MASTER

GJT-12

PHASE II-TITLE I ENGINEERING ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS GUNNISON SITE, GUNNISON, COLORADO

NOVEMBER 1977

PREPARED FOR

UNITED STATES DEPARTMENT OF ENERGY
GRAND JUNCTION, COLORADO, CONTRACT NO. E(05-1)-1658

BY

Ford, Bacon & Davis Utah Inc.

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By

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FB&DU 130-12

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NOTICE

This Phase II - Title I Engineering Assessment has been performed under ERDA Contract No. E(05-1)-1658 executed on June 23, 1975 between the U.S. Energy Research and Development Administration and Ford, Bacon & Davis Utah Inc. On October 1, 1977, ERDA was incorporated into the U.S. Department of Energy; hence, this engineering assessment is issued for the DOE, the present responsible agency.

FOREWORD

This report entitled, "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Gunnison Site, Gunnison, Colorado", was prepared under the U.S. Energy Research and Development Administration (ERDA) Contract No. E(05-1)-1658. It is one of a series of reports on inactive uranium millsites that address the radiological problems and estimated costs of remedial measures that would reduce exposure of the general public. Title I is not a scientific study but an engineering assessment to determine the relative magnitude of the hazards associated with each site, to identify reasonable remedial action options for each site, and to estimate the remedial action costs. If additional information that may alter or have an impact on a final remedial action decision for any site is required, it can be obtained during the Title II Engineering Effort. Chapter 1 of this report is a summary and is published under separate cover for those not requiring all the details of this report.

Ford, Bacon & Davis Utah Inc. (FB&DU) under supplemental authorization currently is investigating uranium mill tailings stabilization techniques. This research could modify some of the estimated costs in this report.

Also, FB&DU acknowledges the excellent cooperation and assistance given in this engineering assessment. Particular recognition is due the ERDA personnel of both the Germantown, MD and Gunnison, CO offices and also the Union Carbide Corporation personnel of the Health Physics Division, Oak Ridge National Laboratory, who provided field radiological measurements and radiometric analyses of samples. The preparation of this report could not have been accomplished without the cooperation and assistance of the following:

(1) Environmental Protection Agency; for consultation, data, and information from prior surveys and studies with notable assistance from the Office of Radiation Programs, Los Vegas, Nevada

(2) State of Colorado: Department of Health, Mr. A. J. Hazle and Mr. G. A. Franz

(3) Gunnison County, Colorado; Mr. Jim Kuzak, Gunnison County Planner

(4) Other local goverment officials from the City of Gunnison, Gunnison County, and U.S. Bureau of Land Management; and local business personnel in the Gunnison area

(5) EG&G, Las Vegas, Nevada; Mr. Jack Doyle; for aerial photography

(6) Center for Health and Environmental Studies, Brigham Young University, Provo, Utah; for socioeconomic and hydrology studies

ABSTRACT

Ford, Bacon & Davis Utah Inc. has performed an engineering assessment of the problems resulting from the existence of radioactive uranium mill tailings at Gunnison, Colorado. The Phase II - Title I services include the preparation of topographic measurements sufficient to determine areas and volumes of tailings and other radium-contaminated materials, the evaluation of resulting radiation exposures of individuals and nearby populations, the investigation of site hydrology and meteorology, and the evaluation and costing of alternative corrective actions.

Radon gas release from the 0.5 million tons of tailings at the Gunnison site constitutes the most significant environmental impact, although windblown tailings and external gamma radiation are also factors. The nine alternative actions presented range from millsite decontamination (Option I), to adding various depths of stabilization cover material (Options II and III), to removal of the tailings to long-term storage sites and decontamination of the present site (Options IV through IX). Cost estimates for the nine options range from $480,000 to $5,890,000.

Reprocessing the tailings for uranium does not appear to be economically attractive at present.

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GLOSSARY

Abbreviations/Terms	Definitions
absorbed dose	Radiation energy absorbed per unit mass.
A-E	Architect-Engineer.
AEC	Atomic Energy Commission.
alpha particle (α)	A positively charged particle emitted from certain radioactive material. It consists of two protons and two neutrons, hence is identical with the nucleus of the helium atom. It is the least penetrating of the common radiation (α, β, γ), hence is not dangerous unless alpha-emitting substances have entered the body.
amenability	The relative ease with which a mineral(s) can be removed from an ore by a particular process.
anomaly (mobile gamma survey)	Any location detected by the mobile gamma survey where the recorded counts per second (c/s) from a large gamma-ray detector exceed the determined background for that area by 50 or more c/s.
aquifer	A water-bearing formation below the surface of the earth; the source of wells. A confined aquifer is overlain by relatively impermeable rock. An unconfined aquifer is one associated with the water table.
atmospheric pressure	Pressure exerted on the earth by the mass of the atmosphere surrounding the earth; expressed in inches of mercury (at sea level and $0^{o}C$, standard pressure is 29.921 in. Hg).
background radiation	Naturally occurring low-level radiation to which all life is exposed. Background radiation levels vary from place to place on the earth.
beta particle (β)	A particle emitted from some atoms undergoing radioactive decay. A negatively charged beta particle

is identical to an electron. A positively charged beta particle is called a positron. Beta radiation can cause skin burns and beta-emitters are harmful if they enter the body.

BEIR	Biological Effects of Ionizing Radiation.
BOM (USBOM)	Bureau of Mines.
CHES	Center for Health and Environmental Studies, Brigham Young University, Provo, Utah.
Ci	Curie (the unit of radioactivity of any nuclide, defined as precisely equal to 3.7 x 10^{10} disintegrations/second).
daughter product	The nuclide remaining after a radioactive decay. A daughter atom may itself be radioactive, producing further daughter products.
diurnal	Daily, cyclic (happening each day or during the day).
dose equivalent	A term used to express the amount of effective radiation when modifying factors have been considered (the numerical product of absorbed dose and quality factor).
EGR	External gamma radiation (gamma radiation emitted from a source(s) external to the body, as opposed to internal gamma radiation emitted from ingested or inhaled sources).
EPA (USEPA)	Environmental Protection Agency.
ERDA (USERDA)	Energy Research and Development Administration.
ERDA-GJO	Energy Research and Development Administration-Grand Junction Office.
erg	The basic unit of work or energy in the centimeter-gram-second.

	system (1 erg is equal to 7.4 x 10^8 ft-lb).
exposure	Related to electrical charge produced in air by ionizing radiation per unit mass of air.
exhalation	Emission of radon from earth (usually thought of as coming from a uranium tailings pile, but actually from any location).
FB&DU	Ford, Bacon & Davis Utah Inc.
gamma background	Natural gamma ray activity everywhere present, originating from two sources: (1) cosmic radiation, bombarding the earth's atmosphere continually, and (2) terrestrial radiation. Whole body absorbed dose equivalent in the U.S. due to natural gamma background ranges from about 60 to about 125 mrem/yr.
gamma ray	High energy electromagnetic radiation emitted from the nucleus of a radioactive atom, with specific energies for the atoms of different elements and having high penetrating power.
GJO	Grand Junction Office.
ground water	Subsurface water in the zone of full saturation which supplies wells and springs.
health effect	Adverse physiological response from tailings (in this report, one health effect is defined as one case of cancer from exposure to radioactivity).
heap leaching	A process for removing uranium from ore, tailings, or other material wherein the material is placed on an impermeable pad and wetted with appropriate reagents. The uranium solution is collected for further processing.
HEW (USHEW)	Department of Health, Education, and Welfare.

insult	Negative impact on the environment or the health of individuals.
Interim Drinking Water Standards (EPA)	Title No. 40 of the Code of Federal Regulations, Chapter 1, Part 141, dated Dec 24, 1975; scheduled to become effective Jun 24, 1977.
iso-exposure line	A line drawn on a map to connect all points having the same exposure rate.
isotope	One of two or more atoms with the same atomic numbers (the same chemical element) but with different atomic weights. Isotopes usually have very nearly the same chemical properties, but somewhat different physical properties.
JCAE	Joint Committee on Atomic Energy.
knot	A unit of velocity, approximately equal to 1.15 mi/hr.
μR/hr	Microroentgen per hour.
mR/hr	Milliroentgen per hour.
MeV	Million electron volts.
MPC	Maximum permissible concentration (the highest concentration in air or water of a particular radionuclide permissible for occupational or general exposure without taking steps to reduce exposure).
NAS	National Academy of Sciences.
NIOSH	National Institute for Occupational Safety and Health.
noble gas	One of the gases, such as helium, neon, radon, etc., with completely filled electron shells which is therefore chemically inert.
NRC	Nuclear Regulatory Commission.

