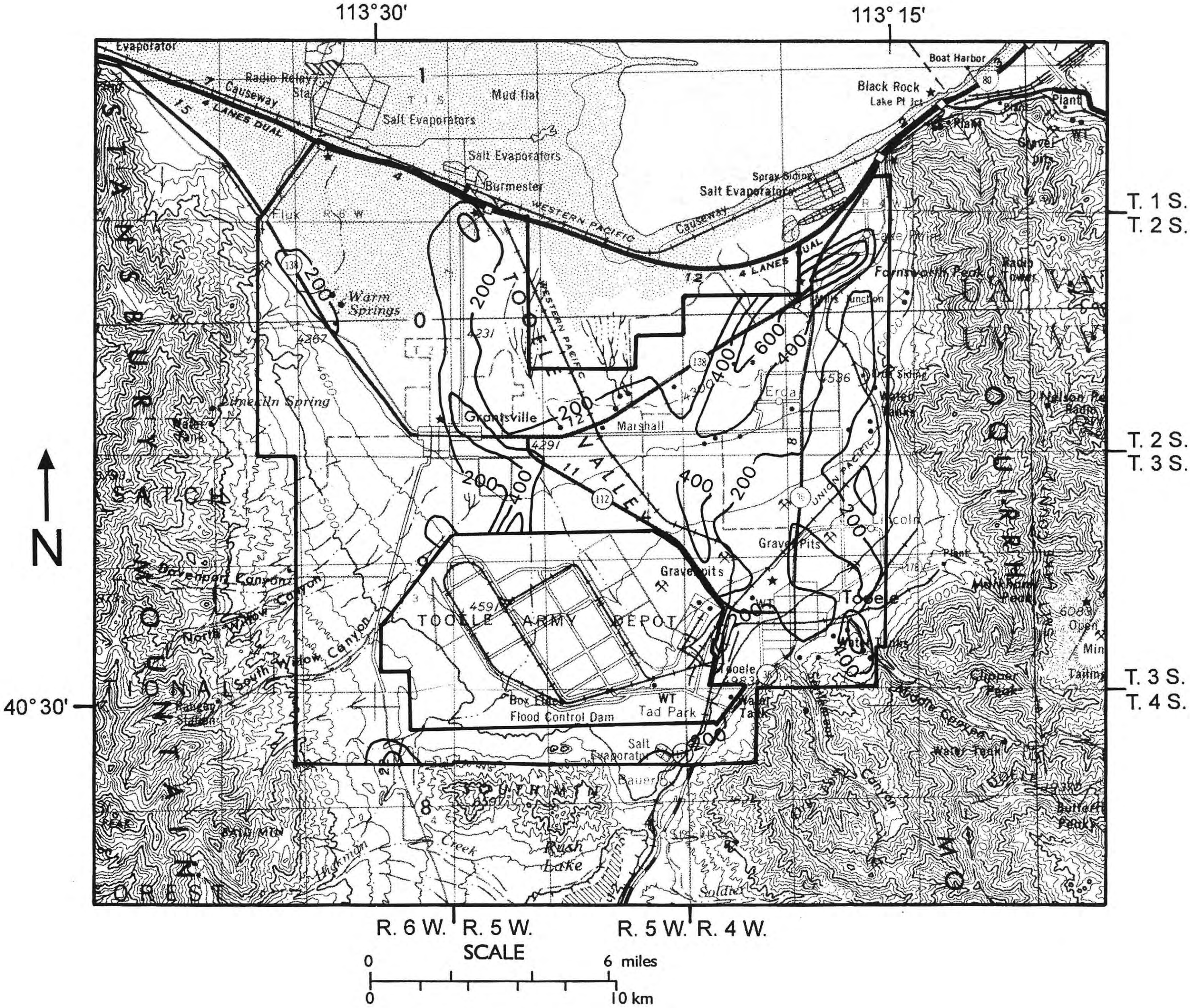

Figure 21. Exclusion isoline map of soil-gas-radon concentrations in Tooele Valley. Contour interval is 200 pCi/L (7.4 x 10^3 Bq/m^3).

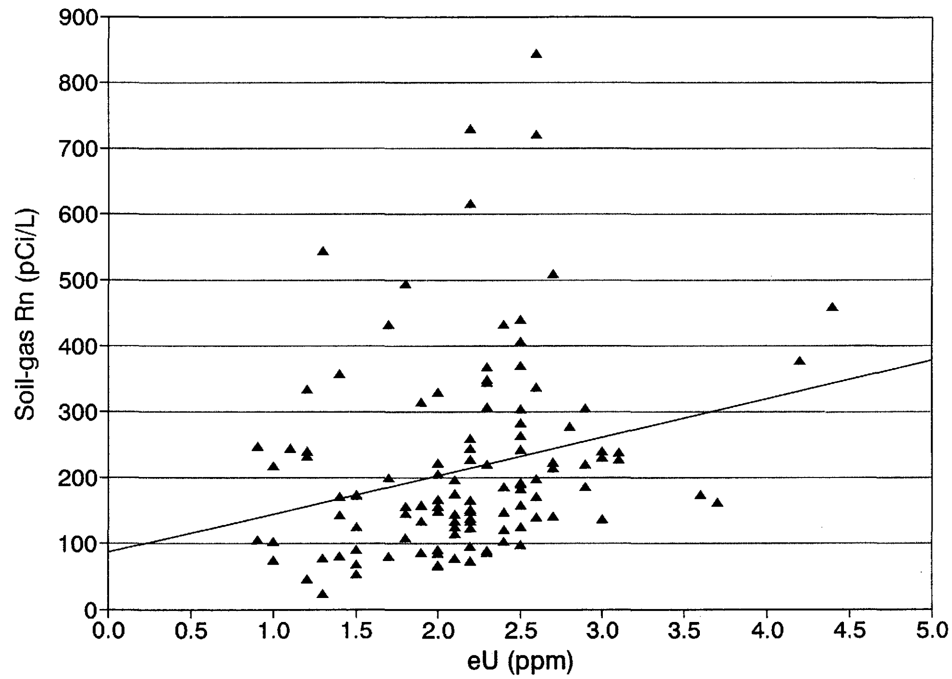

Figure 22. Scatter plot and linear regression of uranium (eU) and soil-gas-radon (Rn) data pairs in Tooele Valley.

nium concentrations generally decrease away from the range front (figure 27).

Two uraniferous bedrock units are present in the Bear River Range, and may be potential sources for uranium in derived sediment. One unit, variously mapped as the Madison Limestone (Mapel, 1956), Brazer Limestone (Mullens and Izett, 1964), and Little Flat Formation (Evans and others, 1991), contains a basal zone of phosphatic black shale from 4 to 10 feet (1-3 m) thick. The shale crops out near canyon heads, and samples from it yielded from 20 to 50 ppm eU (Mapel, 1956). The other unit, the Tertiary Salt Lake Formation, crops out in the foothills of the Bear River Range. This unit contains tuffaceous rock which may also have high uranium concentrations, but no sample analyses are documented. However, high uranium concentrations are often found in similar rocks elsewhere in Utah, such as the Tertiary Norwood Tuff in the Ogden Valley of northern Utah (Solomon, 1995) and the Tertiary Mount Belknap Volcanics near the Sevier Valley of central Utah (Solomon, 1996). Elevated uranium levels in silicic tuffs are consistent with concentration of the element in late-stage differentiation of igneous melts (Nielson and others, 1990).

Lowest uranium concentrations (less than 2 ppm) are common in areas near Logan underlain by fine-grained, undivided Bonneville-lake-cycle deposits, and in the floodplains of the Logan and Little Logan Rivers, which are underlain by latest Pleistocene to Holocene stream alluvium (figure 27). Uranium concentrations are also low in scattered smaller areas underlain by Lake Bonneville shoreline and deltaic deposits, and Holocene alluvial-fan deposits. Similar uranium concentrations were measured in Cambrian and Ordovician sedimentary bedrock along the Bear River Range front. This suggests that uranium-deficient sediment is locally derived, or includes sediment transported by Lake Bonneville longshore currents from these bedrock sources elsewhere.

Ground-Water Depth

Ground water in southeastern Cache Valley, like that of the other two study areas, is in unconsolidated sediments that grade westward from coarse-grained deltaic, alluvial-fan, and slope-wash deposits to fine-grained lake deposits (Bjorklund and McGreevy, 1971; Kariya and others, 1994). Ground water occurs under both confined and unconfined conditions.

Ground water typically greater than 50 feet (15 m) deep in the center of Cache Valley is confined, but confining layers are thin and discontinuous. Upward leakage from confined aquifers in the valley center recharges shallower unconfined aquifers. Ground water in unconfined aquifers is typically less than 50 feet (15 m) deep in the center of the valley, and less than 10 feet (3 m) deep in the northwestern part of the study area (figure 28).

Ground water is also unconfined near the margins of Cache Valley where confining beds are discontinuous or absent. Although several hundred feet of overlying unconsolidated basin fill near Logan is unsaturated, the water-bearing materials are at least 1,000 feet (300 m) thick. Ground water is typically greater than 30 feet (9 m) deep in the eastern and southwestern portions of the study area (figure 28). Perched ground water is found locally where infiltration is inhibited by less-permeable clay layers.

Soil Permeability

Soil permeability in southeastern Cache Valley is, like that of Tooele Valley, generally low to moderate (Erickson and Mortensen, 1974) (figure 29). Highly permeable soils are found locally in alluvial, deltaic, and lacustrine deposits. Soils having moderate permeability are common in alluvial, deltaic, and lacustrine deposits consisting primarily of sand and gravel, and are widespread in the eastern half and west-central portions of the study area. Soils having low permeability are associated with fine-grained lacustrine silt and clay. These soils are common in low-lying areas in the northwestern and southwestern portions of the study area, and near the town of Millville at the distal ends of the Providence and Millville deltas.

Hazard Potential

The radon-hazard potential of southeastern Cache Valley is generally low to moderate and includes isolated areas of high-hazard potential (plate 1C). The hazard potential is strongly

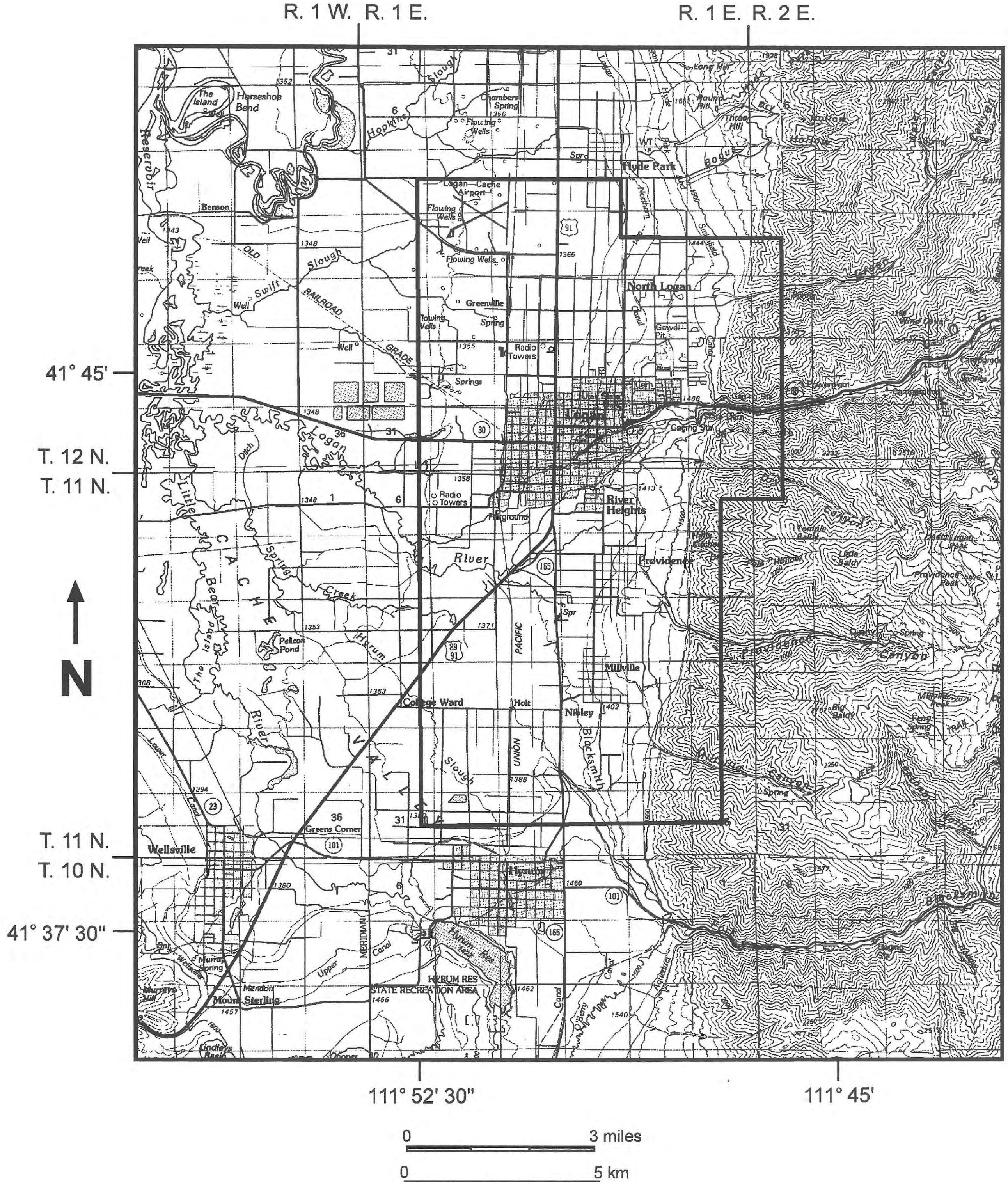

Figure 23. Southeastern Cache Valley study area. Base map from Logan U.S. Geological Survey 30 x 60 minute topographic quadrangle. Contour interval is 50 meters (164 ft).