nuclide	A general term applicable to all atomic forms of the elements; nuclides comprise all the isotopic forms of all the elements. Nuclides are distinguished by their atomic number, atomic mass, and energy state.
ORNL	Oak Ridge National Laboratory.
ORP-LVF (EPA)	Office of Radiation Programs, Las Vegas Facility (Environmental Protection Agency).
pCi/l	Picocurie per liter.
PHS (USPHS)	Public Health Service.
QF	Quality factor (an assigned factor which denotes the modification of the effectiveness of a given absorbed dose by the linear energy transfer).
R	Roentgen (a unit of exposure to ionizing radiation. It is that amount of gamma or X-rays required to produce ions carrying 1 electrostatic unit of electrical charge, either positive or negative, in 1 cubic centimeter of dry air under standard conditions, numerically equal to 2.58×10^{-4} coulombs/kg).
rad	The basic unit of absorbed dose of ionizing radiation. A dose of 1 rad means the absorption of 100 ergs of radiation energy per gram of absorbing material.
radioactivity	The spontaneous decay or disintegration of an unstable atomic nucleus, usually accompanied by the emission of ionizing radiation.
radioactive decay chain	A succession of nuclides each of which transforms by radioactive disintegration into the next until a stable nuclide results. The first member is called the parent, the intermediate members are called daughters, and the final stable member is called the end product.

radium	A radioactive element, chemically similar to barium, formed as a daughter product of uranium (^{238}U). The most common isotope of radium, ^{226}Ra, has a half-life of 1,620 yr. Radium is present in all uranium-bearing ores. Trace quantities of both uranium and radium are found in all areas, contributing to the gamma background.
radon	A radioactive, chemically inert gas, having a half-life of 3.8 days (^{222}Rn); formed as a daughter product of radium (^{226}Ra).
radon background	Low levels of radon gas found in an area, due to the presence of radium in the soil.
radon concentration	The amount of radon per unit volume. In this assessment, the average value for a 24-hr period of atmospheric radon concentrations, determined by collecting data for each 30 min period of a 24-hr day and averaging these values.
radon daughter	One of several short-lived radioactive daughter products of radon (several of the daughters emit alpha particles).
RDC	Radon daughter concentration (the concentration in air of short-lived radon daughters, expressed usually in pCi/l; also measured in terms of working level (WL).
radon flux	The quantity of radon emitted from a surface in a unit time per unit area (typical units are in pCi/cm^2-sec).
raffinate	The liquid part remaining after a product has been extracted in a solvent extraction process.
recharge	The processes by which water is absorbed and added to the zone of saturation of an aquifer, either directly into the formation or indirectly by way of another formation.

rem	(Acronym of roentgen equivalent man) The unit of dose of any ionizing radiation which produces the same biological effect as a unit of absorbed dose of ordinary X-rays, numerically equal to the absorbed dose in rads multiplied by the appropriate quality factor for the type of radiation. The rem is the basic recorded unit of accumulated dose to personnel.
residual value	The value of minerals in tailings material.
riprap	An irregular wall of broken rock, placed as a retaining wall, as a protection for dikes, etc.
sands	Relatively coarse-grained materials produced along with the slimes as waste products of ore processing in uranium mills (see tailings). These sands normally contain less radioactive material than the slimes.
scintillometer	A gamma-ray detection instrument normally utilizing a NaI crystal.
slimes	Extremely fine-grained materials, mixed with small amounts of water, produced along with the sands as waste products of ore processing in uranium mills (see tailings). Most of the radioactive material remaining in tailings is found in the slimes.
tailings	The remaining portion of a metal-bearing ore after the metal, such as uranium, has been extracted. Tailings also may contain other minerals or metals not extracted in the process (e.g. radium).
WL	Working level. A unit of radon daughter exposure, equal to any combination of short-lived radon daughters in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy. This level is equivalent to the energy produced in the

	decay of the daughter products RaA, RaB, RaC, and RaC' that are present under equilibrium conditions in a liter of air containing 100 pCi of Rn-222. It does not include decay of RaD (22 yr half-life) and subsequent daughter products.
WLM	Working level month. One WLM is equal to the exposure received from 170 WL-hours.

CHAPTER 1

SUMMARY

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SUMMARY

1.1 INTRODUCTION

The U.S. Energy Research and Development Administration (ERDA) has contracted with Ford, Bacon & Davis Utah Inc. (FB&DU) of Salt Lake City, Utah, to provide architect-engineering services in the assessment of the problems resulting from the existence of large quantities of radioactive uranium mill tailings at the sites of inactive mills in eight western states.

A preliminary survey (Phase I) was carried out by ERDA in cooperation with the EPA and the affected states and completed in October 1974. In the Summary Report(1), ERDA identified 17 sites in Arizona, Colorado, Idaho, New Mexico, Utah, and Wyoming for which practical remedial measures are to be evaluated. Subsequently, ERDA added five additional sites (Riverton and Converse County, Wyoming; Lakeview, Oregon; Falls City and Ray Point, Texas) to the list for a total of 22 sites. Most of these mills produced by far the greatest part of their output of uranium under contracts with the U.S. Atomic Energy Commission (AEC) during the period 1947 through 1970. After operations ceased, some companies made no attempt to stabilize the tailings, while others did so with varying degrees of success. Recently, concern has increased about the possible adverse effects to the general public from long-term exposure to low-level sources of radiation from the tailings piles and sites.

To date, the studies of radiation levels on and in the vicinity of these sites have been limited in scope. The data available were insufficient to permit assessment of risk to people with any degree of confidence in the conclusions reached. In addition, information on practicable measures to reduce radiation exposures and estimates of their projected costs are limited. The purpose of this study is to develop the necessary information to provide a basis for decision-making for appropriate remedial actions for each of these sites.

In assessing the significance of the conditions existing at the Gunnison site, evaluations of the following factors were included:

(a) Exhalation of radon gas from the tailings

(b) On-site and off-site direct radiation

(c) Land contamination from windblown tailings

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(1) See end of chapter for references.

(d) Hydrology and contamination by water pathways

(e) Potential health impact

(f) Potential for extraction of additional metals from the tailings

Investigation of these and other factors led to the detailed evaluation of nine alternatives. These may be placed within three main categories:

(a) Minimum remedial action, which amounts to off-site remedial action and site decontamination off the pile

(b) Stabilization designed for long-term storage of tailings in their current location

(c) Removal of the tailings to alternative sites suitable for long-term storage and stabilization

The estimated costs of carrying out the remedial work to implement each option depend on such parameters as the degree of decontamination to be achieved, and the degree of stabilization necessary.

1.1.1 Background

On March 12, 1974, the Subcommittee on Raw Materials of the Joint Committee on Atomic Energy (JCAE), Congress of the United States, held hearings on S. 2566 and H.R. 11378, identical bills submitted by Senator Frank E. Moss and Representative Wayne Owens of Utah. The bills provided for a cooperative arrangement between the AEC and the State of Utah in the area of the Vitro tailings site in Salt Lake City.* The bills also provided for the assessment of and appropriate remedial action to limit the exposure of individuals to radiation from uranium mill tailings.

Dr. William D. Rowe, testifying in behalf of the Environmental Protection Agency (EPA), pointed out that there are other sites with similar problems. He recommended the problem be approached as a generic one, structured to address the most critical problem first.

Dr. James L. Liverman, testifying for the AEC, proposed that a comprehensive study should be made of all such piles, rather

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*The proceedings of these hearings and the Summary Report on the Phase I Study were published by the JCAE as Appendix 3 to ERDA Authorizing Legislation for Fiscal Year 1976. Hearings before the Subcommittee on Legislation, JCAE, on Fusion Power, Biomedical and Environmental Research; Operational Safety; Waste Management and Transportation, Feb 18 and 27, 1975, Part 2.

than treating the potential problem on a piecemeal basis. He proposed that the study be a cooperative two-phase undertaking by the states concerned and the appropriate federal agencies, such as the AEC and EPA. Phase I would involve site visits to determine such aspects as their condition, ownership, proximity to populated areas, prospects for increased population near the site, and need for corrective action. A preliminary report then would be prepared which would serve as a basis for determining if a detailed engineering assessment (Phase II) were necessary for each millsite. The Phase II study, if necessary, would include evaluation of the problems, examination of alternative solutions, preparation of cost estimates and of detailed plans and specifications for alternative remedial action measures. This part of the study would include physical measurements to determine exposure or potential exposure to the public.

The Phase I assessment began in May 1974, with teams consisting of representatives of the AEC, the EPA, and the states involved visiting 21 of the inactive sites. The Phase I report was presented to the JCAE in October 1974. Table 1-1 summarizes the conditions at the time of the Phase I visits.[(1)] Based on the findings presented in the report, the decision was made to proceed with Phase II.

On May 5, 1975, ERDA, the successor to AEC, announced that Ford, Bacon & Davis Utah Inc. of Salt Lake City had been selected to provide the architect-engineering (A-E) services for Phase II. ERDA's Grand Junction, Colorado, office (GJO) was authorized to negotiate and administer the terms of a contract with FB&DU. The contract was effective on June 23, 1975. The Salt Lake City Vitro site was assigned as the initial task, and work began immediately. The field survey work at Gunnison was performed from May 3 through May 7, 1976 with additional radon measurements collected from Oct 5 through Oct 7, 1976.

1.1.2 Scope of Phase II Engineering Assessment

Phase II A-E Services are divided into two stages: Title I and Title II.