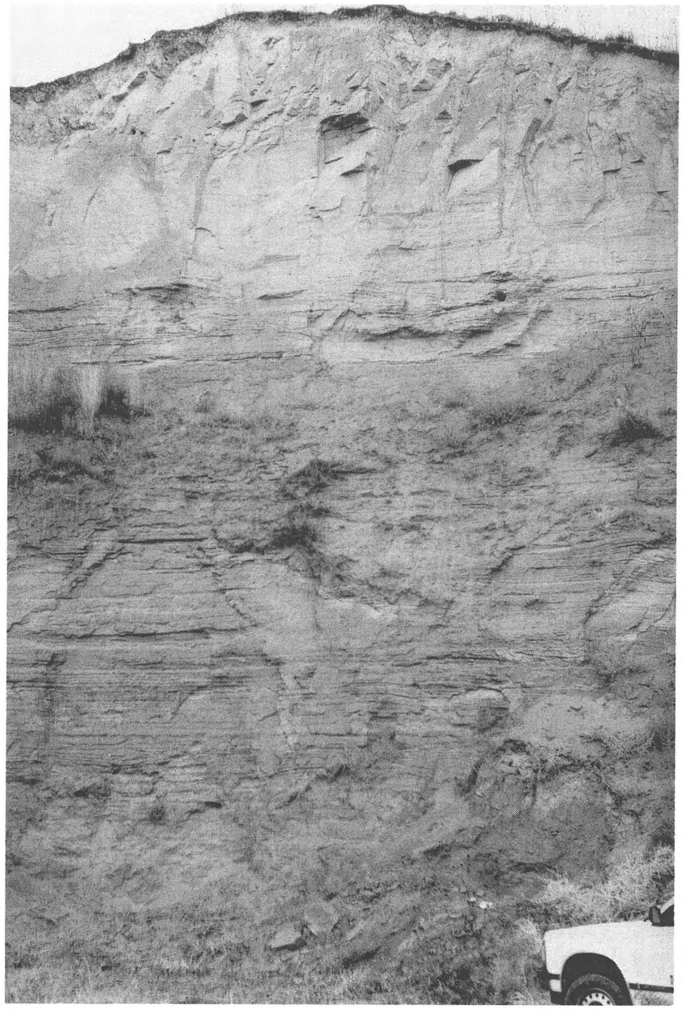

Figure 24. *Thin-bedded Lake Bonneville sand near Hells Kitchen, southeast of Logan in southeastern Cache Valley.*

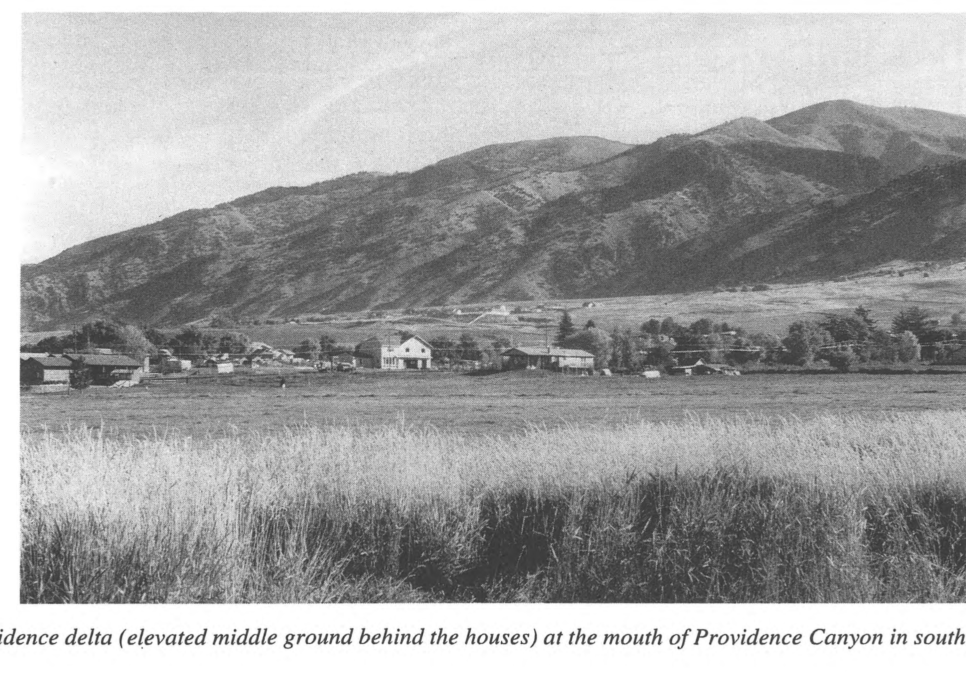

Figure 25. *The Providence delta (elevated middle ground behind the houses) at the mouth of Providence Canyon in southeastern Cache Valley.*

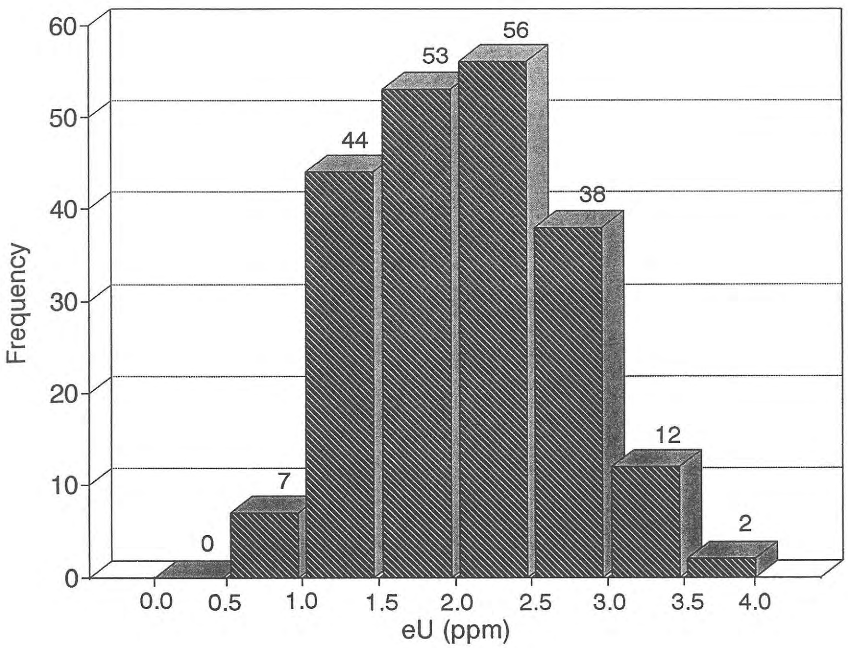

Figure 26. Histogram of uranium concentrations in southeastern Cache Valley.

controlled by soil permeability and, to a lesser extent, ground-water depth. The relation between hazard potential and uranium concentration is weak. The association between hazard potential and soil permeability, ground-water depth, and uranium concentration may have two causes: (1) the range of uranium concentrations is small and does not provide sufficient contrast to significantly affect the hazard potential, and (2) regional distribution of permeability and ground-water depth, unlike that of uranium concentration, varies consistently and correlates well to geology, soil type, and geography. Because of the small range of uranium concentrations, the denser sampling grid in the Millville vicinity added little detail to the hazard interpretation.

The radon-hazard potential is locally high in or near areas of high soil permeability and deep ground water in the eastern and southwestern part of the study area (plate 1C). Uranium concentrations in areas of high-hazard potential are generally moderate (between 2 and 3 ppm) north of the mouth of Providence Canyon, but high (greater than 3 ppm) to the south. Areas of high-hazard potential are commonly found in areas of high permeability. Areas of high-hazard potential are typically rural, but include small parts of the communities of North Logan near the mouth of Green Canyon, Logan in the vicinity of Utah State University, and Millville.

The potential for radon hazards is commonly moderate in areas of moderate permeability, deep ground water, and low to moderate uranium concentration (less than 3 ppm) in the eastern and southwestern part of the study area (plate 1C). These areas are underlain by coarse-grained alluvial, deltaic, and lacustrine deposits. However, areas of moderate-hazard potential near the town of Millville, and in the floodplain of the Logan and Little Logan Rivers in the west-central part of the study area, are underlain by impermeable lacustrine deposits of silt and clay. Although soil permeability in the floodplain is generally moderate, the hazard potential is low due to shallow ground water. Areas of moderate-hazard potential include most of the population centers in the study area.

The radon-hazard potential of southeastern Cache Valley is commonly low in low-lying areas in the west-central and northwestern parts of the study area (plate 1C). Soil permeability is moderate on the floodplain in the west-central part, noted above, but low in the northwestern part where fine-grained lacustrine deposits exist. Ground water is shallow in the low-lying areas, and uranium concentrations are predominantly low (less than 2 ppm) but locally moderate (between 2 and 3 ppm). Areas of low-hazard potential are typically rural and agricultural.

Soil-Gas Radon

Soil-gas radon measured at 100 sample sites in southeastern Cache Valley ranges in concentration from 42 to 1,864 pCi/L (1.55×10^3-6.90×10^4 Bq/m^3); mean concentration is 421 pCi/L (1.56×10^4 Bq/m^3) and the standard deviation is 343 (table 2c). Distribution of soil-gas data is lognormal (figure 30) and has a positive skewness of 7.9×10^7. Median concentration is 277 pCi/L (1.02×10^4 Bq/m^3) (table 2c).

Both the mean and median soil-gas concentrations of southeastern Cache Valley are significantly higher than those of the other two study areas. However, these differences may not be meaningful because of the varied climatic conditions in each area. Barometric pressure affects the movement of radon in soil (Tsang and Narasimhan, 1992), and precipitation affects the diffusion of radon from shallow soil to the atmosphere (Washington and Rose, 1992). The interaction between weather and geologic materials is unique to each area, and measurement of its effects is beyond the scope of this paper.

The relation between soil-gas radon and hazard potential is poorer in southeastern Cache Valley than in the other two study areas, but soil-gas levels closely correspond to the distribution of geologic units (figure 31). Six of the eight highest levels of soil-gas radon (998 pCi/L [3.69×10^4 Bq/m^3] and greater) were measured in the large area of low-hazard potential in the northwestern and west-central parts of the study area. The remaining two of the eight highest levels were measured within one mile (1.6 km) of this area, in an area of moderate-hazard potential. However, all of the eight highest levels were measured in areas underlain by fine-grained lacustrine material deposited on the basin floor. The lowest levels of soil-gas radon (less than 200 pCi/L [7.40×10^3 Bq/m^3]) were measured in scattered areas of both low and moderate-hazard potential, although those in moderate areas are more common because such areas are more widespread. Low soil-gas levels are associated with coarse-grained alluvial, deltaic, and lacustrine shoreline deposits.

The close association of soil-gas radon to geology, and the poor correspondence to hazard potential, suggests that soil-gas levels in southeastern Cache Valley are affected by physical properties of geologic materials that were not considered in the

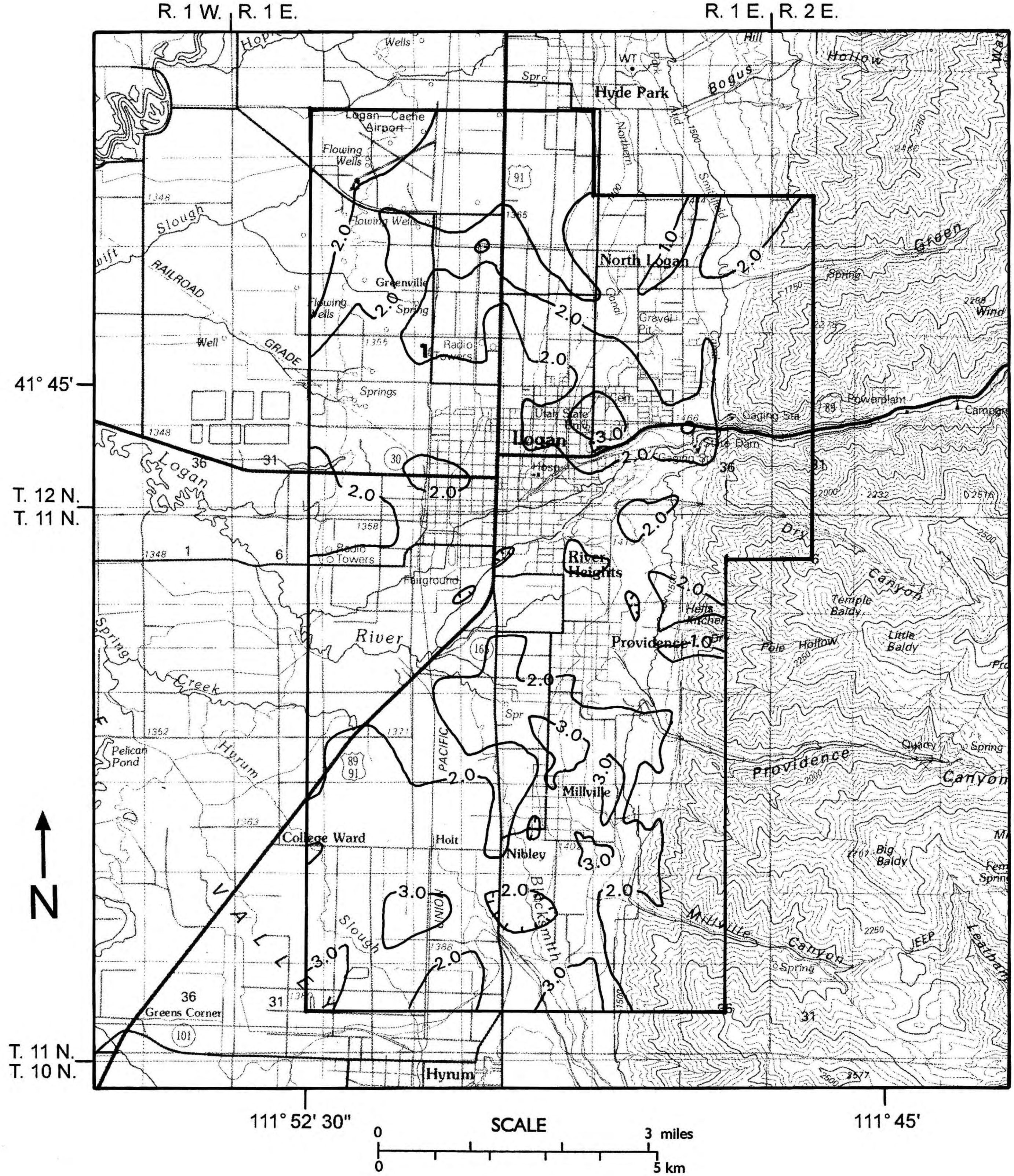

Figure 27. Contour map of uranium (eU) concentrations in southeastern Cache Valley. Contour interval is 1 ppm.

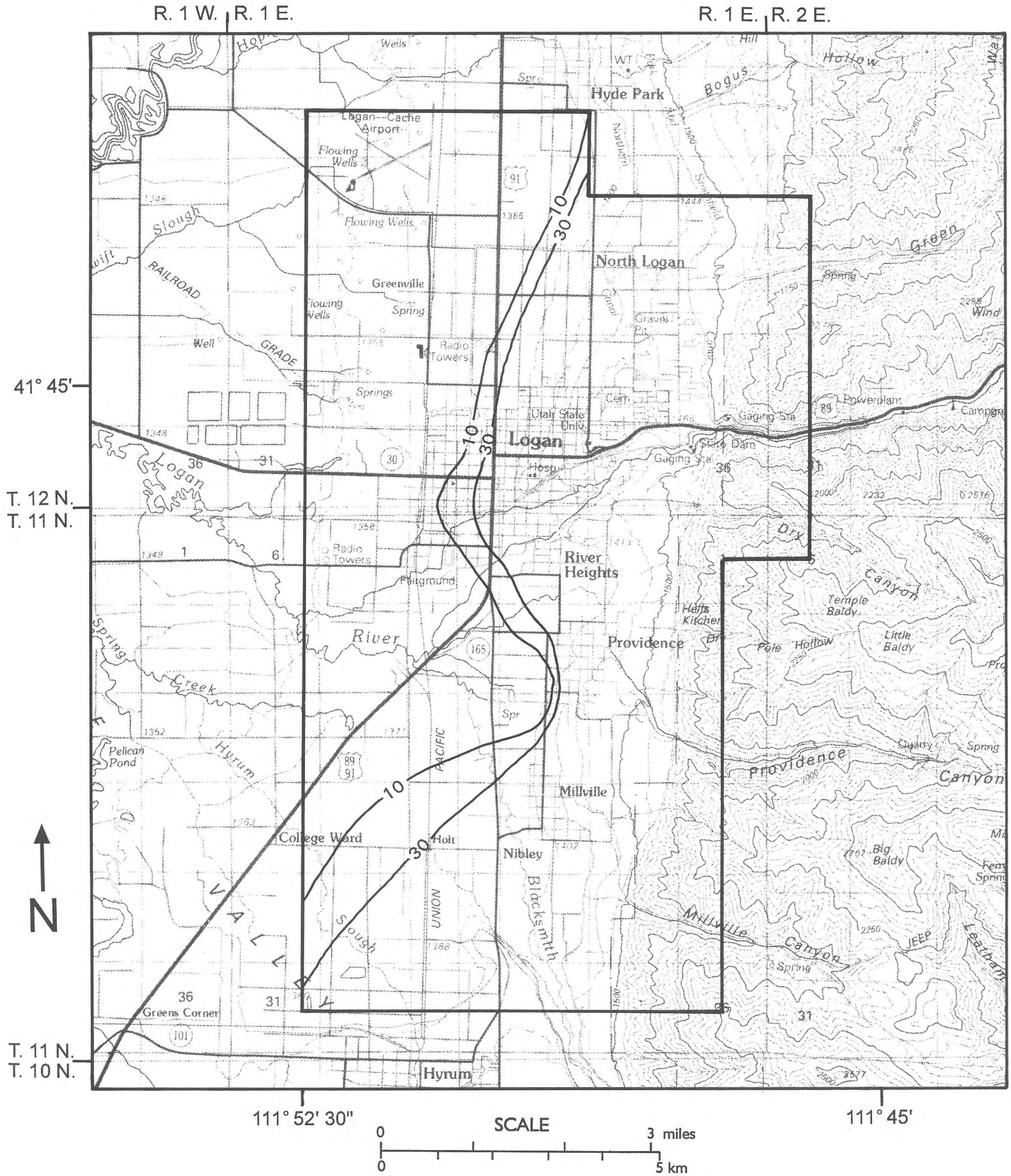

Figure 28. *Depth to shallow ground water in southeastern Cache Valley (modified from McGreevy and Bjorklund, 1970, and Bjorklund and McGreevy, 1971). Contours show depths of 10 feet (3 m) and 30 feet (9 m).*

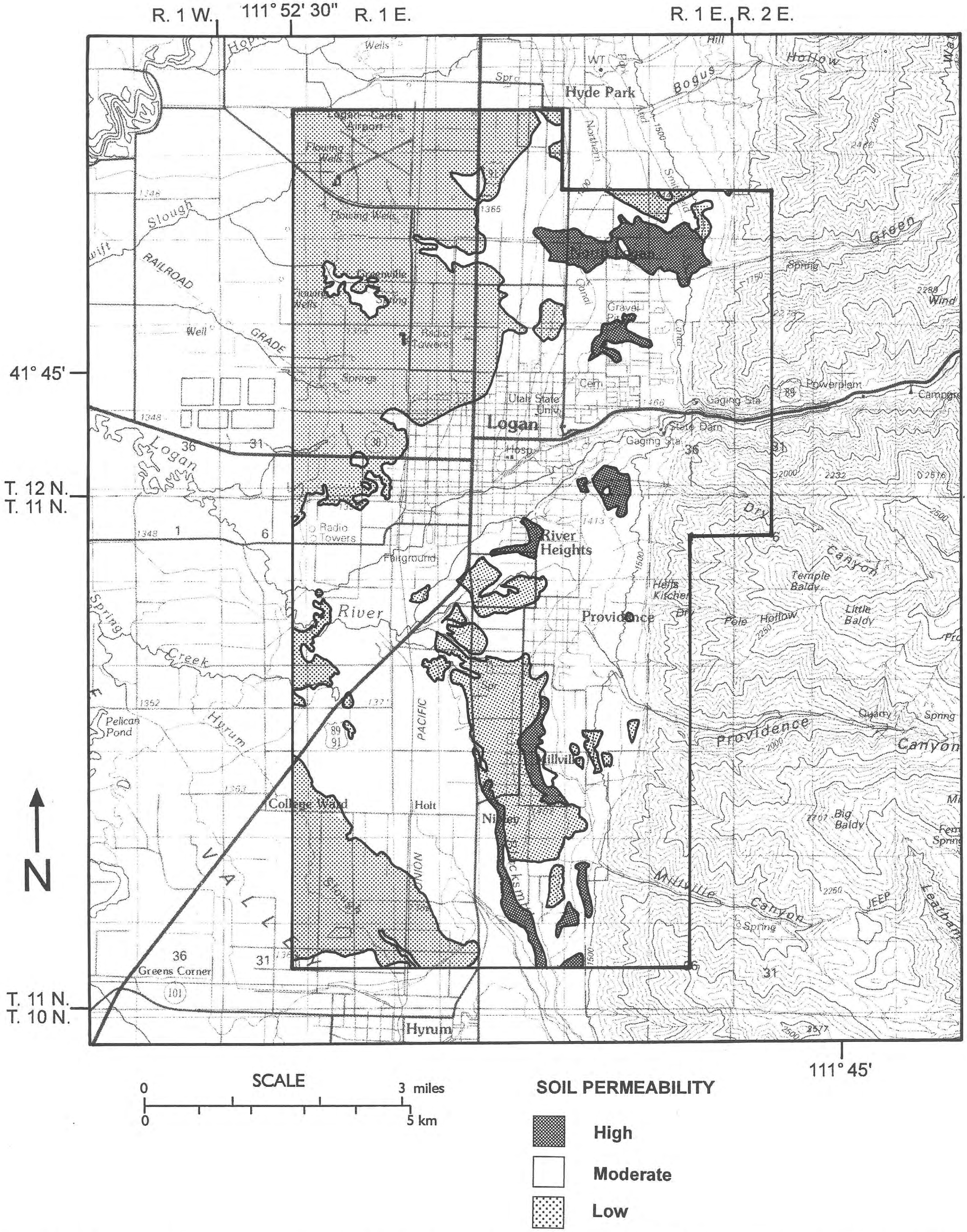

Figure 29. Soil-permeability classes in southeastern Cache Valley (modified from Erickson and Mortensen, 1974). See table 3 for hydraulic conductivities associated with each class.

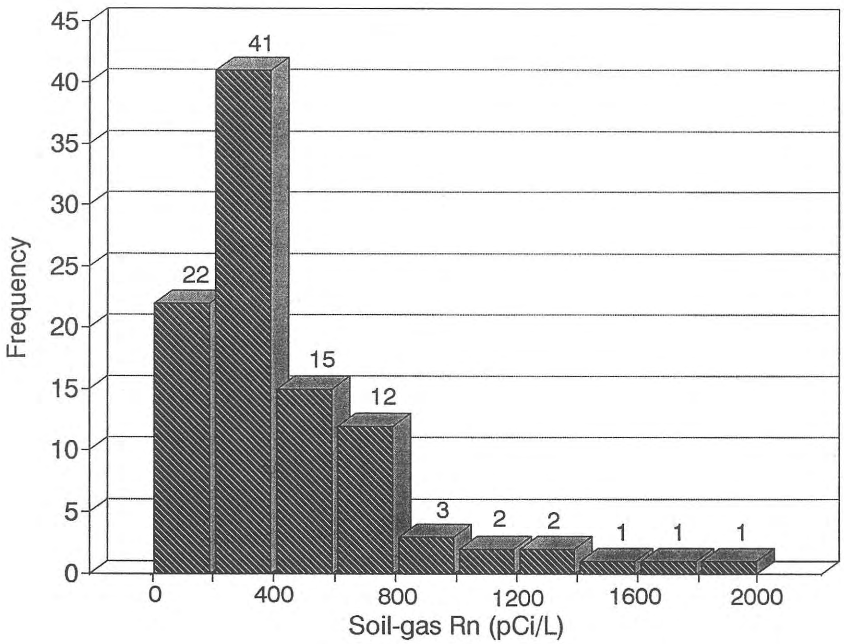

Figure 30. *Histogram of soil-gas-radon concentrations in southeastern Cache Valley.*

hazard assessment. Gravel content is one such property that influenced soil-gas levels in the other two study areas, and is apparently significant in southeastern Cache Valley. Linear regression of uranium-radon data pairs there (figure 32) shows that they are related by the formula:

$$Rn = 406.3 + 7.2\ eU.$$

The Spearman correlation coefficient of 0.066 is statistically significant only at the 74 percent confidence level, where the threshold value is 0.065. This is a poor correlation that results in low soil-gas levels even at high uranium concentrations, and suggests that a large part of the data scatter (figure 32) is due to atmospheric contamination of samples collected in coarse-grained material.

Although the process of radon emanation increases soil-gas levels in fine-grained deposits, the lower permeability of these deposits inhibits radon migration. Radon atoms escape (emanate) more easily from the solid in which they are produced if that solid has a large ratio of surface area to volume, typical of fine-grained deposits (Tanner, 1980). Thus, higher soil-gas levels result from increased emanation in fine-grained material. However, such deposits are relatively impermeable, and although they may have high levels of soil-gas radon, these deposits normally do not pose a significant hazard because low permeability inhibits radon migration. The hazard increases when fine-grained deposits become more permeable from the formation of desiccation cracks (Peake and Schumann, 1991).

Indoor Radon

Mean concentration of 54 indoor-radon samples measured in southeastern Cache Valley is 5.7 pCi/L (211 Bq/m^3); 59.3 percent are greater than or equal to 4 pCi/L (148 Bq/m^3) (table 8). One sample was measured in an area of low-hazard potential, 36 samples were measured in areas of moderate-hazard potential, and 17 samples were measured in areas of high-hazard potential (plate 1C). The lone indoor-radon measurement in the low-hazard area is 2.2 pCi/L (81 Bq/m^3) (table 5). Although this concentration is slightly higher than expected indoor-radon levels in low-hazard areas (table 4), it may be due to the small sample size and lack of representative samples. Indoor-radon levels in moderate-hazard areas range from 0.7 to 23.6 pCi/L (26-873 Bq/m^3), and average 5.2 pCi/L (192 Bq/m^3) (table 5). This average is slightly higher than expected for indoor-radon levels in moderate-hazard areas (table 4), but most of the measurements were conducted near boundaries with high-hazard areas in Millville (plate 1C). Indoor-radon levels in high-hazard areas range from 2.8 to 14.3 pCi/L (104-529 Bq/m^3), and average 7.0 pCi/L (259 Bq/m^3) (table 5). This average is consistent with expected indoor-radon levels in high-hazard areas (table 4).

Most elevated indoor-radon levels, ranging from 4.0 to 23.6 pCi/L (148-873 Bq/m^3), were measured in moderate- and high-hazard areas in Millville (plate 1C). Houses having the highest levels are underlain by highly permeable coarse-grained alluvium and lacustrine sand. Uranium concentrations are between 2 and 4 ppm in the area, and ground water is deep. These conditions are conducive for elevated indoor-radon levels. Three elevated indoor-radon levels, ranging from 4.2 to 7.1 pCi/L (155-263 Bq/m^3), were measured in areas of moderate-hazard potential in North Logan and the northern edge of Logan (plate 1C). The two elevated levels measured in North Logan are from houses underlain by a coarse-grained, highly permeable alluvial-fan deposit west of the mouth of Green Canyon. The third elevated level is from a house underlain by moderately permeable lacustrine sand and silt. Uranium concentrations are between 1 and 2 ppm beneath all three houses, and ground water is deep. Although uranium concentrations appear too low to account for elevated indoor-radon levels in these three houses, uranium concentrations were interpolated from nearby measurements and were not measured on site. Denser sampling of uranium may indicate higher ura-

Table 8.
Summary of indoor-radon measurements in southeastern Cache Valley.

Indoor-Radon Level (pCi/L)	Number of Measurements	Percent of Total
≥20	1	1.9
10 - 20	5	9.3
4 - 10	26	48.1
2 - 4	19	35.2
<2	3	5.5
TOTAL	54	100

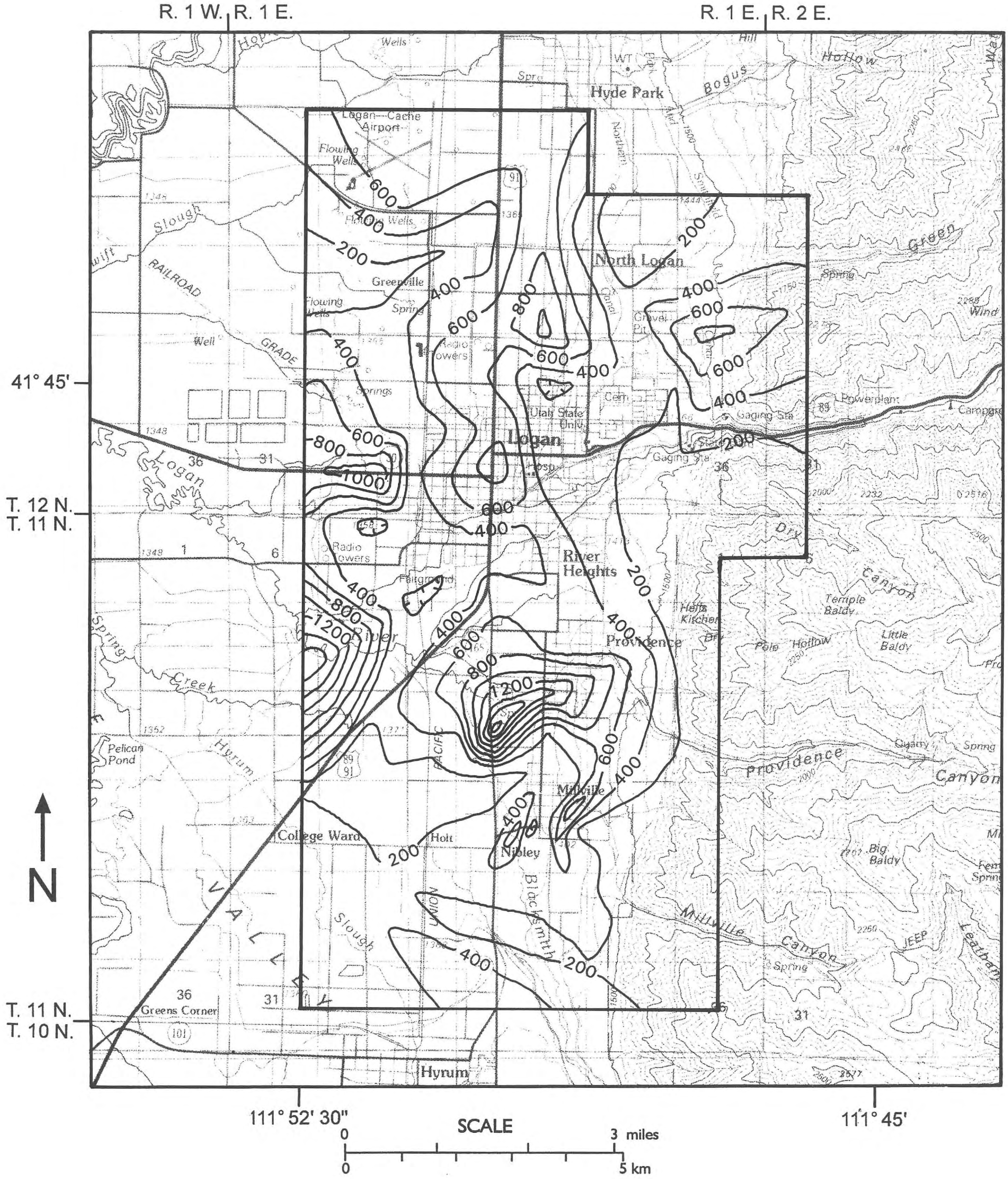

Figure 31. Contour map of soil-gas-radon concentrations in southeastern Cache Valley. Contour interval is 100 pCi/L (3.7×10^3 Bq/m^3).

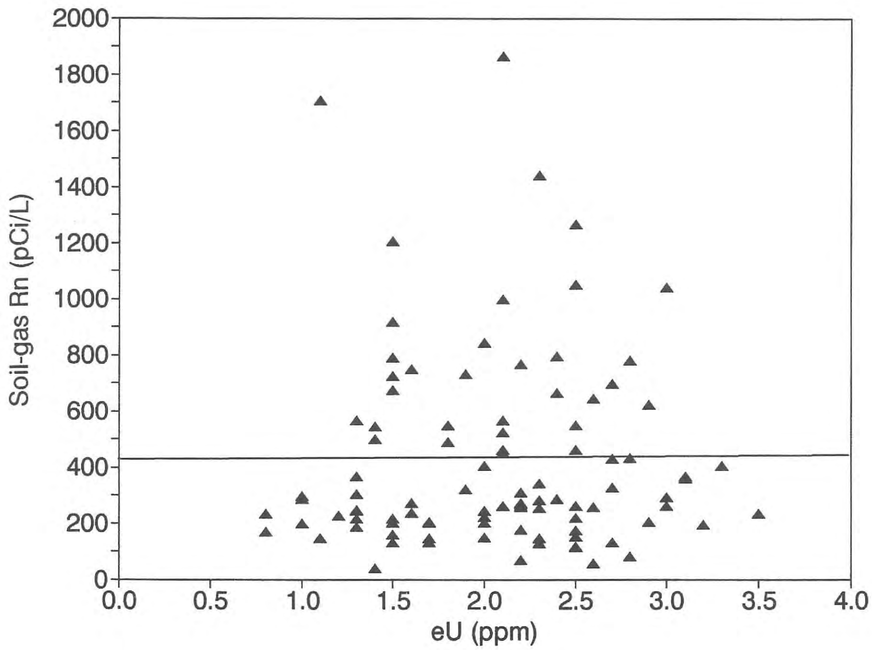

Figure 32. *Scatter plot and linear regression of uranium (eU) and soil-gas-radon (Rn) data pairs in southeastern Cache Valley.*

nium concentrations and a higher hazard potential. However, house construction and occupant lifestyle may also be significant factors, and could cause elevated indoor-radon levels even where uranium concentrations are low.