Title I services include the engineering assessment of existing conditions and the identification, evaluation and costing of alternative remedial actions for each site. Following the selection and funding of a specific remedial action plan, Title II services will be performed. These services will include the preparation of detailed plans and specifications for implementation of the selected remedial action.

This report is the assessment made for Title I requirements and was prepared by FB&DU. The Oak Ridge National Laboratory (ORNL) at Oak Ridge, Tennessee, under separate agreement with ERDA, provided measurements of the radioactivity concentrations in the soil and water samples and gamma surveys. The EPA staff provided the results of radiation surveys they previously had made at the Gunnison site.

The specific scope requirements of the Title I assessment as given in the contract may include but are not limited to the following:

(a) Preparation of an engineering assessment report for each site, and preparation of a comprehensive report suitable for submission to the Congress on reasonable remedial action alternatives and their estimated costs.

(b) Determination of property ownership in order to obtain release of federal government and A-E liability for performance of engineering assessment work at both inactive millsites and privately owned structures.

(c) Preparation of topographic maps of millsites and other sites to which tailings and other radioactive materials might be moved.

(d) Performance of core drillings and radiometric measurements ample to determine volumes of tailings and other radium-contaminated materials.

(e) Performance of radiometric surveys, as required, to determine areas and structures requiring cleanup or decontamination.

(f) Determination of the adequacy and the environmental suitability of sites to which mill tailings containing radium can be moved for long-term (>50 yr) storage; and once such sites are identified, perform evaluation and estimate the costs involved.

(g) Performance of engineering assessments of structures where uranium mill tailings have been used in off-site construction to arrive at recommendations and estimated costs of performing remedial action.

(h) Evaluation of various methods, techniques and materials for stabilizing uranium mill tailings to prevent wind and water erosion, to inhibit or eliminate radon exhalation, and to minimize maintanance and control costs.

(i) Evaluation of availability of suitable fill and stabilization cover materials that could be used.

(j) Evaluation of radiation exposures of individuals and nearby populations resulting from the inactive uranium millsite, with specific attention to:

   (1) Gamma radiation

   (2) Radon

   (3) Radon daughter concentrations

   (4) Radium and other naturally occurring radioisotopes in the tailings

(k) Investigation of site hydrology and meteorology.

(l) Evaluation of recovering residual values, such as uranium and vanadium in the tailings and other residues on the sites.

(m) Performance of demographic and land use studies. Investigation of community and area planning, and industrial and growth projections.

(n) Evaluation of the alternative corrective actions for each site in order to arrive at recommendations, estimated costs, and socioeconomic impact based on population and land use projections.

(o) Preparation of preliminary plans, specifications, and cost estimates for alternative corrective actions for each site.

Not all of these items received attention at this site.

1.2 SITE DESCRIPTION

1.2.1 Location and Topography

The Gunnison millsite is a 61.5-acre tract located on the southwest side of the city of Gunnison. This site and its relationship to the surrounding area are shown in the aerial photograph in Figure 2-1, Chapter 2. The city and the site are located in the valley of the Gunnison River and Tomichi Creek, and are surrounded by mountains which rise to 12,000 ft above sea level. The elevation of the site is about 7,635 ft. The vegetation varies from sagebrush in the foothills to pine and fir in the National Forests which surround the site at higher elevations.

1.2.2 Ownership and History of Milling Operations and Processing

The mill was owned and operated by the Gunnison Mining Company between 1958 and December 1961. Gunnison Mining Company merged with Kermac Nuclear Fuels Corporation, a wholly owned subsidiary of Kerr-McGee Oil Industries, in late 1961. Kermac operated the mill until it closed in April 1962. Colorado Ventures, Inc. bought the property in December 1964. In 1966, the County of Gunnison was deeded a narrow 3.5-acre strip of land along the north edge of the site for future airport expansion. Most of the tailings on that area were moved to the present pile. In August 1973 the property was purchased by a limited partnership consisting of three individuals: Clarence A. Decker, N. Marcus Bishop, and Roger L. McEachern of Denver, Colorado. Solution Engineering Co. of Alice, Texas recently has leased the tailings pile from the partners.

During its approximate 4-yr operation, the mill produced uranium for sale to the AEC. About 540,000 tons of ore were processed. Ore averaging 0.15% U_3O_8 was delivered to the mill from mines in the Cochetopa Pass area, southeast of Gunnison.

1.2.3 Present Condition of the Site

The tailings were impounded in a rectangular-shaped pile approximately 950 ft wide, 1,440 ft long, and about 13 ft high. During deposition the tailings were contained by a dike on the four sides. The dike was constructed of pit-run rock and earth scraped from the bottom of the area. The pile now covers an area of about 39 acres of the total millsite area of 61.5 acres and contains 540,000 tons. The east side of the pile is about 20 ft from the edge of the highway. The pile has been contoured, covered with material excavated from a nearby gravel pit, and vegetated with a mixture of grasses in accordance with plans approved at the time by the Colorado Department of Health. The pile was sprinkled for several summers, and the vegetation now is sustained by natural precipitation. The top of the pile is well vegetated, and although portions of the slopes are not as well vegetated, there is but minor visible evidence of wind or surface water erosion. A water tower, office building and the metal mill building still remain. Figure 2-3, Chapter 2 is a descriptive map of the site as it now exists. Figure 2-4 is a typical cross-section of the site.

1.2.4 Tailings and Soil Characteristics

The Gunnison tailings pile is made up of uranium tailings, dike material and stabilization cover. The tailings consist of gray-to-white finely ground sands with a medium clay content; bulk densities of the material range between 114.6 and 127.5 lb/ft^3. The amounts of tailings site materials are presented in Table 2-1, Chapter 2. The millsite and tailings are located on an alluvial deposit layer, formed by the Gunnison River.

1.2.5 Geology, Hydrology, and Meterology

The Gunnison tailings and millsite are located on flood plain gravels of the Gunnison River and Tomichi Creek. The unconsolidated river-run material underlying the site is at least 100 ft thick and probably 200 ft thick. Bedrock geology consists of Mesozoic sedimentary rocks that overlie Precambrian igneous and metamorphic basement.

The tailings pile is located 1.5 mi from the confluence of the Gunnison River and Tomichi Creek. Flooding of the tailings as a result of peak discharges of these rivers is unlikely because the land surface at the tailings is 10 ft above the stream beds and the flood plains are extensive. Under unusual conditions, which would include the blocking of the Gunnison River at the bridge of U.S. Highway 50 by iceflow, some of the tailings could become saturated but not eroded by flood waters.

The natural surface drainage from the site is to the southwest to the Gunnison River or to Tomichi Creek. There are no berms or other barriers to surface water runoff from the tailings.

The unconfined ground water in the unconsolidated riverbed material of the valley floor is the major aquifer for city and private water supplies. The general direction of ground water flow parallels surface water flow to the southwest. The city's water supplies are upgradient from the pile. There are water wells for limited ground water use southwest of the pile and a potential for additional ground water development. There has been no evidence of contamination of ground or surface waters, but there is a potential for such contamination.

The annual precipitation in the Gunnison area is 11 in., although high-intensity rainfall such as thunderstorms are common. The prevailing winds are from the west and the strongest winds are from the southwest quadrant.

1.3 RADIOACTIVITY AND POLLUTANT IMPACTS ON THE ENVIRONMENT

About 85% of the total radioactivity originally in uranium ore remained in the tailings after removal of the uranium because the radium and thorium, principal contributors to radioactive emissions, were not normally removed from the uranium ores during milling. The principal environmental radiological impact and associated health effects arise from the ^{230}Th, ^{226}Ra, ^{222}Rn, and ^{222}Rn daughters contained in the uranium tailings. Although these radionuclides occur in nature, their concentrations in tailings material are several orders of magnitude greater than their average concentrations in the earth's crust.

1.3.1 Radiation Exposure Pathways, Contamination Mechanisms, and Background Levels

The major potential environmental routes of exposure to man are:

(a) Inhalation of ^{222}Rn and its daughter products, resulting from the continuous radioactive decay of ^{226}Ra in the tailings. Radon is a gas which diffuses from the piles. The principal exposure results from inhalation of the ^{222}Rn and Rn daughters. This exposure affects the lungs. For this assessment, no criteria have been established for radon concentrations in air. However, the pathway for radon and radon daughters accounts for the major portion of the exposure to the population.

(b) External whole-body gamma exposure directly from radionuclides in the piles.

(c) Inhalation and ingestion of windblown tailings. The primary health effect relates to the alpha emitters ^{230}Th and ^{226}Ra, each of which causes exposure to the bones and lungs.

(d) Ingestion of ground and surface water contaminated with radioactive elements (primarily ^{222}Ra) and other toxic materials.

(e) Contamination of food through uptake and concentration of radioactive elements by plants and animals is another pathway which can occur; however, this pathway was not considered in this study.