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 the lower Weber River area, Tooele Valley, and southeastern Cache 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.

Each of the three areas of Utah where the hazard potential was mapped are characterized by distinctive geology and geography, but there are some common characteristics reflected in the pattern of hazard potential in all three areas. Each area has permeable, coarse-grained lacustrine-shoreline and alluvial-fan deposits along valley margins. These thick, permeable deposits have deep ground water in unconfined aquifers. Unconfined aquifers are also formed in valley interiors, where ground water is shallow and recharges by upward leakage from deeper, confined aquifers through confining beds of relatively impermeable clay-rich, lake-bottom deposits.

High uranium concentrations are found along the range front in the lower Weber River area, but are distributed unevenly in Tooele and southeastern Cache Valleys. Uranium concentrations govern the radon-hazard potential of the lower Weber River area, but where uranium concentrations are lower, such as in Tooele Valley and southeastern Cache Valley, permeability and ground-water depth are the dominant factors. However, regardless of the dominant factor, hazard potential is generally highest on valley margins and lowest in valley interiors. In the lower Weber River area, the hazard potential is commonly high on benches along the Wasatch Range front and decreases westward toward low-lying areas on the margin of the Weber delta. In Tooele Valley, the hazard potential on benches and piedmont slopes along the Stansbury and Oquirrh Mountains is generally moderate but locally high, and decreases toward the north-central part of the valley near Great Salt Lake. The hazard potential of southeastern Cache Valley is also generally moderate along the Bear River Range front, decreasing westward toward the valley interior. This pattern of radon-hazard-potential distribution is expected in similar structural basins in western Utah.

Radon-hazard-potential maps based on geologic factors accurately represent the regional distribution of average indoor-radon levels, although locally anomalous indoor levels exist because of the local influence of unmeasured factors or the influence of measured factors beyond the map-scale resolution. Soil-gas measurements provide useful information, but are unreliable for the assessment of hazard potential because of possible inaccuracies introduced by sampling techniques and variations caused by weather.

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APPENDIX

Radiometric Data
Lower Weber River Area

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.	Location T.	R.	Sec.	Total Counts (ppm)	K (%)	eU (ppm)	eTH (ppm)	eU/eTh	Soil-Gas Radon (pCi/L)
1	5N	2W	NE 1/4 Sec. 11	7.6	0.9	2.8	5.1	0.55	113.0
2	5N	2W	NE 1/4 Sec. 11	6.5	0.7	2.6	3.8	0.68	103.2
3	5N	2W	NE 1/4 Sec. 2	7.9	1.1	1.6	5.8	0.28	144.0
4	6N	2W	SW 1/4 Sec. 34	7.1	0.8	1.7	5.3	0.32	226.6
5	6N	2W	NE 1/4 Sec. 33	7.6	1.1	1.4	6.4	0.22	—
6	6N	2W	NE 1/4 Sec. 34	7.4	0.9	2.5	6.2	0.40	18.2
7	6N	2W	NW 1/4 Sec. 36	6.9	1.0	2.0	3.7	0.54	49.7
8	6N	2W	SE 1/4 Sec. 26	5.6	0.6	2.0	3.9	0.51	—
9	6N	2W	NE 1/4 Sec. 3	9.2	1.3	2.1	7.5	0.28	—
10	5N	2W	NE 1/4 Sec.9	8.6	1.3	1.9	5.9	0.32	—
11	5N	2W	SW 1/4 Sec. 2	7.4	1.0	2.3	6.2	0.37	—
12	5N	2W	NW 1/4 Sec. 15	8.3	1.3	2.1	5.8	0.36	744.6
13	5N	2W	SW 1/4 Sec. 11	7.7	1.1	2.4	6.3	0.38	259.6
14	5N	2W	NW 1/4 Sec. 14	8.1	1.2	1.5	6.7	0.22	41.1
15	5N	2W	SE 1/4 Sec. 12	7.2	1.0	1.1	6.9	0.16	146.7
16	5N	1W	SW 1/4 Sec. 6	6.7	0.8	1.8	5.3	0.34	309.1
17	6N	2W	SE 1/4 Sec. 36	7.0	1.2	1.4	5.6	0.25	29.9
18	6N	2W	SE 1/4 Sec. 25	7.3	0.9	2.4	5.1	0.47	—
19	6N	2W	NE 1/4 Sec. 25	7.5	0.9	1.6	6.1	0.26	—
20	6N	2W	SW 1/4 Sec. 24	6.1	0.7	2.0	4.2	0.48	—
21	6N	2W	NE 1/4 Sec. 21	7.8	1.0	2.1	5.1	0.41	—
22	6N	1W	NE 1/4 Sec. 19	7.7	1.1	2.0	6.3	0.32	—
23	5N	2W	SW 1/4 Sec. 14	7.5	0.9	2.7	6.5	0.42	132.0
24	5N	2W	NE 1/4 Sec. 23	6.2	0.8	1.9	4.0	0.48	288.8
25	5N	2W	SE 1/4 Sec. 23	7.1	0.9	2.2	4.9	0.45	256.1
26	5N	2W	NE 1/4 Sec. 35	7.3	0.9	2.1	5.0	0.42	—
27	5N	2W	SE 1/4 Sec. 26	7.8	0.9	2.6	5.8	0.45	340.7
28	5N	2W	SE 1/4 Sec. 27	7.5	1.0	2.5	3.4	0.74	786.6
29	5N	2W	NW 1/4 Sec. 27	8.7	1.0	2.8	6.6	0.42	152.4
30	5N	2W	SW 1/4 Sec. 13	6.6	0.8	1.6	5.5	0.29	—
31	5N	1W	NW 1/4 Sec. 19	12.2	1.5	3.3	9.2	0.36	—
32	5N	2W	NE 1/4 Sec. 13	9.0	1.1	3.1	7.3	0.42	289.9
33	5N	2W	NW 1/4 Sec. 12	8.2	1.1	2.4	7.4	0.32	387.8
34	6N	1W	NW 1/4 Sec. 31	5.6	0.8	1.1	4.4	0.25	—
35	5N	1W	NW 1/4 Sec. 5	9.5	1.4	1.9	7.1	0.27	327.3
36	5N	1W	NW 1/4 Sec. 4	10.1	1.5	2.4	8.6	0.28	734.1
37	5N	1W	SE 1/4 Sec. 4	9.4	1.2	3.2	6.3	0.51	182.1
38	5N	1W	NW 1/4 Sec. 3	15.8	2.1	1.9	15.8	0.12	180.9
39	6N	1W	NW 1/4 Sec. 35	17.4	2.3	4.1	15.5	0.26	—
40	5N	1W	NE 1/4 Sec. 3	9.7	1.3	2.5	8.7	0.29	—
41	5N	1W	SE 1/4 Sec. 3	12.1	1.6	2.0	11.9	0.17	—
42	5N	1W	NW 1/4 Sec. 17	5.8	0.6	1.9	5.0	0.38	305.1
43	5N	1W	SE 1/4 Sec. 18	7.1	1.0	1.0	5.2	0.19	29.1

No.	Location T.	R.	Sec.	Total Counts (ppm)	K (%)	eU (ppm)	eTH (ppm)	eU/eTh	Soil-Gas Radon (pCi/L)
44	5N	1W	SW 1/4 Sec. 17	7.3	1.0	1.3	6.0	0.22	210.2
45	5N	1W	SE 1/4 Sec. 17	6.0	0.7	1.8	4.7	0.38	80.1
46	5N	1W	NW 1/4 Sec. 8	8.3	1.1	2.4	5.6	0.43	138.4
47	5N	1W	NW 1/4 Sec. 9	7.6	0.9	1.6	5.9	0.27	358.6
48	5N	1W	NW 1/4 Sec. 8	10.5	1.3	2.7	8.6	0.31	—
49	5N	1W	SE 1/4 Sec. 7	8.6	1.1	0.9	9.5	0.09	—
50	5N	1W	NE 1/4 Sec. 7	9.2	1.3	2.7	6.6	0.41	—
51	5N	1W	SW 1/4 Sec. 5	7.4	1.1	1.2	5.5	0.22	—
52	5N	1W	NE 1/4 Sec. 16	14.2	2.1	3.0	12.4	0.24	284.3
53	5N	1W	NW 1/4 Sec. 16	6.6	0.8	1.4	6.3	0.22	100.1
54	5N	1W	NE 1/4 Sec. 16	5.8	0.9	1.4	4.5	0.31	46.5
55	5N	1W	SE 1/4 Sec. 10	22.5	3.2	4.5	19.7	0.23	178.0
56	5N	1W	NW 1/4 Sec. 14	26.6	3.3	5.0	24.0	0.21	268.6
57	5N	1W	SE 1/4 Sec. 15	12.1	2.0	2.3	8.1	0.28	447.5
58	5N	1W	SE 1/4 Sec. 22	8.1	1.2	2.0	5.4	0.37	—
59	5N	1W	NE 1/4 Sec. 21	10.4	1.4	1.7	9.9	0.17	—
60	5N	1W	NW 1/4 Sec. 21	8.5	1.3	2.2	6.0	0.37	—
61	5N	1W	NW 1/4 Sec. 10	6.9	1.0	1.6	4.6	0.35	—
62	5N	1W	SW 1/4 Sec. 21	9.1	1.0	2.2	9.1	0.24	69.3
63	5N	1W	SE 1/4 Sec. 20	9.8	1.3	2.3	7.6	0.30	88.5
64	5N	1W	NE 1/4 Sec. 29	8.6	1.2	2.8	5.5	0.51	115.0
65	5N	1W	SW 1/4 Sec. 20	12.6	1.9	2.2	8.0	0.28	584.5
66	5N	1W	NW 1/4 Sec. 33	11.5	1.3	2.5	10.1	0.25	188.3
67	5N	1W	NW 1/4 Sec. 34	7.2	0.8	2.4	4.9	0.49	843.1
68	5N	1W	NE 1/4 Sec. 34	9.2	1.2	2.8	7.7	0.36	—
69	5N	1W	SE 1/4 Sec. 26	9.7	1.2	1.9	9.0	0.21	339.7
70	5N	1W	NE 1.4 Sec. 35	8.7	1.1	2.2	7.0	0.31	—
71	5N	1W	SE 1/4 Sec. 25	18.1	2.4	3.4	16.2	0.21	—
72	5N	1W	SW 1/4 Sec. 14	16.9	2.2	2.5	14.5	0.17	78.3
73	5N	1W	NE 1/4 Sec. 23	17.2	2.1	3.0	16.3	0.18	105.4
74	5N	1W	SW 1/4 Sec. 24	14.0	1.7	2.1	12.7	0.17	137.9
75	5N	1W	NE 1/4 Sec. 23	10.8	1.0	3.3	8.6	0.38	206.2
76	5N	1W	NE 1/4 Sec. 27	8.4	1.0	2.4	7.2	0.33	—
77	5N	1W	SE 1/4 Sec. 23	12.7	1.7	1.8	13.4	0.13	—
78	5N	1W	NE 1/4 Sec. 26	7.7	0.9	2.2	7.2	0.31	51.5
79	5N	1W	NE 1/4 Sec. 27	12.7	1.4	4.7	9.5	0.49	187.8
80	5N	1W	NW 1/4 Sec. 27	12.6	1.7	3.5	10.9	0.32	—
81	5N	1W	NE 1/4 Sec. 28	9.5	1.4	2.2	7.3	0.30	—
82	5N	1W	NW 1/4 Sec. 26	21.6	2.9	4.0	20.3	0.20	—
83	5N	1W	SW 1/4 Sec. 36	23.2	3.0	3.6	24.2	0.15	292.2
84	5N	1W	SW 1/4 Sec. 35	9.2	1.2	2.2	8.2	0.27	153.1
85	4N	1W	NE 1/4 Sec. 2	8.0	1.0	1.9	6.4	0.30	71.1
86	4N	1W	SW 1/4 Sec. 2	11.1	1.8	2.3	7.1	0.32	208.0
87	4N	1W	SW 1/4 Sec. 3	9.5	1.2	2.2	7.2	0.31	115.2
88	4N	1W	N 1/2 Sec. 3	6.5	0.8	2.0	4.5	0.44	64.5
89	4N	1W	NW 1/4 Sec.9	6.9	1.0	1.2	6.4	0.19	—
90	4N	1W	NE 1/4 Sec. 8	6.5	1.0	1.6	3.9	0.41	—
91	4N	1W	NE 1/4 Sec. 8	8.0	1.2	2.3	6.0	0.38	—

No.	Location T.	R.	Sec.	Total Counts (ppm)	K (%)	eU (ppm)	eTH (ppm)	eU/eTh	Soil-Gas Radon (pCi/L)
92	4N	1W	NW 1/4 Sec. 7	10.4	1.3	2.3	7.3	0.32	—
93	4N	1W	SW 1/4 Sec. 1	15.5	2.2	4.2	13.0	0.32	152.9
94	4N	1W	NW 1/4 Sec. 12	21.6	2.4	5.0	20.6	0.24	260.8
95	4N	1W	SW 1/4 Sec. 12	24.4	3.2	3.3	25.0	0.13	140.5
96	4N	1W	NW 1/4 Sec. 13	15.8	2.0	3.4	15.4	0.22	196.1
97	4N	1W	NW 1/4 Sec. 14	18.2	2.3	4.6	15.8	0.29	387.4
98	4N	1W	NW 1/4 Sec. 15	15.7	2.0	4.2	12.5	0.34	200.3
99	4N	1W	NW 1/4 Sec. 15	18.3	2.1	4.9	16.1	0.30	—
100	4N	1W	SE 1/4 Sec. 10	9.3	1.3	1.9	6.3	0.30	—
101	4N	1W	SW 1.4 Sec. 11	12.4	1.6	2.6	11.0	0.24	—
102	4N	1W	SE 1/4 Sec. 11	11.2	1.6	2.3	8.7	0.26	—
103	4N	1W	NE 1/4 Sec. 22	11.0	1.6	2.7	7.9	0.34	329.0
104	4N	1W	NE 1/4 Sec. 21	16.0	1.6	2.6	7.0	0.37	2143.6
105	4N	1W	SW 1/4 Sec. 22	16.8	2.0	3.3	18.0	0.18	1211.6
106	4N	1W	NE 1/4 Sec. 23	12.5	1.6	2.7	12.2	0.22	370.9
107	4N	1W	NE 1/4 Sec. 26	13.2	2.0	2.8	11.4	0.25	195.4
108	4N	1W	SW 1/4 Sec. 23	14.3	2.1	1.7	13.7	0.12	529.9
109	4N	1W	NE 1/4 Sec. 16	13.5	1.6	2.8	11.5	0.24	—
110	4N	1W	NE 1/4 Sec. 16	13.5	1.8	3.4	10.1	0.34	—
111	4N	1W	NW 1/4 Sec. 16	10.2	1.5	2.4	8.6	0.28	—
112	4N	1W	SE 1/4 Sec. 7	9.9	1.6	1.7	7.0	0.24	—
113	4N	1W	SW 1/4 Sec. 24	21.4	2.3	5.0	20.0	0.25	267.7
114	4N	1W	NW 1/4 Sec. 25	28.8	2.6	4.6	33.9	0.14	130.2
115	4N	1W	SE 1/4 Sec. 26	15.4	2.1	3.2	13.0	0.25	99.5
116	4N	1W	NE 1/4 Sec. 34	16.0	2.1	4.0	12.6	0.32	491.5
117	4N	1W	NW 1/4 Sec. 26	17.9	2.2	3.6	15.6	0.23	287.0
118	4N	1W	SE 1/4 Sec. 27	13.6	1.9	3.4	9.4	0.36	240.6
119	4N	1W	SE 1/4 Sec. 34	11.9	1.5	3.0	8.8	0.34	—
120	3N	1W	NW 1/4 Sec. 2	11.2	1.3	3.3	7.6	0.43	—
121	3N	1W	SW 1/4 Sec. 2	10.0	1.4	1.3	8.1	0.16	—
122	3N	1W	NE 1/4 Sec. 11	12.9	1.8	2.8	10.5	0.27	—
123	5N	2W	SW 1/4 Sec. 36	7.0	1.0	1.7	5.7	0.30	1256.2
124	4N	2W	NW 1/4 Sec. 1	6.8	1.1	1.4	4.6	0.30	158.8
125	4N	2W	SE 1/4 Sec. 1	6.6	0.9	1.7	4.9	0.35	590.1
126	4N	1W	SW 1/4 Sec. 7	10.3	1.5	2.4	8.3	0.29	350.9
127	5N	2W	NE 1/4 Sec. 22	7.4	1.1	1.7	6.4	0.27	—
128	5N	2W	NW 1/4 Sec. 22	8.5	1.2	2.4	6.5	0.37	—
129	5N	2W	SE 1/4 Sec. 15	8.0	1.1	2.0	5.2	0.38	—
130	3N	1W	NE 1/4 Sec. 12	19.8	2.6	4.1	18.8	0.22	229.5
131	3N	1W	SE 1/4 Sec. 1	17.9	2.2	3.8	17.3	0.22	246.0
132	3N	1W	NE 1/4 Sec. 1	19.9	2.1	4.2	22.1	0.19	183.9
133	3N	1W	NE 1/4 Sec. 2	13.3	1.7	3.3	11.4	0.29	191.0
134	4N	1W	SE 1/4 Sec. 35	16.0	2.2	3.4	14.8	0.23	178.9
135	4N	1W	NW 1/4 Sec. 36	15.7	1.9	3.6	15.1	0.24	252.1
136	4N	1W	SW 1/4 Sec. 25	23.7	2.8	4.3	25.8	0.17	—
137	3N	1W	NE 1/4 Sec. 1	12.9	1.7	3.4	10.7	0.32	—
138	3N	1W	SW 1/4 Sec. 1	14.0	1.6	4.3	11.4	0.38	—
139	3N	1W	NW 1/4 Sec. 12	10.7	1.5	2.3	8.7	0.26	88.2

No.	Location T.	R.	Sec.	Total Counts (ppm)	K (%)	eU (ppm)	eTH (ppm)	eU/eTh	Soil-Gas Radon (pCi/L)
140	4N	1W	NW 1/4 Sec. 24	8.8	1.3	1.5	7.1	0.21	68.2
141	4N	1W	NE 1/4 Sec. 23	11.2	1.6	1.6	9.9	0.16	402.2
142	4N	1W	SW 1/4 Sec. 11	6.6	0.8	1.1	6.3	0.17	—
143	4N	1W	NE 1/4 Sec. 9	8.9	1.2	1.9	7.3	0.26	—
144	4N	1W	SE 1/4 Sec. 3	6.6	0.8	1.4	4.4	0.32	—
145	5N	1W	NW 1/4 Sec. 34	13.4	1.4	2.6	12.5	0.21	—
146	5N	1W	SW 1/4 Sec. 27	8.7	1.1	2.2	6.8	0.32	132.7
147	5N	1W	SW 1/4 Sec. 28	10.8	1.4	2.8	8.8	0.32	—
148	5N	1W	NE 1/4 Sec. 19	9.4	1.2	2.5	7.4	0.34	—
149	5N	1W	SW 1/4 Sec. 18	9.5	1.4	1.8	6.2	0.29	—
150	5N	1W	NW 1/4 Sec. 17	6.7	0.9	1.7	6.2	0.27	—
151	5N	1W	SE 1/4 Sec. 8	7.6	1.0	2.2	6.3	0.35	—
152	5N	1W	NW 1/4 Sec. 15	14.6	1.9	3.8	11.9	0.32	299.6
153	6N	2W	SW 1/4 Sec. 36	10.8	1.9	2.2	6.5	0.34	—
154	6N	2W	NW 1/4 Sec. 36	11.5	1.7	2.5	7.8	0.32	164.0
155	6N	2W	NE 1/4 Sec. 25	10.1	1.4	2.2	8.0	0.28	194.0
156	5N	1W	SW 1/4 Sec. 3	11.9	1.6	2.5	9.5	0.26	—
157	5N	1W	SE 1/4 Sec. 5	6.5	1.0	1.4	4.5	0.31	—
158	6N	1W	NW 1/4 Sec. 32	10.7	1.3	2.5	9.9	0.25	—
159	6N	1W	SE 1/4 Sec. 31	9.7	1.4	2.5	6.5	0.38	—

Radiometric Data
Tooele 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.	Location T.	R.	Sec.	Total Counts (ppm)	K (%)	eU (ppm)	eTH (ppm)	eU/eTh	Soil-Gas Radon (pCi/L)
1	4S	6W	SW 1/4 Sec. 11	12.9	2.0	2.4	10.9	0.22	433.5
2	4S	6W	NW 1/4 Sec. 11	13.2	1.9	2.2	12.2	0.18	165.6
3	4S	6W	SW 1/4 Sec. 12	15.1	2.6	1.5	11.7	0.13	173.7
4	4S	6W	NW 1/4 Sec. 12	11.1	1.7	2.9	8.2	0.35	—
5	4S	5W	SW 1/4 Sec. 6	11.1	1.6	2.2	8.2	0.27	124.0
6	4S	5W	SW 1/4 Sec. 5	12.0	2.1	2.6	9.8	0.27	199.2
7	4S	5W	SW 1/4 Sec. 7	9.7	1.8	1.7	5.5	0.31	—
8	4S	5W	SW 1/4 Sec. 8	9.7	1.6	2.0	6.7	0.30	—
9	4S	5W	SW 1/4 Sec. 9	12.0	2.4	1.8	6.5	0.28	—
10	4S	5W	SW 1/4 Sec. 4	9.0	1.6	1.5	5.8	0.26	91.4
11	4S	5W	SW 1/4 Sec. 3	7.3	1.5	1.3	3.5	0.37	24.9
12	4S	5W	SE 1/4 Sec. 9	12.9	2.2	2.5	8.8	0.28	—
13	4S	5W	SW 1/4 Sec. 13	11.0	1.6	2.3	7.9	0.29	—
14	4S	5W	SE 1/4 Sec. 10	11.5	1.9	2.2	7.2	0.31	73.7
15	4S	4W	SW 1/4 Sec. 7	9.0	1.5	2.2	5.5	0.40	259.3
16	4S	4W	NE 1/4 Sec. 7	7.7	1.2	1.5	5.9	0.25	125.5
17	4S	4W	SW 1/4 Sec. 7	9.1	1.5	1.7	5.9	0.29	200.4
18	4S	5W	SE 1/4 Sec. 12	11.7	2.0	2.1	7.9	0.27	135.4
19	4S	5W	NE 1/4 Sec. 12	10.6	1.7	2.0	8.7	0.23	223.1
20	4S	4W	SW 1/4 Sec. 5	10.9	1.7	1.4	9.6	0.15	357.9
21	4S	5W	NE 1/4 Sec. 5	8.5	1.3	1.8	6.2	0.29	—
22	3S	4W	NW 1/4 Sec. 33	7.1	1.0	1.8	4.4	0.41	—
23	3S	4W	NE 1/4 Sec. 33	7.2	1.1	1.0	7.0	0.14	217.7
24	3S	4W	NE 1/4 Sec. 34	9.3	1.3	2.2	8.0	0.28	—
25	3S	4W	SE 1/4 Sec. 26	12.0	1.8	1.9	11.2	0.17	—
26	3S	4W	NE 1/4 Sec. 27	5.4	0.9	0.9	4.1	0.22	106.2
27	3S	4W	SW 1/4 Sec. 26	9.0	1.3	2.2	7.6	0.29	616.3
28	3S	4W	SW 1/4 Sec. 25	9.6	1.7	1.6	5.6	0.29	—
29	3S	4W	NE 1/4 Sec. 35	5.7	1.0	1.2	4.1	0.29	—
30	3S	4W	SE 1/4 Sec. 22	6.0	0.9	2.0	3.0	0.67	205.7
31	3S	4W	SE 1/4 Sec. 23	9.3	1.6	2.1	5.6	0.38	197.5
32	3S	4W	NE 1/4 Sec. 23	7.8	1.2	2.1	4.7	0.45	176.0
33	3S	4W	NW 1/4 Sec. 23	5.3	0.9	0.9	4.3	0.21	—
34	3S	4W	NE 1/4 Sec. 22	6.2	1.0	2.2	4.4	0.50	229.1
35	3S	4W	NW 1/4 Sec. 22	8.6	1.3	1.2	8.2	0.15	334.3
36	3S	4W	SW 1/4 Sec. 22	5.1	0.8	1.2	4.3	0.28	—
37	3S	4W	NW 1/4 Sec. 27	7.9	1.2	1.0	7.6	0.13	—
38	3S	4W	SW 1/4 Sec. 27	6.0	0.9	1.6	3.8	0.42	—
39	3S	4W	SE 1/4 Sec. 31	5.7	0.8	1.2	5.6	0.21	232.6
40	3S	4W	SW 1/4 Sec. 32	7.0	1.0	1.9	5.2	0.37	315.3
41	3S	4W	NE 1/4 Sec. 31	6.4	0.9	1.4	5.9	0.24	143.8
42	3S	4W	NW 1/4 Sec. 32	9.0	1.2	2.5	5.6	0.45	304.8
43	3S	4W	SE 1/4 Sec. 29	7.3	1.2	1.6	3.1	0.52	—

No.	Location T.	R.	Sec.	Total Counts (ppm)	K (%)	eU (ppm)	eTH (ppm)	eU/eTh	Soil-Gas Radon (pCi/L)
44	3S	4W	SW 1/4 Sec. 29	8.1	1.2	1.2	5.8	0.21	—
45	3S	4W	NW 1/4 Sec. 28	6.9	1.2	1.2	6.3	0.19	—
46	3S	4W	SW 1/4 Sec. 21	6.2	0.9	1.4	4.7	0.30	172.3
47	3S	4W	SE 1/4 Sec. 20	9.0	1.4	2.0	7.5	0.27	150.1
48	3S	4W	NE 1/4 Sec. 29	6.8	1.0	1.3	5.2	0.25	—
49	3S	4W	SW 1/4 Sec. 20	6.9	0.9	2.2	4.5	0.49	139.3
50	3S	4W	NE 1/4 Sec. 19	8.8	1.4	1.8	6.7	0.27	—
51	3S	4W	SW 1/4 Sec. 17	10.1	1.4	2.4	6.9	0.35	—
52	3S	4W	SW 1/4 Sec. 16	7.5	1.1	1.7	6.8	0.25	—
53	3S	4W	NE 1/4 Sec. 21	8.9	1.3	2.0	6.8	0.29	—
54	3S	4W	NW 1/4 Sec. 17	9.4	1.4	2.0	7.5	0.27	—
55	3S	4W	NW 1/4 Sec. 17	6.9	1.0	1.3	5.4	0.24	77.9
56	3S	4W	NE 1/4 Sec. 17	13.1	2.2	2.2	11.6	0.19	—
57	3S	4W	NW 1/4 Sec. 8	15.2	2.4	2.3	12.6	0.18	368.7
58	3S	4W	NW 1/4 Sec. 5	13.2	2.0	2.6	9.3	0.28	—
59	3S	4W	NE 1/4 Sec. 6	12.7	2.2	2.3	9.3	0.25	307.0
60	3S	4W	SE 1/4 Sec. 31	13.5	2.2	2.7	9.3	0.29	—
61	3S	4W	NW 1/4 Sec. 6	14.0	2.2	2.9	10.6	0.27	305.6
62	3S	5W	SE 1/4 Sec. 1	14.7	2.3	2.3	10.9	0.21	—
63	3S	4W	NW 1/4 Sec. 7	14.3	2.3	1.8	12.5	0.14	496.0
64	3S	4W	SE 1/4 Sec. 18	13.0	1.9	2.5	11.7	0.21	407.6
65	3S	5W	NE 1/4 Sec. 13	9.2	1.2	2.6	6.0	0.43	337.7
66	3S	5W	SW 1/4 Sec. 12	11.7	1.8	2.4	7.3	0.33	—
67	3S	5W	NW 1/4 Sec. 12	10.7	1.7	2.5	7.6	0.33	264.7
68	3S	5W	SW 1/4 Sec. 1	9.8	1.4	3.2	6.2	0.52	—
69	3S	5W	NW 1/4 Sec. 1	13.1	2.2	2.9	9.2	0.32	221.9
70	2S	5W	NW 1/4 Sec. 36	9.7	1.6	2.0	6.3	0.32	—
71	2S	5W	SW 1/4 Sec. 25	9.0	1.5	2.8	2.4	1.17	277.2
72	2S	4W	NW 1/4 Sec. 31	12.2	1.7	2.3	10.1	0.23	—
73	2S	4W	SW 1/4 Sec. 30	9.0	1.5	1.5	6.6	0.23	174.8
74	2S	4W	SE 1/4 Sec. 31	7.5	1.2	1.6	3.7	0.43	—
75	2S	4W	SE 1/4 Sec. 30	6.2	0.9	1.3	6.0	0.22	544.9
76	2S	4W	SE 1/4 Sec. 32	12.2	2.0	2.6	8.8	0.30	—
77	3S	4W	NE 1/4 Sec. 5	14.9	2.5	2.7	11.6	0.23	215.8
78	3S	4W	NE 1/4 Sec. 5	11.8	1.8	2.3	9.4	0.24	87.7
79	2S	4W	SE 1/4 Sec. 29	9.0	1.4	2.3	6.5	0.35	—
80	2S	4W	SW 1/4 Sec. 28	8.3	1.1	2.2	6.9	0.32	—
81	2S	4W	SE 1/4 Sec. 35	8.6	1.4	1.9	5.8	0.33	—
82	2S	4W	SW 1/4 Sec. 35	11.7	1.6	3.1	7.0	0.44	228.5
83	2S	4W	NW 1/4 Sec. 35	10.0	1.5	1.7	7.5	0.23	81.5
84	2S	4W	SW 1/4 Sec. 23	7.9	1.2	2.0	5.6	0.36	85.8
85	2S	4W	NE 1/4 Sec. 26	10.1	1.5	2.0	7.7	0.26	67.0
86	2S	4W	SE 1/4 Sec. 27	11.3	2.0	2.4	6.6	0.36	—
87	2S	4W	SW 1/4 Sec. 27	9.9	1.5	2.3	5.7	0.40	—
88	2S	4W	SE 1/4 Sec. 33	11.2	1.5	2.9	6.1	0.48	—
89	3S	4W	NE 1/4 Sec. 3	8.5	1.3	2.5	6.0	0.42	191.0
90	3S	4W	NE 1/4 Sec. 3	8.1	1.3	1.2	7.0	0.17	241.0
91	3S	4W	NE 1/4 Sec. 10	11.7	2.0	2.4	9.8	0.24	187.6