1.3.1.1 Radon Gas Diffusion and Transport

Short-term radon measurements were performed with ERDA supplied continuous radon monitors at 11 locations in the vicinity of the Gunnison tailings pile. The locations and values of the 24-hr radon concentrations, including background, are shown in Figure 3-3, Chapter 3. The highest outdoor radon concentration was measured on the pile (3.6 pCi/l for a 24-hr average sample), but the value may be low due to moisture in the cover material from rainfall the preceding 2 days. Background measurements of atmospheric radon at 5 locations from 0.7 to 5.1 mi from the site averaged 1.0 pCi/l. Radon above the average background level was detected to 0.6 mi from the site.

1.3.1.2 Direct Gamma Radiation

The range of natural background values in the Gunnison area was between 10 and 15 μR/hr, averaging 13 μR/hr as measured 3 ft above ground with an energy-compensated Geiger Mueller detector.[2]

Above the surface of the tailings piles, gross gamma readings ranged to a maximum 280 μR/hr. In the mill and ore storage areas, gamma radiation rates varied from 2 times background to 230 μR/hr near the southern edge of the tailings pile.

1.3.1.3 Windblown Contaminants

Prevailing winds in the area are from the west. Surface soil samples indicate very little windblown contamination. Very limited windblown contamination is also shown by the iso-exposure lines illustrated in Figure 3-10, Chapter 3, which were obtained by EPA from gamma radiation measurements. The 40-μR/hr line extends north of the pile around an area adjacent to the east-west airport runway.

1.3.1.4 Ground and Surface Water Contamination

Fourteen water samples taken from the Gunnison River, Blue Mesa Reservoir, Tomichi Creek, and from wells surrounding the pile ranged in ^{226}Ra content from 0.02 to 0.16 pCi/l. There was no definitive evidence demonstrating the contamination of the surface or unconfined ground water in the vicinity of the Gunnison tailings; however, the hydrologic conditions at the site indicate a potential for contamination. The ground water level in the soil varies from 1 to 10 ft beneath the tailings and could remove leachate from that soil.

1.3.1.5 Soil Contamination

The leaching of radium from the tailings into the subsoil ranges from 1 to 4 ft beneath the tailings and averages about 3 ft before reaching the average background radium concentration in the soil. The average background concentration of ^{226}Ra in soil from western Colorado is 1.5 pCi/g.(2) In the ore storage area there are isolated locations where contamination also reaches at least 3 ft deep.

1.3.2 Remedial Action Criteria

Radiological criteria established for this engineering assessment are divided into two general categories:

(a) Criteria applicable to structures with tailings underneath them or within 10 ft

(b) Criteria pertaining to the mill tailings site and open land

The criteria utilized for habitable structures are the guidelines published by the Surgeon General of the United States for use in the Grand Junction, Colorado, remedial program. These guidelines recommend graded levels (based on yearly average values) for remedial action in terms of the external gamma radiation (EGR) levels and of the indoor radon daughter concentration (RDC) levels above background found within dwellings constructed on or near uranium mill tailings. (In this usage, the word "external" refers to gamma radiation from sources outside the human body to which an individual may be exposed.)

The recommended graded levels are as follows:

EGR	RDC[a]	Recommendations
Greater than 0.1 mR/hr[b]	Greater than 0.05 WL[c]	Remedial action indicated
From 0.05 to 0.1 mR/hr	From 0.01 to 0.05 WL	Remedial action may be suggested
Less than 0.05 mR/hr	Less than 0.01 WL	No remedial action indicated

[a]Based upon yearly average values from 6 air samples of at least 100-hr duration taken at a minimum of 4-wk intervals throughout the year.

[b]mR/hr = milliroentgen per hour, a measure of gamma radiation; 1 mR/hr = 1,000 μR/hr

[c]WL = working level, a measure of alpha radiation from short-lived radon daughter elements

The criteria for land decontamination have the objective of reducing residual gamma radiation to levels which are as low as practicable. However, topographic and economic considerations frequently preclude complete decontamination. A provisional maximum of 40 μR/hr above background is used in such circumstances. Average background in the Gunnison area was determined in this study to be 13 μR/hr. As a guideline for the land beyond the site, if residual gamma levels are less than 10 μR/hr above background, the land may be released for unrestricted use. Where cleanup is necessary the radium content of the soil should be reduced to no more than twice the radium background in the area. If the radioactive tailings material is stabilized in place, the same criteria apply, but control of gamma radiation would be by an earth covering. However, the area should be designated a controlled area, be fenced to limit access, and be restricted as to human occupancy. The numerical guidelines provide a basis for the engineering assessment, but are subject to review based on the overall findings of Phase II.

The radium and gross alpha content of ground and surface water should meet applicable state and federal standards.

1.3.3 Potential Health Impact

Radon gas exhalation from the pile and the subsequent inhalation of radon daughters account for most of the total dose.

to the population from the Gunnison site under present conditions. The gamma radiation exposure from the pile is essentially zero since there are very few persons who live or work within 0.2 mi of the pile where gamma radiation is above background.

Gamma radiation can be reduced effectively by shielding with any dense material. However, experience has shown that it is very difficult to control the movement of radon gas through porous solid materials. Once released from the radium-bearing minerals in the tailings, the gaseous radon diffuses by the path of least resistance to the surface. The radon has a half-life of about 4 days, and its daughter products are solids. Therefore, part of the radon decays en route to the surface and leaves daughter products within the tailings pile. If the diffusion path can be made long enough, then, theoretically, substantially all the radon and its daughter products can be made to decay before escaping to the atmosphere. Calculations using the techniques of Kraner, Schroeder, and Evans(3) indicate that 13 ft of earth cover theoretically would be required to reduce the radon diffusion from the Gunnison tailings by 95%.

The health significance to man of long-term exposure to radiation is a subject that has been studied extensively for many years. Since the end results of long-term exposure to low-level radiation are usually diseases such as lung cancer or leukemia, which also are attributable to many other causes, the determination of specific cause in any given case becomes very difficult. Therefore, the usual approach to evaluation of the health impact of low-level radiation exposures is to make projections from observed effects of high exposures on the premise that the effects are linear. A considerable amount of information has been accumulated on the high incidence of lung cancer in uranium miners exposed to radon and its daughters in mine air. This provides a basis for calculating the probable health effects of low-level exposure to large populations. (The term "health effect" refers to an incidence of disease; for radon daughter exposure, 1 health effect = 1 case of lung cancer.) This is the basis of the health effects calculations in this report. It should be recognized, however, that there is a large degree of uncertainty in such projections. Among the complicating factors is the combined effect of radon daughters with other carcinogens. As an example, the incidence of lung cancer among uranium miners who smoke is far higher than can be explained on the basis of either smoking or the radiation alone.

The risk estimators used in this report are given in the report of the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR report).(4) This report presents risk estimators for lung cancer derived from epidemiological studies of both uranium miners and fluorspar miners. The average of the absolute risk estimator for these two groups is: 6 cancers per year per 10^6 person-WLM exposure. The term WLM means working level month, or an exposure to a concentration of one working level of radon daughter products in air for

170 hr, which is a work-month. A working level (WL) is a unit of measure of radon daughter products which recognizes that the several daughter elements are frequently not in equilibrium with each other nor with the parent radon. Because of the many factors which contribute to natural biological variability, and of the many differences between exposure conditions in mines and residences, this estimator (6 cancer cases per year per 10^6 person-WLM) is considered to have an uncertainty factor of about 3. The relative risk estimator can be several factors larger than the absolute risk estimator.(5)

For the purpose of the mill tailings assessment, it was assumed that about 50% equilibrium exists inside structures between radon and its daughter elements resulting in the following conversion factors:

$$1 \text{ pCi/l of } ^{222}\text{Rn} = 0.005 \text{ WL}$$

For continuous exposure:

$$0.005 \text{ WL} = 0.25 \text{ WLM/yr}$$

On the basis of radon concentrations in excess of the background value, it is calculated that the average radon-induced lung cancer risk due to the pile in the area within 2.5 mi from the Gunnison site is 2.1×10^{-6} per person per year, or slightly more than 1% of the average cancer risk due to all causes for Colorado residents (1.8×10^{-4}).(6)

The 25-yr health effects were calculated for two population projections using a present population of 7,100 in the 0- to 2.5-mi area. The results for pile-induced Rn and background Rn were as follows:

25-Yr Cumulative Health Effects 0-2.5 Mi from Edge of Pile

Projected Population Growth	Pile-Induced RDC	Background RDC
2% growth rate	0.8	17
3.3% growth rate	1.3	27

Pile-induced radon daughter health effects are approximately 5% of the background radon daughter health effects. The exposure and consequent risk will continue as long as the radiation source remains in its present location and condition.

1.3.4 Nonradioactive Pollutants

There are other potentially toxic materials in the tailings. Chemical analyses of tailings samples from drill holes on the Gunnison tailings pile showed arsenic as high as 450 ppm, selenium at about 1 ppm. Lead and barium content was between 30 and 150 ppm. Samples of surface waters in the vicinity of the Gunnison tailings pile contained selenium in concentrations above the EPA Interim Drinking Water Standards. However, the contamination was very localized and cannot be ascribed definitely to the tailings pile. While there is not definitive evidence demonstrating the contamination of the surface water or unconfined ground water in the vicinity of the tailings, the hydrologic conditions of the site indicate a potential for contamination.

1.4 SOCIOECONOMIC AND LAND USE IMPACTS

The area near the tailings is characterized by two primary land use patterns: commercial and agricultural. The area south of the tailings is grazing and pasture land although due south of the tailings are the mill buildings and a sand and gravel operation. To the east and north of the site are the airport and light industrial and commercial operations. To the west of the tailings area is agricultural land, but also some tourist and recreational facilities. The entire area is zoned for industrial use. West of the Gunnison River, developers are planning condominium, residential, and tourist-related facilities.

The presence of the tailings cannot be demonstrated to have had a direct impact on the use or values of surrounding lands, but if industrial development takes place south of the airport, there will be strong pressures to use the tailings site and surrounding areas.

The assessed property value of the tailings acreage and surrounding land is $10/acre at 30% value. The mill buildings on the adjacent site were assessed at $12,140. More valuable property lies northwest of the airport. In general, the land surrounding the tailings site has market values ranging from $1,500 to $8,000/acre.

1.5 RECOVERY OF RESIDUAL VALUES

Samples of tailings obtained during this study were composited and analyzed. The composited sample contained 0.009% U_3O_8. Estimates of the Gunnison tailings from AEC records show an average of 0.017% U_3O_8. The latter value was used for evaluating the economic viability of reprocessing the tailings.

There are five factors that should be employed to evaluate whether reprocessing the Gunnison tailings to extract residual uranium and other mineral values would be practicable:

(a) The amount of tailings present

(b) Concentrations of residual values

(c) Projected recovery

(d) Current market price of recovered values

(e) Proximity to processing mills

Based on the aforementioned criteria, reprocessing of the Gunnison tailings does not appear to be a practical economic consideration at this time and would not be practical until the market value of U_3O_8 reaches $74/lb in present dollars.

1.6 MILL TAILINGS STABILIZATION

Present practices and technology of mill tailings stabilization are being examined. This investigation indicates that much research and development remains to be performed before complete and permanent stabilization of radioactive mill tailings can be realized.

Reasonably effective means of wind and water erosion control are available, although they will involve continued maintenance costs. Lining of containment areas or chemical solidification of the tailings are possible methods for control of leaching.

Up to this time, no attempt has been made to contain radon in a tailings pile. Although a thick earth cover is theoretically effective, it has not actually been tried. The observed variability of radon exhalation rates indicates that with better understanding of the mechanism involved, control may be possible.

The existing cover on the Gunnison tailings has been effective in controlling tailings erosion from wind and rainfall and has provided partial control over gamma radiation, but little control over radon exhalation.

1.7 OFF-SITE REMEDIAL ACTION

A mobile scanning unit, operated by the AEC under interagency agreement for the EPA, was used to perform a gamma radiation survey of the Gunnison, Colorado area in 1971. A subsequent field survey identified only three off-site locations where tailings use was suspected or confirmed. The cost of remedial action for these locations is estimated to be $13,000. Cleanup of the windblown tailings surrounding the pile is estimated to cost a total of $27,000. The total remedial action cost for off-site structures and for decontamination of off-pile open lands is estimated to be $40,000, exclusive of engineering costs and contingency. The locations at which tailings are on vacant lands or are greater than 10 ft from structures were not subject to the criteria used in Phase II, but could constitute a problem in the future.

1.8 LONG-TERM STORAGE SITE SELECTION

Six of the alternative remedial action options include moving the Gunnison tailings to a long-term (greater than 50 yr) storage site. The sites were selected after consultation with State of Colorado, local and federal agencies, concerned individuals, and personnel in industry. Each site was evaluated on the basis of hydrology, meteorology, geology, ecology, economics, and proximity to population centers. The 6 sites were selected from 13 sites initially considered.

The sites referred to in Table 1-2 under Options IV through IX are shown on a map in Figure 8-1, Chapter 8. In each of these options, surface material would be removed and stockpiled, and a retaining dike and diversion ditches would be constructed if necessary. The tailings would be emplaced, contoured, and covered with 2 ft of cover from the stockpiled material, and fenced. In all options, continuing maintenance would be required to monitor the site and to repair fences and erosion of the cover material. These annual maintenance costs have been provided for by an endowment fund in costing each option.

1.9 REMEDIAL ACTIONS AND COST-BENEFIT ANALYSES

1.9.1 Remedial Action Options

The remedial options examined cover a range from: (a) site decontamination and off-site remedial action only, to (b) stabilizing the tailings pile in its present location and in its present configuration, to (c) removal of all radioactive materials to an area where they could be isolated from the public.

The base case, from which the cost and effectiveness of other remedial alternatives can be judged, is Option I. In Option I no work is expended on the pile; but the site, including the mill building is decontaminated, the tailings are fenced with chainlink fencing, and off-site remedial action is taken as described in paragraph 1.7. Also, the tailings and contaminated earth located on the 3.5 acres owned by Gunnison County would be relocated onto the surface of the tailings and covered with 0.5 ft of cover. This option would not reduce direct exposure to radiation or radon gas exhalation from the tailings. Resistance of the pile to wind and water erosion would not be improved.

Option II adds to Option I the cost for more completely stabilizing the pile by the addition of 1.5 ft of cover, making a total of 2 ft. Wind and water erosion of the tailings would be controlled; however, radon exhalation would be reduced very little. The site still would be unsuitable for most uses. Option III is the same as Option II except that 13 ft of cover would be provided by the addition of 12.5 ft of material. This would reduce limitations on use of the remainder of the site.

Six sites were evaluated, including preparation of cost estimates, as possible repositories for the tailings (see Figure 8-1, Chapter 8).

The relative total cost differences between these sites are small and reflect the haul distance and routing and the site preparation variances. The site which offers the most direct and easiest access to the tailings is the one on the west side of Gold Basin, south of the tailings. It is remote, and vehicles hauling the tailings would not be required to go through any traffic areas. The closest site is northwest of the tailings on the west side of Steers Gulch. About half of the haul route would have to be on a specially built road. Although located on a long steep slope, this particular site is at the head of a ridge between two gullies which will offer a well protected, natural site.

The Long Gulch site would be well hidden from view, have an access for hauling either through the main street in Gunnison or through a "rear" access south of Gunnison over what is now a jeep trail.

There are two storage sites suggested in the Maggie Gulch area north of Gunnison. One would be in a natural depression near the top of the ridge separating Antelope Creek Valley from Ohio Creek Valley. The other site is in a gully just below the highest ridge which separates the two valleys. Both sites would be well protected from winds, and haul access could be north from the tailings up Antelope Creek Valley over a specially built road or through the two main streets of Gunnison, then north and west into Ohio Creek Valley, entering the site from the east.

The North Sheep Gulch site is located on the south slope of the mountain which forms the north slope of Sheep Gulch and is north of what is known as Lost Canyon Road. The haul distance and steep grade over the last 0.5 mi of the haul are large cost factors making this site the most costly of the options.

Security fencing around the relocated tailings is included in all options.

1.9.2 Cost-Benefit Analyses

As summarized in Table 1-2, the total costs for the nine remedial action options vary from $480,000 to $5,890,000. Each of these costs would yield a distinct health and monetary benefit. The number of cancer cases avoided per million dollars expended for each option is given in Figure 9-3, Chapter 9. The option numbers are identified as follows:

Option	Description
I	Decontamination, minimum stabilization where contaminated material is added to the tailings.
II	Tailings Stabilization (2 ft)

Option	Description
III	Tailings Stabilization (13 ft)
IV	Removal to South Gold Basin Area
V	Removal to West Steers Gulch
VI	Removal to West Long Gulch
VII	Removal to Maggie Gulch Depression
VIII	Removal to Maggie Gulch Peak Area
IX	Removal to North Sheep Gulch Area

The curves in Figure 9-3, Chapter 9, indicate an increase in the health benefit/cost ratio with time as a result of the increasing number of health effects avoided. The potential cancer cases avoided for each option and the cost per potential cancer case avoided are given in Table 9-2, Chapter 9.