No.	Location T.	R.	Sec.	Total Counts (ppm)	K (%)	eU (ppm)	eTH (ppm)	eU/eTh	Soil-Gas Radon (pCi/L)
92	3S	4W	SW 1/4 Sec. 2	12.2	1.9	2.7	7.7	0.35	510.0
93	3S	4W	SE 1/4 Sec. 10	8.0	1.4	1.9	5.6	0.34	158.9
94	3S	4W	NE 1/4 Sec. 15	6.4	1.0	1.0	4.7	0.21	75.7
95	3S	4W	NW 1/4 Sec. 13	6.8	1.1	2.0	3.5	0.57	—
96	3S	4W	NW 1/4 Sec. 12	9.2	1.3	3.0	5.8	0.52	—
97	3S	4W	SW 1/4 Sec. 10	8.4	1.1	1.9	5.5	0.35	—
98	3S	4W	NE 1/4 Sec. 16	8.1	1.3	1.9	6.0	0.32	—
99	3S	4W	NW 1/4 Sec. 16	8.3	1.3	1.4	5.9	0.24	—
100	3S	4W	SE 1/4 Sec. 9	7.7	1.3	1.5	5.6	0.27	—
101	3S	4W	SW 1/4 Sec. 3	7.5	1.1	2.4	3.2	0.75	—
102	3S	4W	NW 1/4 Sec. 3	5.4	0.8	1.7	2.6	0.65	—
103	2S	4W	NW 1/4 Sec. 27	11.1	1.5	2.5	10.2	0.25	—
104	3S	6W	NE 1/4 Sec. 35	5.5	0.7	1.1	5.6	0.20	244.6
105	4S	6W	NE 1/4 Sec. 2	6.2	0.9	1.5	5.0	0.30	54.2
106	3S	6W	NW 1/4 Sec. 35	8.6	1.0	1.7	7.8	0.22	—
107	4S	6W	NW 1/4 Sec. 2	12.8	2.0	1.9	9.6	0.20	87.1
108	3S	6W	NW 1/4 Sec. 26	8.6	1.2	1.2	7.9	0.15	47.3
109	3S	6W	SW 1/4 Sec. 23	9.8	1.5	2.1	7.1	0.30	115.4
110	3S	6W	NW 1/4 Sec. 23	15.1	2.3	1.8	13.6	0.13	109.9
111	3S	6W	SE 1/4 Sec. 11	12.9	2.0	3.0	10.2	0.29	—
112	3S	6W	NW 1/4 Sec. 12	9.0	1.4	1.1	9.5	0.12	—
113	3S	6W	NW 1/4 Sec. 1	8.8	1.2	1.4	7.9	0.18	—
114	3S	6W	NW 1/4 Sec. 24	12.9	2.2	1.0	11.6	0.09	103.3
115	3S	6W	SE 1/4 Sec. 13	13.8	2.1	3.0	10.7	0.28	138.2
116	3S	6W	NW 1/4 Sec. 18	12.3	1.8	3.0	10.4	0.29	231.8
117	3S	6W	NE 1/4 Sec. 13	13.6	1.9	2.7	11.3	0.24	224.0
118	3S	6W	SW 1/4 Sec. 11	12.3	1.9	2.5	11.3	0.22	126.5
119	3S	6W	SW 1/4 Sec. 2	14.5	2.2	2.4	11.2	0.21	102.8
120	2S	6W	NW 1/4 Sec. 35	13.1	1.9	2.4	11.5	0.21	122.1
121	3S	6W	NE 1/4 Sec. 35	13.7	1.9	2.5	10.5	0.24	—
122	2S	6W	SE 1/4 Sec. 36	13.0	2.0	2.7	10.6	0.25	—
123	2S	5W	SW 1/4 Sec. 31	10.9	1.6	2.9	8.5	0.34	—
124	2S	5W	SW 1/4 Sec. 32	9.7	1.4	1.8	7.9	0.23	—
125	2S	5W	SW 1/4 Sec. 33	13.6	1.3	5.1	11.2	0.46	—
126	3S	5W	NW 1/4 Sec. 7	11.5	1.8	2.0	10.8	0.19	156.6
127	3S	5W	NW 1/4 Sec. 6	8.5	1.2	1.7	6.8	0.25	—
128	3S	6W	SE 1/4 Sec. 1	15.1	2.2	3.6	11.6	0.31	175.8
129	3S	5W	NW 1/4 Sec. 5	15.0	2.2	2.5	13.5	0.19	370.9
130	3S	5W	SW 1/4 Sec. 5	13.2	1.9	2.6	11.7	0.22	141.3
131	3S	5W	NW 1/4 Sec. 4	10.1	1.4	2.5	8.1	0.31	441.0
132	3S	5W	SW 1/4 Sec. 3	11.0	1.6	2.6	7.2	0.36	171.5
133	3S	5W	NW 1/4 Sec. 3	12.3	2.0	2.3	7.5	0.31	345.5
134	2S	5W	SE 1/4 Sec. 33	11.0	1.3	2.9	9.0	0.32	—
135	2S	5W	NW 1/4 Sec. 34	11.3	1.9	2.0	7.2	0.28	—
136	2S	5W	SE 1/4 Sec. 34	11.6	1.6	3.3	9.5	0.35	—
137	2S	5W	NE 1/4 Sec. 35	12.9	2.2	2.7	9.8	0.28	—
138	2S	6W	NW 1/4 Sec. 26	10.3	1.4	2.7	8.3	0.33	143.0
139	2S	6W	SE 1/4 Sec. 26	12.0	1.7	2.2	8.8	0.25	153.3

No.	Location T.	R.	Sec.	Total Counts (ppm)	K (%)	eU (ppm)	eTH (ppm)	eU/eTh	Soil-Gas Radon (pCi/L)
140	2S	6W	NW 1/4 Sec. 25	10.4	1.8	1.7	8.7	0.20	—
141	2S	6W	SE 1/4 Sec. 25	10.5	1.6	1.8	10.9	0.17	147.4
142	2S	6W	SE 1/4 Sec. 24	13.1	1.9	2.2	11.5	0.19	149.8
143	2S	5W	SW 1/4 Sec. 30	12.1	1.8	1.7	11.6	0.15	433.6
144	2S	5W	SE 1/4 Sec. 19	6.7	1.0	1.8	3.4	0.53	157.7
145	2S	5W	SW 1/4 Sec. 29	9.5	1.5	1.1	9.9	0.11	—
146	2S	5W	SW 1/4 Sec. 29	9.2	1.4	2.3	7.7	0.30	90.8
147	2S	5W	NE 1/4 Sec. 29	9.6	1.4	1.8	8.7	0.21	—
148	2S	5W	SW 1/4 Sec. 26	7.5	1.1	2.0	4.7	0.43	—
149	3S	5W	SE 1/4 Sec. 11	13.3	2.1	2.0	10.7	0.19	167.8
150	3S	5W	SE 1/4 Sec. 10	12.4	1.9	2.2	10.0	0.22	96.6
151	3S	5W	SW 1/4 Sec. 10	11.9	1.9	3.0	8.9	0.34	240.0
152	3S	5W	SW 1/4 Sec. 9	13.9	2.4	3.1	8.9	0.35	238.6
153	3S	5W	SE 1/4 Sec. 8	12.7	2.0	2.2	11.4	0.19	729.3
154	3S	5W	SE 1/4 Sec. 7	13.7	2.1	2.2	12.1	0.18	135.4
155	4S	6W	NW 1/4 Sec. 10	13.3	2.1	2.4	10.2	0.24	147.9
156	4S	6W	SW 1/4 Sec. 3	13.2	2.1	2.9	9.6	0.30	—
157	3S	6W	SE 1/4 Sec. 34	13.2	2.1	2.5	10.9	0.23	—
158	3S	6W	SE 1/4 Sec. 33	9.2	1.3	2.1	8.6	0.24	—
159	3S	6W	NW 1/4 Sec. 34	11.8	1.6	2.9	10.4	0.28	—
160	3S	6W	SW 1/4 Sec. 26	9.6	1.4	1.4	9.1	0.15	—
161	3S	6W	NE 1/4 Sec. 21	15.0	2.3	2.1	13.2	0.16	125.6
162	3S	6W	SE 1/4 Sec. 22	13.0	1.9	3.0	11.9	0.25	—
163	3S	6W	SE 1/4 Sec. 16	9.6	1.3	2.1	7.7	0.27	78.1
164	3S	6W	SW 1/4 Sec. 10	14.8	2.2	2.7	13.5	0.20	—
165	3S	6W	SW 1/4 Sec. 9	13.7	2.1	2.6	13.4	0.19	—
166	2S	6W	SE 1/4 Sec. 27	9.7	1.4	2.5	6.4	0.39	—
167	2S	6W	SW 1/4 Sec. 34	11.0	1.5	2.0	9.3	0.22	—
168	2S	6W	SE 1/4 Sec. 32	10.2	1.5	1.9	8.8	0.22	—
169	2S	6W	NE 1/4 Sec. 32	10.2	1.5	2.9	7.8	0.37	—
170	2S	6W	SE 1/4 Sec. 28	10.8	1.6	2.4	8.1	0.30	—
171	2S	6W	SE 1/4 Sec. 22	12.6	1.8	3.3	9.6	0.34	—
172	2S	6W	SE 1/4 Sec. 21	13.0	2.0	2.5	12.6	0.20	184.7
173	2S	6W	NW 1/4 Sec. 22	11.7	1.9	2.9	7.3	0.40	186.4
174	2S	6W	NE 1/4 Sec. 20	7.4	1.0	2.4	5.3	0.45	—
175	2S	6W	SW 1/4 Sec. 16	4.2	0.5	1.4	3.7	0.38	80.6
176	2S	6W	SW 1/4 Sec. 9	11.9	1.6	2.3	9.7	0.24	349.8
177	2S	6W	SE 1/4 Sec. 8	10.6	1.8	1.9	8.3	0.23	134.7
178	2S	6W	SW 1/4 Sec. 4	13.6	2.0	4.2	8.8	0.48	377.3
179	2S	6W	NE 1/4 Sec. 5	13.5	2.2	2.2	11.7	0.19	—
180	1S	6W	SW 1/4 Sec. 33	7.3	1.0	1.2	7.2	0.17	—
181	1S	6W	NW 1/4 Sec. 33	7.8	1.2	2.1	5.1	0.41	—
182	1S	6W	NE 1/4 Sec. 28	7.5	1.0	2.4	4.3	0.56	—
183	1S	6W	NW 1/4 Sec. 26	8.0	1.1	1.8	6.4	0.28	—
184	2S	4W	SW 1/4 Sec. 19	7.4	1.1	1.5	6.0	0.25	69.3
185	2S	4W	NW 1/4 Sec. 20	7.9	1.2	2.5	4.0	0.63	283.6
186	2S	4W	SE 1/4 Sec. 17	9.7	1.5	2.6	6.0	0.43	720.6
187	2S	4W	NE 1/4 Sec. 16	9.6	1.4	2.6	5.9	0.44	—

No.	Location T.	R.	Sec.	Total Counts (ppm)	K (%)	eU (ppm)	eTH (ppm)	eU/eTh	Soil-Gas Radon (pCi/L)
188	2S	4W	NW 1/4 Sec. 21	7.6	1.1	1.9	6.0	0.32	—
189	2S	4W	NW 1/4 Sec. 14	7.4	0.8	2.5	4.8	0.52	158.0
190	2S	4W	SW 1/4 Sec. 14	9.4	1.4	3.4	6.2	0.55	—
191	2S	4W	NW 1/4 Sec. 23	11.7	1.9	2.1	8.9	0.24	145.8
192	2S	4W	SE 1/4 Sec. 14	9.7	1.6	2.5	5.9	0.42	99.6
193	2S	4W	SW 1/4 Sec. 12	13.3	2.1	2.5	9.7	0.26	244.0
194	2S	4W	NW 1/4 Sec. 12	10.1	1.6	3.7	4.5	0.82	162.5
195	2S	4W	NW 1/4 Sec. 11	12.5	1.9	2.6	8.5	0.31	844.4
196	2S	4W	NW 1.4 Sec. 1	9.8	1.6	2.3	5.8	0.40	221.0
197	1S	4W	NW 1/4 Sec. 36	7.1	1.0	2.7	3.1	0.87	—
198	2S	4W	NW 1/4 Sec. 2	10.9	1.7	2.0	8.1	0.25	68.4
199	2S	4W	SE 1/4 Sec. 3	8.5	1.2	2.4	7.4	0.32	—
200	2S	4W	SW 1/4 Sec. 10	13.3	2.0	2.0	10.4	0.19	—
201	2S	4W	NW 1/4 Sec. 22	10.8	1.8	2.9	7.8	0.37	—
202	2S	5W	NW 1/4 Sec. 19	7.8	1.2	0.9	7.1	0.13	247.9
203	2S	5W	NE 1/4 Sec. 8	5.8	0.8	2.0	3.5	0.57	91.8
204	2S	5W	SW 1/4 Sec. 5	7.2	1.0	2.0	6.4	0.31	329.4
205	2S	5W	SW 1/4 Sec. 6	7.4	1.0	2.2	6.4	0.34	245.7
206	2S	6W	SW 1/4 Sec. 1	9.8	1.5	2.5	5.7	0.44	193.1
207	2S	5W	NW 1/4 Sec. 6	6.7	0.5	4.4	3.0	1.47	459.5
208	1S	5W	SE 1/4 Sec. 31	8.1	1.1	2.6	5.6	0.46	—
209	2S	5W	NW 1/4 Sec. 5	4.4	0.4	1.9	2.3	0.83	—
210	2S	5W	SW 1/4 Sec. 7	10.1	1.3	2.5	8.1	0.31	—
211	2S	5W	SW 1/4 Sec. 18	9.0	1.2	2.7	6.2	0.44	—

Radiometric Data
Southeastern Cache 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.