TABLE 1-1
SUMMARY OF CONDITIONS NOTED AT TIME OF PHASE I SITE VISITS [a]

	Cond. of Tailings	Cond. of Structures on Site	Mill Housing	Adequate Fencing, Posting, Security	Property Close by River or Stream	Houses-Industry w/in 1/2 Mile	Evidence of Wind Water Erosion	Possible Water Contami-nation	Tailings Removed for Pri-vate Use	Other Hazards On-site
ARIZONA										
Monument	U	R	N	No	No	Yes	No	No	No	No
Tuba City	U	PR-UO	E-O	No	No	Yes	Yes	No	No	Yes
COLORADO										
Durango	P	PR-UO	N	Yes	Yes	Yes	Yes	No	Yes	Yes
Grand Junction	S	PR-O	N	Yes	Yes	Yes	No	No	Yes	No
Gunnison	S	B-O	N	Yes	No	Yes	No	Yes	No	No
Maybell	S	R	N	Yes	No	No	No	No	No	No
Naturita	S	PR-O	E-P	Yes	Yes	No	Yes	Yes	No	No
New Rifle	P	M-O	N	Yes	Yes	Yes	Yes	Yes	No	No
Old Rifle	S	PR-UO	N	Yes	Yes	Yes	No	Yes	Yes	No
Slick Rock (NC)	S	R	N	No	Yes	Yes	Yes	No	No	No
Slick Rock (UCC)	S	R	E-P	Yes	Yes	Yes	No	No	No	No
IDAHO										
Lowman	U	R	N	No	Yes	Yes	No	No	Yes	No
NEW MEXICO										
Ambrosia Lake	U	PR-O	N	Yes	No	No	Yes	No	No	No
Shiprock	P	PR-O	E-O	Yes	Yes	Yes	No	No	Yes	Yes
OREGON										
Lakeview	U	M-UO	N	Yes	No	Yes	Yes	No	No	No
TEXAS										
Falls City	P	M-UO	N	Yes	No	No	No	No	No	No
Ray Point	P	M-UO	N	Yes	No	No	No	No	No	No

TABLE 1-1 (Cont)

	Cond. of Tailings	Cond. of Structures on Site	Mill Housing	Adequate Fencing, Posting, Security	Property Close by River or Stream	Houses-Industry w/in 1/2 Mile	Evidence of Wind Water Erosion	Possible Water Contami-nation	Tailings Removed for Pri-vate Use	Other Hazards On-site
<u>UTAH</u>										
Green River	S	B-O	N	Yes	No	Yes	Yes	Yes	No	No
Mexican Hat	U	B-O	E-O	No	No	Yes	Yes	Yes	No	No
Salt Lake City	U	R	N	No	Yes	Yes	Yes	Yes	Yes	Yes
<u>WYOMING</u>										
Converse County	U	R	N	No	No	No	No	No	No	No

(1) S - Stabilized but requires improvement

P - Partially stabilized

U - Unstabilized.

(2) M - Mill intact

B - Building(s) intact

R - Mill and/or buildings removed

PR- Mill and/or buildings partially removed

O - Occupied or used

UO- Unoccupied or unused.

(3) N - None

E - Existing

O - Occupied

P - Part occupied.

[a]This table does not necessarily represent conditions at the present time.

TABLE 1-2

SUMMARY OF REMEDIAL ACTION OPTIONS AND EFFECTS

Option Number	Cost ($000)	Description of Remedial Action	Benefits	Adverse Effects
I	480	On-site and off-site contaminated soil including tailings on county property would be cleaned up. The pile would be stabilized by the addition of 6 in. of cover over areas where contaminated material is added, then reseeded in these areas. The mill building would be decontaminated and the site would be fenced.	A	V W X Y Z
II	850	The pile would be stabilized with 2 ft of local earth cover, and natural vegetation would be established. On-site and off-site contaminated soil would be cleaned up.	A B D	V W X
III	2,730	The scope of work is the same as for Option II except that 13 ft of earth cover would be placed on the pile.	A C B E	V W X
IV	5,009	The tailings, contaminated soil and rubble would be removed from the site to a long-term storage area in Gold Basin Gulch where the tailings would be buried and stabilized. Native vegetation would be reestablished both on the site and at the long-term storage site. Cleanup and decontamination would be as in Option I.	B F G	V
V	5,200	Same as Option IV except tailings would be removed to a location in the Steers Gulch area.	B G F	V

TABLE 1-2 (Cont)

Option Number	Cost ($000)	Description of Remedial Action	Benefits	Adverse Effects
VI	5,309	Same as Option IV except tailings would be removed to the Long Gulch area disposal site.	B G F	V
VII	5,470	Same as Option IV except tailings would be removed to a site in the Maggie Gulch Depression area.	B G F	V
VIII	5,733	Same as Option IV except tailings would be removed to a site in the Maggie Gulch Peak area.	B G F	V
IX	5,890	Same as Option IV except tailings would be removed to a site in the Sheep Gulch area.	B G F	V

Notes

1. All options include on- and off-site remedial action consisting of tailings cleanup on and adjacent to the tailings and at three locations away from the tailings.

2. For Options IV through IX, costs include removal of 3 ft of contaminated earth below the tailings, but not for backfill to bring the area up to a previous natural grade.

Definition of Benefits

A. Better security provided for tailings
B. Wind and water erosion controlled
C. Site available for limited other uses
D. Radon exhalation reduced by 25%
E. Radon exhalation reduced by 95%
F. The source of gamma radiation and radon gas removed from site
G. Total tailings site available for unrestricted usage

TABLE 1-2 (Cont)

Definition of Adverse Effects

V. Some security and maintenance required
W. Tailings remain near the center of the community
X. Restricted use of tailings site
Y. No further reduction of radon exhalation
Z. No decrease in gamma radiation

CHAPTER 1 REFERENCES

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2. F. F. Haywood, et al; "Assessment of Radiological Impact of the Inactive Uranium Mill Tailings Pile at Gunnison, Colorado"; ORNL (in preparation).

3. H. W. Kraner, G. L. Schroeder, and R. D. Evans; "Measurements of the Effects of Atmospheric Variables on Radon-222 Flux and Soil-Gas Concentrations"; The Natural Radiation Environment; J. A. S. Adams and W. M. Lowder, eds; University of Chicago Press; 1964.

4. "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation"; Report of Advisory Committee on Biological Effects of Ionizing Radiation; NAS, National Research Council; Nov 1972.

5. "Health Effects of Alpha-Emitting Particles in the Respiratory Tract"; Report of the Advisory Committee on the Biological Effects of Ionizing Radiation; EPA/ORP; EPA-520/4-76-013; Washington, D.C.; Oct 1976.

6. Vital Statistics of the U.S.; Vol II; Mortality; National Center for Health Statistics; HEW; 1968.

CHAPTER 2

SITE DESCRIPTION

CHAPTER 2

SITE DESCRIPTION

The purpose of this chapter is to describe the Gunnison site and the characteristics of the tailings materials present on the site.

2.1 LOCATION

The Gunnison millsite is located just outside the city limits of Gunnison, Gunnison County, Colorado. (See Figure 2-1). The site is bordered on the north and east by the Gunnison County airport. More specifically, the site is located in Sections 2 and 11, Township 49 North, Range 1 West, New Mexico Principal Meridian at 38 deg 32 min north latitude and 106 deg 56 min west longitude.

2.2 TOPOGRAPHY

The site is located in a valley formed by the Gunnison River approximately 10 mi downstream from the intersection of the Taylor and East Rivers which form the Gunnison. Tomichi Creek enters the Gunnison River near the site. The elevation of the site is approximately 7,635 ft above sea level. Gunnison is the focal point of four valleys and is surrounded by mountain peaks which rise to over 12,000 ft. The valley is surrounded by the Gunnison National Forest on the north, east and south and it is about 20 mi west of the Continental Divide of the Rocky Mountains. There are many creeks which begin in these mountains that flow into the Gunnison River near the site. At the higher elevations and on north and east exposures the mountains are forested while at lower elevations and on south and west exposures the hills are mainly covered with sagebrush. The soil in the low hills surrounding the valley is largely a gravel-based mixture.

There is one tailings pile on the site. This pile covers approximately 39 acres to an average depth of 13 ft. The base of the pile (at ground level) is about 20 ft above the Gunnison river. The pile contains approximately 540,000 tons of tailings and its surface is slightly convex.

The millsite and ore storage areas are on the south side of the site and cover approximately 22 acres. Figure 2-2 is a topographic map of the site.

2.3 OWNERSHIP

Gunnison Mining Company operated the mill between February 1958 and December 1961, at which time Gunnison Mining Company merged with Kermac Nuclear Fuels Corporation (the surviving company), a wholly owned subsidiary of Kerr-McGee Oil Industries.

In December 1964, the entire property was sold to Colorado Ventures, Inc. In December 1966 Colorado Ventures, Inc. deeded 3.5 acres at the north end of the original 65 acres to the County of Gunnison, Colorado, for airport expansion. In August 1973 Colorado Ventures, Inc. sold the remaining 61.5 acres to Messrs. Clarence A. Decker, N. Marcus Bishop and Roger L. McEachern of Denver, Colorado, a limited partnership.

In recent months, Solution Engineering, Inc. of Alice, Texas has leased the tailings pile from the partnership.

2.4 HISTORY OF MILLING OPERATIONS AND PROCESSING[1]

The mill was operated for the production of uranium for sale to the AEC by the Gunnison Mining Company from February 1958 until December 1961 and by Kermac Nuclear Fuels Corporation from then until shutdown in April of 1962. The initial design capacity was about 200 tons/day. Ore was delivered to the mill from tne Cochetopa Pass area (about 25 mi southeast of Gunnison) by truck.

Ground ore at a minus 65-mesh size was leached using sodium chlorate and sulfuric acid. After leaching, the pregnant solution and solids were separated by a four-stage countercurrent classifier and thickener circuit, with the washed solids from the final units being sent to tailings. Pregnant solutions were treated by solvent extraction to recover and concentrate the uranium.[2]

2.5 PRESENT CONDITION OF THE SITE

The pile has been contoured, covered with 6 in. of material excavated from a nearby gravel pit and vegetated with a mixture of grasses in accordance with plans approved at the time by the Colorado Department of Health. The pile was sprinkled for several summers, and the vegetation is now sustained by natural precipitation. The top of the pile is well vegetated, and although portions of the slopes are not as well vegetated, there is but minor visible evidence of wind or surface water erosion.

Between the tailings and the airport is a paved state highway which leads south into Stubb's Gulch. The east side of the pile is about 20 ft from the edge of this road. South of the site is a sand, gravel and batch concrete plant operation. West of the site there is a private campground area used seasonally by tourists as well as year-round by a few trailer-type homes.

The 3.5 acres of the site which were deeded to the county in 1966 are in the form of a narrow strip next to the north edge of the present tailings pile. State Highway 341 goes through

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[1] See end of chapter for references.

this 3.5-acre area. Figure 2-3 is a descriptive map of the site Figure 2-4 is a cross-section of the tailings.

Of the original mill structures, only a steel water tower, an office building (with an adjoining trailer housing a caretaker) and the metal mill building remain. The mill building is used for storage. The site is enclosed with a five-strand barbed-wire fence and locked gates, but access is not always restricted. In the mill yard south of the tailings and west of the water tower there are debris and rubble left over from the milling operation. On the south side of the mill building there is an earth ramp which was used for unloading ore. North of the tailings in the area between State Highway 341 and the paved runway of the airport there are some tailings and contaminated earth remaining from the original cleanup operations on the 3.5-acre county property.

2.6 TAILINGS AND SOIL CHARACTERISTICS

The types of materials on the site and their volumes and weights are summarized in Table 2-1. The Gunnison tailings consist of gray-to-white finely ground sands with a medium clay content. The calculated average bulk density of the tailings is 119.3 lb/ft^3. The bulk density and pH of soil samples from on-site test holes are given in Table 2-2. Assays of composite uranium tailings samples are shown in Table 5-1, Chapter 5.

The millsite rests on a plain of alluvial deposits of the Gunnison River consisting of a mixture of sands and small-to-medium rocks.

2.7 GEOLOGY, HYDROLOGY, AND METEOROLOGY

2.7.1 Geology (3)

The Gunnison site is located on flood plain gravels of the Gunnison River and Tomichi Creek. The bedrock geology of the surrounding hills consists of Precambriam igneous and metamorphic rocks overlain unconformably by a relatively thin sequence of sedimentary rocks. These strata consist of the Morrison Formation, the Dakota Sandstone, and the Mancos Shale and are overlain by volcanic rock sequences of Cenozoic age. During Pleistocene time, the Gunnison River and Tomichi Creek carved deep valleys into the bedrock hills and then filled the valleys with alluvial sand and gravel to their present levels. The thickness of the alluvium underlying the tailings pile is not known but is deeper than the 100-ft water wells at the site. It is estimated that these deposits are 200 ft thick although local variations in buried terrain cause alluvium thicknesses to vary.

2.7.2 Surface Water Hydrology

The Gunnison tailings pile is located approximately 0.3 mi southeast of the Gunnison River and approximately 0.3 mi northwest of Tomichi Creek. These streams flow toward the southwest and merge approximately 1.5 mi downstream of the site. The natural surface drainage from the vicinity of the tailings is to the southwest to either Tomichi Creek or the Gunnison River.

Flooding of the tailings as a result of peak discharge of either the Gunnison River or Tomichi Creek is unlikely because the tailings are well above the stream bed and the flood plains have a wide cross-sectional area to accept peak flows. Only if flooding is associated with ice jams at the bridge across U.S. Highway 50 could some of the tailings become saturated. Even so, they would not be eroded by flood waters.

Contamination of surface waters near the pile could occur by physical transport of the tailings by overland runoff; however, there is little evidence of erosion except on the steepest slopes at the south side of the pile. There are no berms or other barriers to surface water runoff from the tailings. Monitoring of the Gunnison River upstream and downstream from the pile from December 1961 to June 1965 showed no ^{226}Ra contamination of the river by the pile.(4)

2.7.3 Ground Water Hydrology

The tailings lie on a relatively thick section of unconsolidated river bed material. The water in these unconsolidated materials is the major aquifer in the valley and is recharged by the Gunnison River and Tomichi Creek. The base of the tailings pile (interface) is about 10 ft above the level of the streams and saturated material is reached within 3-10 ft of the tailings-subsoil interface. Contamination of the unconfined aquifer could occur by seepage through the pile, especially considering the low pH of the tailings. The general direction of ground water flow parallels surface water flow to the southwest as depicted in Figure 2-5. Although the area to the southwest of the site is one of the least developed areas near Gunnison, there are nearby tourist and agricultural facilities (see Chapter 4). The plentiful ground water within a few feet of the land surface is an easily accessible water supply for future development. Such development could create changes in ground water gradients and increase the flow of contaminants into the unconfined ground water. At present all the city's water supplies are upgradient from the tailings pile.

The monitoring program referenced in Paragraph 2.7.2 indicates no measurable contamination of the Gunnison River from possible ground water contamination.

2.7.4 Meteorology(5)

The average annual precipitation in the Gunnison area is 11 in. High-intensity rainfall such as thunderstorms can be expected in the Gunnison area although most of the area's precipitation comes from winter snows. A rainfall of 6-hr duration totalling 1 in. has a probability of occurring once in 5 yr. Although there has been little erosion on the tailings pile and although the surface of the pile is stabilized physically by river-run gravel and by vegetation, nevertheless, tailings could be transported by overland flow into the ditch to the west of the tailings, and contaminated soil southwest of the main pile also could be eroded.

The weather data for Gunnison has been gathered at the airport. The strongest winds blow from the west and have the greatest potential of carrying material from the pile. The magnitude and direction of valley winds are depicted in Figure 2-6 and a wind rose from the Gunnison airport is given in Figure 2-7. Wind records verify the strong winds from the west. There is no evidence of on-going wind erosion at the site.