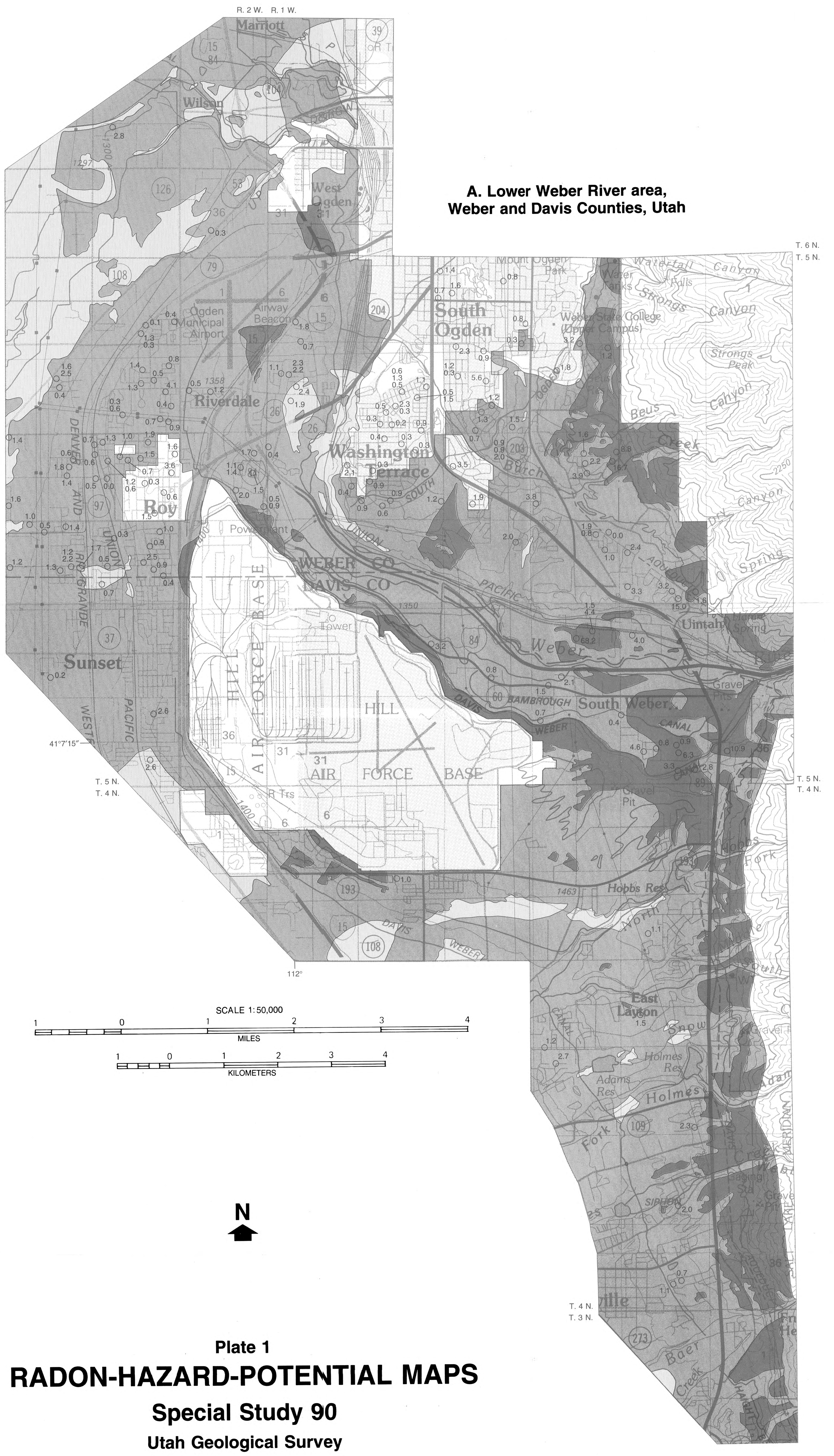
No.	Location T.	R.	Sec.	Total Counts (ppm)	K (%)	eU (ppm)	eTH (ppm)	eU/eTh	Soil-Gas Radon (pCi/L)
1	11N	1E	SW 1/4 Sec. 27	7.3	0.9	2.9	3.8	0.76	—
2	11N	1E	NE 1/4 Sec. 27	11.9	1.9	2.1	9.5	0.22	—
3	11N	1E	NE 1/4 Sec. 27	10.5	1.5	2.2	8.4	0.26	—
4	11N	1E	NE 1/4 Sec. 27	10.4	1.6	2.2	8.8	0.25	259.07
5	11N	1E	NE 1/4 Sec. 27	6.1	0.8	2.0	4.4	0.45	—
6	11N	1E	NE 1/4 Sec. 34	10.9	1.6	3.0	7.3	0.41	—
7	11N	1E	NE 1/4 Sec. 34	13.6	2.0	3.2	9.7	0.33	194.50
8	11N	1E	SW 1/4 Sec. 26	7.7	1.0	1.8	5.3	0.34	—
9	11N	1E	NE 1/4 Sec. 26	5.5	0.9	1.7	3.2	0.53	—
10	11N	1E	NE 1/4 Sec. 26	7.0	1.1	1.1	5.7	0.19	147.21
11	11N	1E	SW 1/4 Sec. 23	7.4	1.0	2.5	4.8	0.52	114.30
12	11N	1E	SW 1/4 Sec. 22	6.6	0.8	2.2	4.1	0.54	—
13	11N	1E	NW 1/4 Sec. 27	5.8	0.7	1.6	4.7	0.34	—
14	11N	1E	NE 1/4 Sec. 33	8.2	1.4	1.6	5.5	0.29	—
15	11N	1E	SW 1/4 Sec. 29	12.4	1.8	2.5	10.2	0.25	151.78
16	11N	1E	SW 1/4 Sec. 28	10.5	1.6	2.5	7.6	0.33	547.49
17	11N	1E	NW 1/4 Sec. 29	13.9	2.3	2.5	12.0	0.21	219.50
18	11N	1E	NW 1/4 Sec. 29	8.1	1.1	2.2	6.6	0.33	270.27
19	11N	1E	NE 1/4 Sec. 29	8.3	1.3	2.5	5.2	0.48	—
20	11N	1E	NE 1/4 Sec. 29	13.4	2.0	3.9	7.8	0.50	—
21	11N	1E	NE 1/4 Sec. 28	8.9	1.4	2.5	7.0	0.36	117.01
22	11N	1E	NE 1/4 Sec. 28	8.0	1.0	2.2	5.8	0.38	309.20
23	11N	1E	NW 1/4 Sec. 32	14.5	2.1	3.4	10.8	0.31	—
24	11N	1E	SW 1/4 Sec. 29	14.6	2.1	2.3	12.6	0.18	128.85
25	11N	1E	NW 1/4 Sec. 29	13.5	2.1	2.2	9.6	0.23	269.37
26	11N	1E	SW 1/4 Sec. 20	14.2	2.1	3.0	12.6	0.24	262.76
27	11N	1E	SW 1/4 Sec. 20	6.8	0.9	2.4	6.1	0.39	—
28	11N	1E	NE 1/4 Sec. 21	6.9	0.9	2.9	4.1	0.71	204.82
29	11N	1E	NE 1/4 Sec. 21	6.6	1.0	2.2	4.7	0.47	69.38
30	11N	1E	NE 1/4 Sec. 20	5.9	0.6	2.0	3.9	0.51	—
31	11N	1E	NE 1/4 Sec. 20	8.0	1.0	2.8	3.6	0.78	84.01
32	11N	1E	NW 1/4 Sec. 20	8.8	1.4	2.0	6.5	0.31	150.40
33	11N	1E	NE 1/4 Sec. 20	8.0	1.2	2.5	4.8	0.52	174.11
34	11N	1E	SE 1/4 Sec. 16	5.0	0.6	2.0	4.0	0.50	—
35	11N	1E	NE 1/4 Sec. 21	6.3	0.8	1.6	5.6	0.29	235.91
36	11N	1E	SW 1/4 Sec. 22	11.0	1.5	2.9	9.2	0.32	—
37	11N	1E	SE 1/4 Sec. 22	6.3	1.0	2.1	3.8	0.55	—
38	11N	1E	NW 1/4 Sec. 23	13.4	1.9	3.3	10.8	0.31	—
39	11N	1E	NE 1/4 Sec. 23	5.4	0.7	1.2	4.8	0.25	—
40	11N	1E	SW 1/4 Sec. 23	6.2	0.7	2.9	3.7	0.78	—
41	11N	1E	SW 1/4 Sec. 23	5.8	0.7	2.5	3.4	0.74	—
42	11N	1E	SW 1/4 Sec. 23	8.0	1.1	2.7	4.9	0.55	—
43	11N	1E	SE 14 Sec. 23	5.3	0.6	2.1	2.9	0.72	—

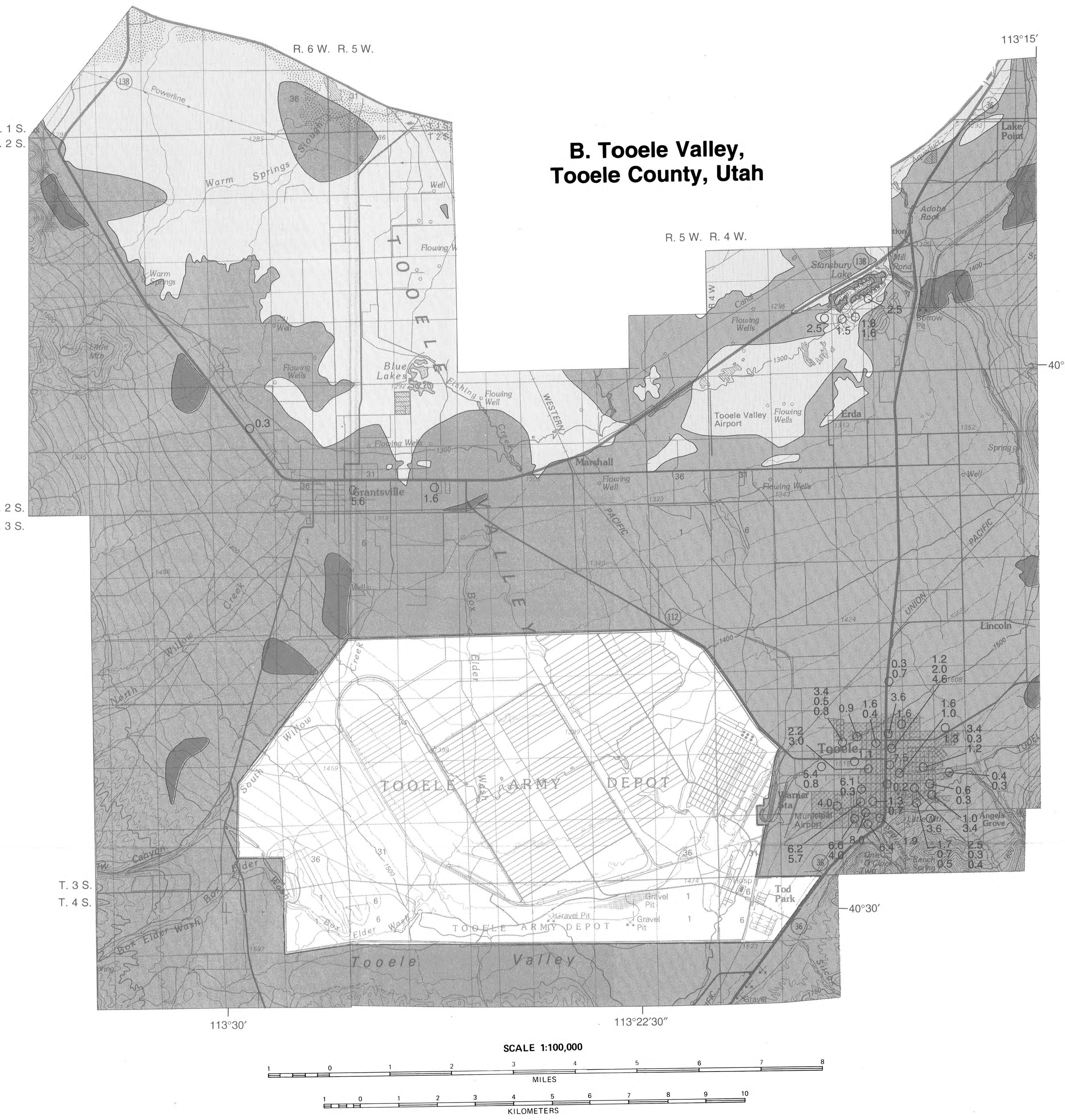
No.	Location T.	R.	Sec.	Total Counts (ppm)	K (%)	eU (ppm)	eTH (ppm)	eU/eTh	Soil-Gas Radon (pCi/L)
44	11N	1E	NE 1/4 Sec. 23	8.7	1.0	1.8	9.1	0.20	—
45	11N	1E	SW 1/4 Sec. 22	12.2	1.8	2.2	11.0	0.20	262.79
46	11N	1E	SW 1/4 Sec. 22	11.7	1.7	2.4	10.2	0.24	287.05
47	11N	1E	SE 1/4 Sec. 22	8.9	1.1	2.1	7.0	0.30	523.19
48	11N	1E	SE 1/4 Sec. 22	9.1	1.3	2.6	7.0	0.37	—
49	11N	1E	SE 1/4 Sec. 22	10.2	1.3	3.3	7.2	0.46	—
50	11N	1E	SW 1/4 Sec. 23	8.8	1.2	2.9	5.3	0.55	—
51	11N	1E	SE 1/4 Sec. 22	10.2	1.3	3.5	7.6	0.46	233.40
52	11N	1E	SE 1/4 Sec. 22	6.9	0.8	2.8	5.1	0.55	—
53	11N	1E	SW 1/4 Sec. 22	8.1	0.9	2.5	5.5	0.45	—
54	11N	1E	SW 1/4 Sec. 22	9.1	1.3	1.7	8.5	0.20	132.15
55	11N	1E	SW 1/4 Sec. 22	11.9	1.8	2.7	7.7	0.35	696.54
56	11N	1E	SE 1/4 Sec. 22	10.9	1.7	3.0	7.8	0.38	—
57	11N	1E	SE 1/4 Sec. 22	10.1	1.6	2.2	6.9	0.32	177.07
58	11N	1E	NE 1/4 Sec. 22	11.1	1.7	2.6	8.1	0.32	—
59	11N	1E	NE 1/4 Sec. 22	10.6	1.5	2.6	7.7	0.34	—
60	11N	1E	NW 1/4 Sec. 22	8.8	1.3	2.1	7.2	0.29	—
61	11N	1E	NW 1/4 Sec. 22	10.5	1.5	1.9	9.8	0.19	320.04
62	11N	1E	NW 1/4 Sec. 22	8.8	1.1	2.9	6.6	0.44	—
63	11N	1E	NW 1/4 Sec. 22	5.9	0.6	2.8	3.8	0.74	—
64	11N	1E	NW 1/4 Sec. 22	10.8	1.8	2.3	6.8	0.34	280.85
65	11N	1E	NE 1/4 Sec. 22	13.2	2.1	3.1	8.2	0.38	359.88
66	11N	1E	SW 1/4 Sec. 23	11.1	1.7	2.3	8.9	0.26	—
67	11N	1E	NE 1/4 Sec. 22	8.9	1.3	3.0	6.1	0.49	1039.91
68	11N	1E	NE 1/4 Sec. 22	10.8	1.6	2.6	9.0	0.29	—
69	11N	1E	NE 1/4 Sec. 22	10.8	1.5	2.8	8.7	0.32	—
70	11N	1E	NW 1/4 Sec. 22	11.4	1.8	2.3	9.8	0.23	253.65
71	11N	1E	NW 1/4 Sec. 22	8.5	1.2	2.5	5.4	0.46	463.12
72	11N	1E	NW 1/4 Sec. 22	11.5	1.7	2.5	9.2	0.27	262.24
73	11N	1E	NW 1/4 Sec. 22	12.4	1.8	3.0	9.4	0.32	292.45
74	11N	1E	NE 1/4 Sec. 22	10.5	1.4	2.6	7.0	0.37	259.25
75	11N	1E	NE 1/4 Sec. 22	11.9	1.7	2.0	10.8	0.19	244.16
76	11N	1E	SE 1/4 Sec. 15	8.6	1.2	2.4	6.6	0.36	—
77	11N	1E	SE 1/4 Sec. 15	9.4	1.4	1.8	6.4	0.28	—
78	11N	1E	SE 1/4 Sec. 15	10.0	1.5	2.1	8.4	0.25	—
79	11N	1E	SW 1/4 Sec. 15	11.5	1.7	3.5	6.7	0.52	—
80	11N	1E	SW 1/4 Sec. 15	10.4	1.6	2.0	7.1	0.28	201.14
81	11N	1E	SW 1/4 Sec. 15	7.8	1.2	1.7	5.4	0.31	—
82	11N	1E	SW 1/4 Sec. 15	10.4	1.4	2.7	7.7	0.35	327.99
83	11N	1E	SE 1/4 Sec. 15	9.5	1.4	3.1	5.2	0.60	—
84	11N	1E	SE 1/4 Sec. 15	7.8	1.0	2.7	4.1	0.66	—
85	11N	1E	SE 1/4 Sec. 15	11.9	1.6	3.3	10.0	0.33	—
86	11N	1E	SW 1/4 Sec. 15	7.9	1.0	2.7	5.3	0.51	—
87	11N	1E	SW 1/4 Sec. 15	13.2	2.0	3.1	9.7	0.32	365.60
88	11N	1E	NW 1/4 Sec. 15	13.2	2.0	3.3	10.4	0.32	405.55
89	11N	1E	NE 1/4 Sec. 17	5.2	0.6	1.6	4.4	0.36	272.34
90	11N	1E	NW 1/4 Sec. 17	5.5	0.7	1.6	4.5	0.36	—
91	11N	1E	SW 1/4 Sec. 17	4.6	0.6	2.0	1.6	1.25	—

No.	Location T.	R.	Sec.	Total Counts (ppm)	K (%)	eU (ppm)	eTH (ppm)	eU/eTh	Soil-Gas Radon (pCi/L)
92	11N	1E	SW 1/4 Sec. 17	5.3	0.6	2.3	3.7	0.62	146.60
93	11N	1E	SW 1/4 Sec. 16	4.5	0.6	1.4	3.1	0.45	—
94	11N	1E	NW 1/4 Sec. 16	3.7	0.3	1.6	2.8	0.57	—
95	11N	1E	SW 1/4 Sec. 9	8.4	1.0	2.4	5.7	0.42	666.64
96	11N	1E	NE 1/4 Sec. 16	9.5	1.3	2.5	7.5	0.33	1266.09
97	11N	1E	NE 1/4 Sec. 16	9.9	1.6	2.1	6.7	0.31	1864.08
98	11N	1E	SE 1/4 Sec. 16	5.9	0.7	2.0	5.0	0.40	221.38
99	11N	1E	SE 1/4 Sec. 10	7.8	1.2	2.3	4.8	0.48	1438.81
100	11N	1E	SE 1/4 Sec. 2	5.0	0.8	1.0	3.2	0.31	—
101	11N	1E	NE 1/4 Sec. 11	14.9	2.7	2.8	6.9	O.41	—
102	11N	1E	NE 1/4 Sec. 11	5.0	0.7	0.8	6.6	0.12	170.86
103	11N	1E	SW 1/4 Sec. 12	6.4	0.9	1.9	4.8	0.40	—
104	11N	1E	SW 1/4 Sec. 13	4.3	0.6	1.4	3.1	0.45	—
105	11N	1E	SE 1/4 Sec. 14	8.2	1.3	2.5	3.9	0.64	—
106	11N	1E	SW 1/4 Sec. 14	10.9	1.5	2.9	8.7	0.33	624.23
107	11N	1E	NE 1/4 Sec. 15	7.1	1.0	1.7	6.3	0.27	—
108	11N	1E	SW 1/4 Sec. 11	6.8	1.1	1.8	5.0	0.36	—
109	11N	1E	NW 1/4 Sec. 11	6.3	1.0	1.2	4.3	0.28	—
110	11N	1E	NW 1/4 Sec. 11	4.5	0.7	1.5	2.5	0.60	—
111	11N	1E	SW 1/4 Sec. 4	4.6	0.6	1.0	3.5	0.29	296.25
112	11N	1E	NW 1/4 Sec. 9	7.2	1.1	1.7	6.0	0.28	146.98
113	11N	1E	SE 1/4 Sec. 5	3.6	0.5	1.4	2.6	0.54	—
114	11N	1E	NE 1/4 Sec. 8	3.5	0.5	1.4	2.7	0.52	—
115	11N	1E	SW 1/4 Sec. 8	5.3	0.7	1.1	3.9	0.28	1707.61
116	11N	1E	SE 1/4 Sec. 8	4.1	0.6	1.1	3.5	0.31	—
117	11N	1E	SW 1/4 Sec. 9	6.7	1.0	1.2	4.9	0.24	—
118	11N	1E	SE 1/4 Sec. 9	8.6	1.2	2.4	5.8	0.41	794.99
119	11N	1E	SE 1/4 Sec. 10	6.1	1.0	1.4	3.9	0.36	546.36
120	11N	1E	NW 1/4 Sec. 10	5.0	0.8	1.4	3.8	0.37	499.62
121	11N	1E	NE 1/4 Sec. 10	6.1	1.0	1.1	5.4	0.20	—
122	11N	1E	NE 1/4 Sec. 9	4.2	0.7	1.3	3.1	0.42	567.57
123	11N	1E	NW 1/4 Sec. 8	5.3	0.7	1.9	3.6	0.53	—
124	11N	1E	SE 1/4 Sec. 6	4.2	0.5	1.8	2.2	0.82	548.27
125	11N	1E	NE 1/4 Sec. 6	11.0	1.4	2.8	10.3	0.27	434.75
126	11N	1E	NE 1/4 Sec. 5	6.5	0.8	2.7	4.9	0.55	132.09
127	11N	1E	SE 1/4 Sec. 5	5.7	0.7	1.3	5.1	0.25	367.38
128	11N	1E	NE 1/4 Sec. 5	6.7	1.0	1.4	6.1	0.23	—
129	11N	1E	NE 1/4 Sec. 5	4.5	0.5	1.3	4.1	0.32	244.48
130	11N	1E	NW 1/4 Sec. 4	5.9	0.9	1.8	5.1	0.35	—
131	11N	1E	SW 1/4 Sec. 4	4.8	0.7	1.5	2.6	0.58	217.00
132	11N	1E	SW 1/4 Sec. 3	4.2	0.5	1.0	4.0	0.25	287.04
133	11N	1E	SE 1/4 Sec. 3	6.5	1.0	1.9	3.9	0.49	—
134	11N	1E	SW 1/4 Sec. 34	5.5	0.7	1.8	3.9	0.46	—
135	11N	1E	SE 1/4 Sec. 34	5.2	0.6	1.8	3.3	0.55	489.26
136	11N	1E	SE 1/4 Sec. 3	8.2	1.4	2.2	5.5	0.40	—
137	11N	1E	NW 1/4 Sec. 2	8.2	1.2	1.8	8.1	0.22	—
138	12 N	1E	SE 1/4 Sec. 34	4.1	0.7	1.2	2.1	0.57	226.63
139	11N	1E	NW 1/4 Sec. 2	8.6	1.2	2.3	4.7	0.49	—

No.	Location T.	R.	Sec.	Total Counts (ppm)	K (%)	eU (ppm)	eTH (ppm)	eU/eTh	Soil-Gas Radon (pCi/L)
140	11N	1E	NW 1/4 Sec. 1	6.5	1.1	1.3	5.1	0.25	—
141	11N	1E	NW 1/4 Sec. 1	8.7	1.3	1.5	7.7	0.19	130.12
142	11N	1E	NE 1/4 Sec. 1	5.4	0.8	1.8	3.2	0.56	—
143	12N	1E	SE 1/4 Sec. 36	4.8	0.6	1.4	3.1	0.45	41.92
144	12N	1E	SW 1/4 Sec. 36	8.9	1.3	1.8	8.8	0.20	—
145	12N	1E	NW 1/4 Sec. 36	4.7	0.7	1.5	2.4	0.63	—
146	12N	1E	NE 1/4 Sec. 36	4.9	0.7	1.5	2.7	0.56	200.51
147	12N	1E	NW 1/4 Sec. 36	7.0	0.9	3.1	3.5	0.89	—
148	12N	1E	NE 1/4 Sec. 35	6.6	0.9	2.7	3.3	0.82	—
149	12N	1E	SW 1/4 Sec. 26	8.1	0.9	3.8	5.5	0.69	—
150	12N	1E	SW 1/4 Sec. 27	7.8	1.1	2.6	5.4	0.48	259.62
151	12N	1E	NW 1/4 Sec. 34	6.9	1.1	1.5	4.3	0.35	725.02
152	12N	1E	NW 1/4 Sec. 33	5.6	0.8	1.1	4.1	0.27	—
153	12N	1E	SE 1/4 Sec. 33	6.4	0.9	2.0	4.4	0.45	—
154	12N	1E	NE 1/4 Sec. 33	4.6	0.6	1.5	1.9	0.79	919.27
155	12N	1E	SE 1/4 Sec. 34	7.1	1.0	1.3	6.9	0.19	248.09
156	12N	1E	SW 1/4 Sec. 35	4.1	0.5	2.0	3.7	0.54	—
157	12N	1E	SW 1/4 Sec. 35	4.8	0.7	1.6	2.3	0.70	—
158	12N	1E	SE 1/4 Sec. 35	10.0	1.7	1.5	8.3	0.18	158.44
159	12N	1E	SE 1/4 Sec. 31	7.9	1.1	2.1	5.3	0.40	997.51
160	12N	1E	SE 1/4 Sec. 32	4.3	0.6	1.5	2.4	0.63	1205.62
161	12N	1E	SW 1/4 Sec. 33	6.9	0.9	2.3	4.4	0.52	342.28
162	12N	1E	NW 1/4 Sec. 33	9.7	1.5	1.7	7.1	0.24	201.55
163	12N	1E	NW 1/4 Sec. 32	4.7	0.7	1.3	2.7	0.48	—
164	12N	1E	NE 1/4 Sec. 31	6.1	0.9	1.9	4.4	0.43	732.93
165	12N	1E	NE 1/4 Sec. 30	6.7	0.8	1.7	5.1	0.33	—
166	12N	1E	NW 1/4 Sec. 29	4.5	0.7	1.2	3.5	0.34	—
167	12N	1E	SW 1/4 Sec. 29	11.0	1.6	1.7	10.2	0.17	—
168	12N	1E	NE 1/4 Sec. 28	7.2	1.0	1.5	7.1	0.21	790.77
169	12N	1E	SW 1/4 Sec. 27	5.5	0.9	1.5	3.1	0.48	—
170	12N	1E	SW 1/4 Sec. 27	5.1	0.7	1.3	3.4	0.38	187.31
171	12N	1E	NE 1/4 Sec. 27	5.9	0.7	2.3	3.7	0.62	—
172	12N	1E	NE 1/4 Sec. 26	8.3	1.2	2.1	5.1	0.41	260.50
173	12N	1E	SE 1/4 Sec. 26	6.1	0.9	1.5	4.3	0.35	200.98
174	12N	1E	SW 1/4 Sec. 25	7.2	1.1	2.1	5.3	0.40	566.57
175	12N	1E	NW 1/4 Sec. 25	6.8	1.0	2.0	5.6	0.36	843.42
176	12N	1E	SW 1/4 Sec. 24	7.5	1.3	1.5	6.0	0.25	674.45
177	12N	1E	NE 1/4 Sec.26	7.5	1.1	1.9	6.7	0.28	—
178	12N	1E	SW 1/4 Sec. 23	7.6	1.2	2.0	6.3	0.32	—
179	12N	1E	NW 1/4 Sec. 27	11.6	2.0	2.5	9.3	0.27	1050.22
180	12N	1E	NE 1/4 Sec. 28	8.1	1.3	1.6	6.7	0.24	749.49
181	12N	1E	NW 1/4 Sec. 28	8.0	1.0	2.7	4.2	0.64	—
182	12N	1E	NW 1/4 Sec. 28	8.8	1.3	2.3	6.2	0.37	—
183	12N	1E	NE 1/4 Sec. 29	7.2	1.1	1.6	5.6	0.29	—
184	12N	1E	NE 1/4 Sec. 30	7.4	0.8	2.1	5.0	0.42	461.47
185	12N	1E	SW 1/4 Sec. 20	5.9	0.7	2.6	2.0	1.30	57.56
186	12N	1E	SW 1/4 Sec. 20	5.0	0.8	1.7	2.6	0.65	206.85
187	12N	1E	NE 1/4 Sec. 20	7.8	1.1	1.7	6.1	0.28	—

No.	Location T.	R.	Sec.	Total Counts (ppm)	K (%)	eU (ppm)	eTH (ppm)	eU/eTh	Soil-Gas Radon (pCi/L)
188	12N	1E	SW 1/4 Sec. 21	9.8	1.3	2.7	6.4	0.42	429.60
189	12N	1E	SE 1/4 Sec. 21	10.2	1.6	2.1	8.9	0.24	—
190	12N	1E	SE 1/4 Sec. 22	11.3	1.9	1.9	7.4	0.26	—
191	12N	1E	SW 1/4 Sec. 23	7.9	1.3	2.1	4.4	0.48	452.52
192	12N	1E	SE 1/4 Sec. 23	7.5	1.2	1.0	6.1	0.16	199.87
193	12N	1E	SE 1/4 Sec. 23	6.0	0.8	1.3	4.3	0.30	304.93
194	12N	1E	SW 1/4 Sec. 24	7.5	1.3	1.5	5.4	0.28	—
195	12N	1E	NW 1/4 Sec. 19	4.9	0.7	1.2	3.4	0.35	—
196	12N	1E	NE 1/4 Sec. 24	13.0	2.0	2.0	10.5	0.19	—
197	12N	1E	NW 1/4 Sec. 24	10.3	1.5	2.8	8.3	0.34	—
198	12N	1E	NW 1/4 Sec. 24	5.6	0.9	0.8	5.8	0.14	—
199	12N	1E	SW 1/4 Sec. 14	4.9	0.7	1.3	2.7	0.48	—
200	12N	1E	SW 1/4 Sec. 14	7.1	1.2	1.3	5.8	0.22	216.14
201	12N	1E	SE 1/4 Sec. 15	7.0	1.0	2.2	4.7	0.47	766.37
202	12N	1E	NE 1/4 Sec. 21	9.5	1.4	1.7	9.2	0.18	—
203	12N	1E	NE 1/4 Sec. 21	4.7	0.8	0.8	3.7	0.22	233.09
204	12N	1E	SW 1/4 Sec. 16	8.0	1.2	1.2	6.2	0.19	—
205	12N	1E	SE 1/4 Sec. 17	7.7	1.1	2.4	4.3	0.56	—
206	12N	1E	NE 1/4 Sec. 18	12.9	2.0	1.6	12.0	0.13	—
207	12N	1E	SW 1/4 Sec. 17	7.2	0.9	2.2	5.2	0.42	—
208	12N	1E	NE 1/4 Sec. 17	9.9	1.4	2.6	7.3	0.36	644.70
209	12N	1E	SE 1/4 Sec. 16	12.5	2.0	2.8	9.8	0.29	—
210	12N	1E	SW 1/4 Sec. 15	7.6	1.2	2.0	4.7	0.43	404.82
211	12N	1E	SW 1/4 Sec. 15	10.4	1.6	2.4	7.3	0.33	—
212	12N	1E	SE 1/4 Sec. 10	13.1	2.1	2.8	11.0	0.25	780.11





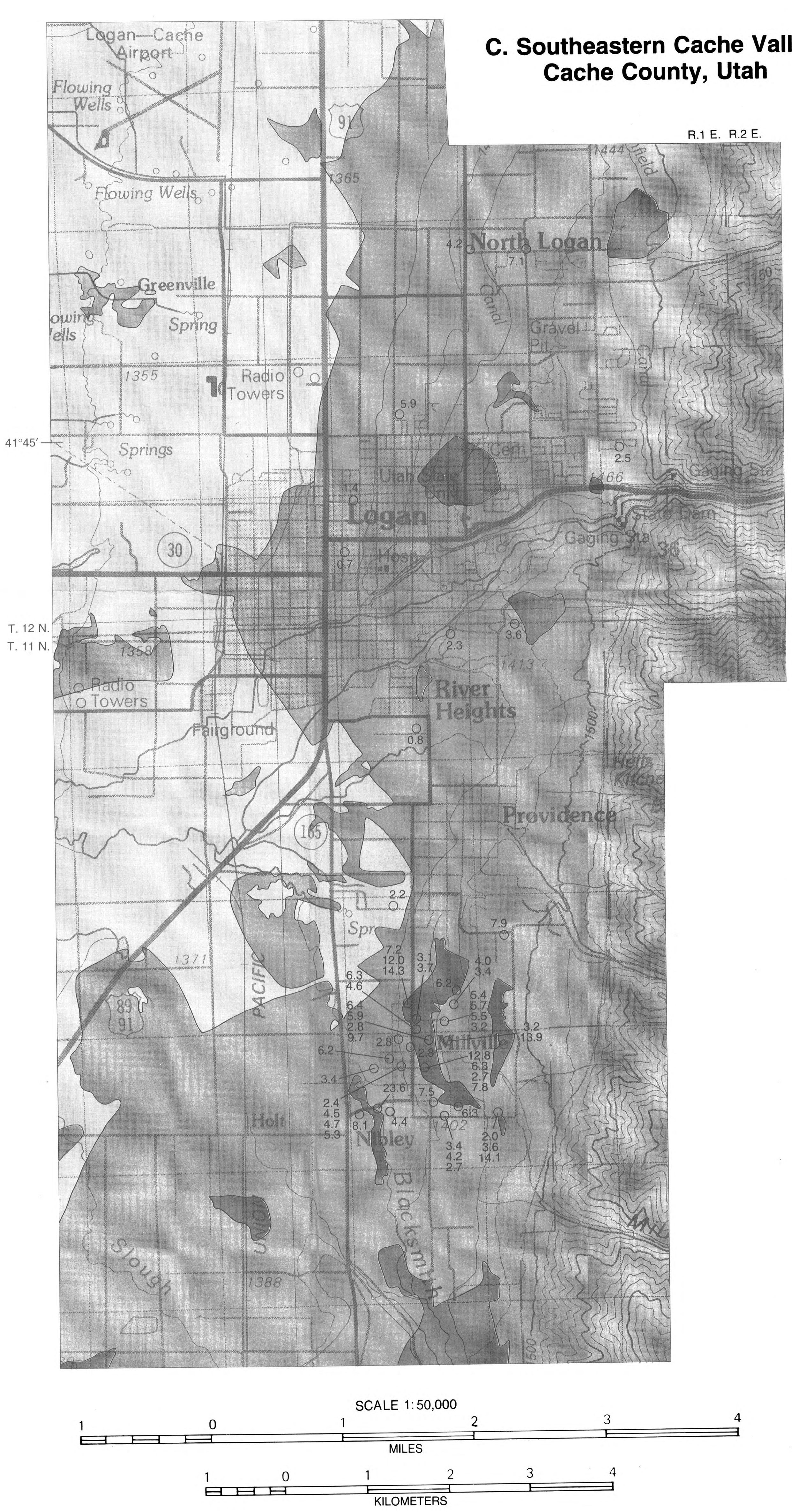


Plate 1

RADON-HAZARD-POTENTIAL MAPS

Special Study 90

Utah Geological Survey

1996

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EXPLANATION

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

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

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

Areas not studied due to lack of access or soil-permeability data.

○ 4.0 Indoor radon sample location and concentration in picocuries per liter (pCi/L). Multiple concentrations indicate several closely spaced sample locations.