FIGURE 2-1. AERIAL PHOTOGRAPH OF SITE

130-12

FIGURE 2-2. TOPOGRAPHIC MAP

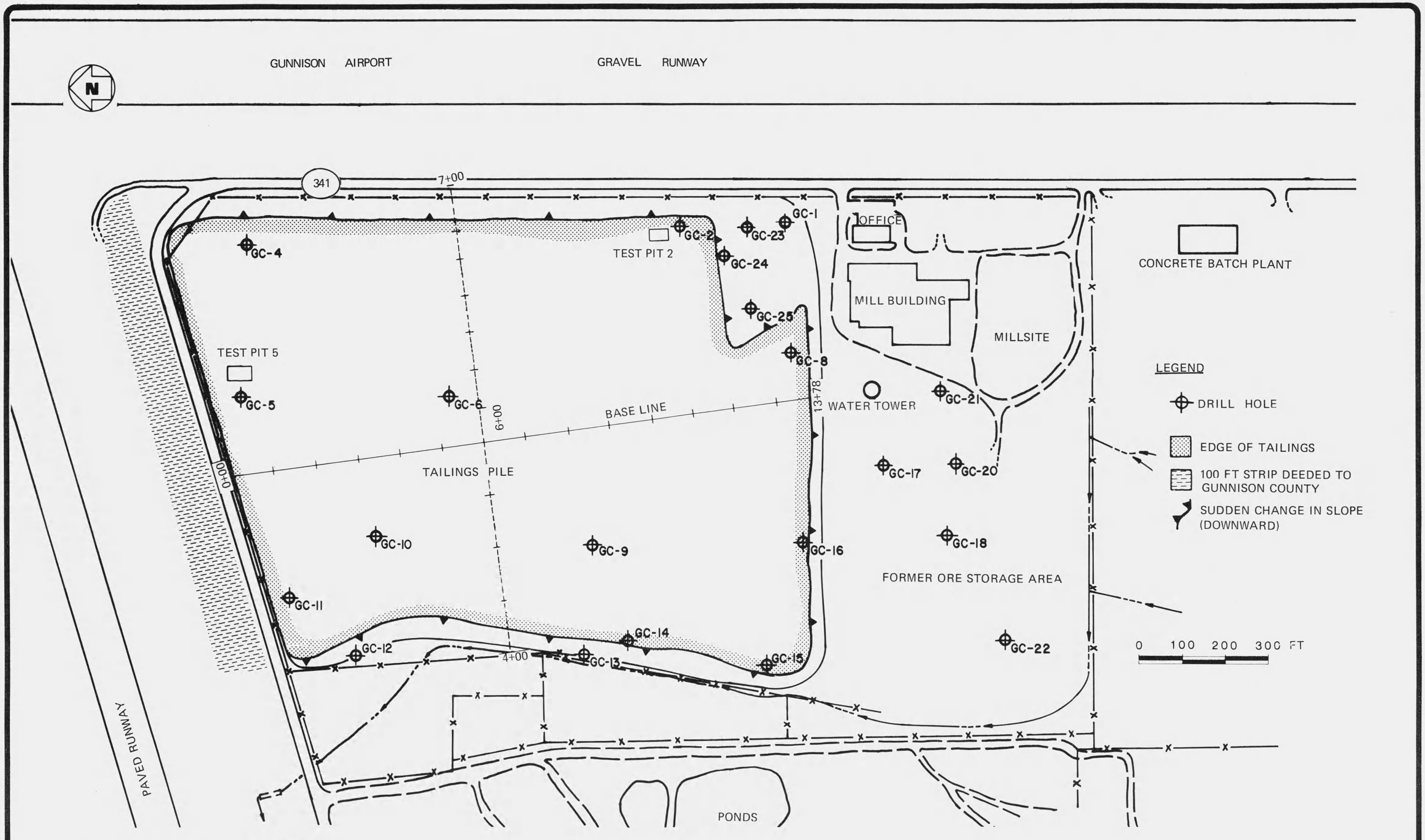

FIGURE 2-3. DESCRIPTIVE MAP

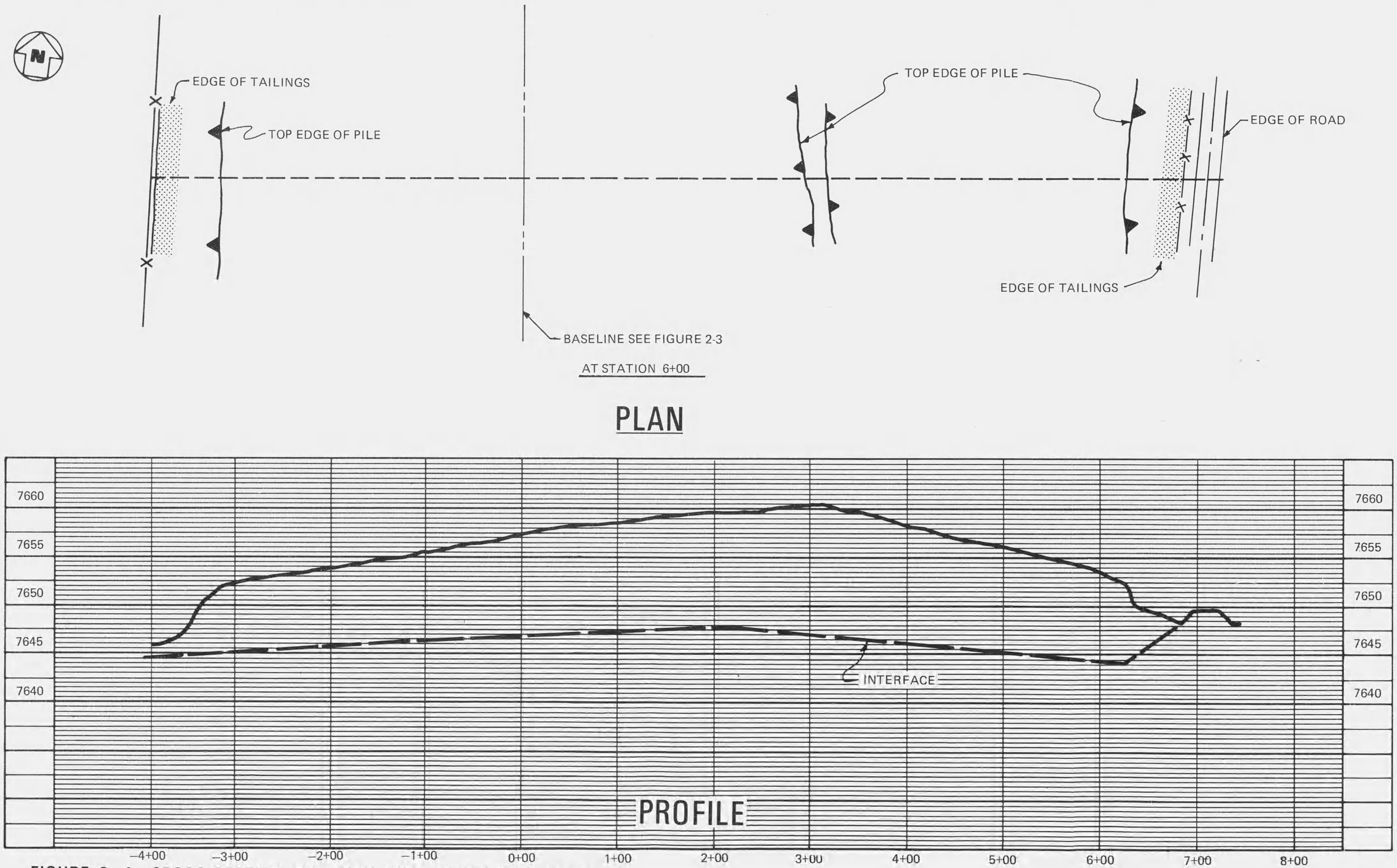

FIGURE 2–4. CROSS-SECTION THROUGH PILE AT STATION 6+00

130-12

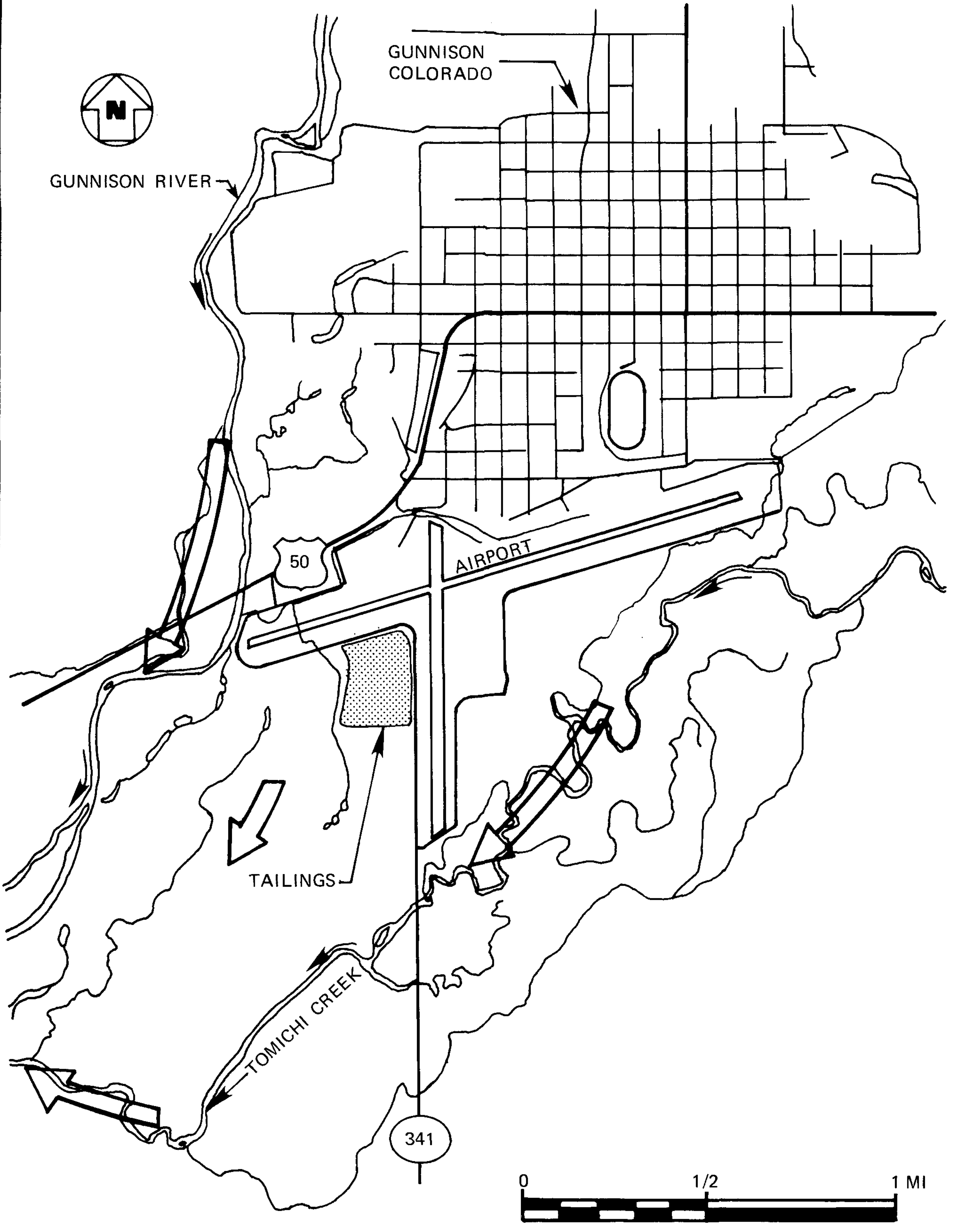

FIGURE 2-5. PROBABLE DIRECTION OF SURFACE AND GROUND WATER FLOW

130-12

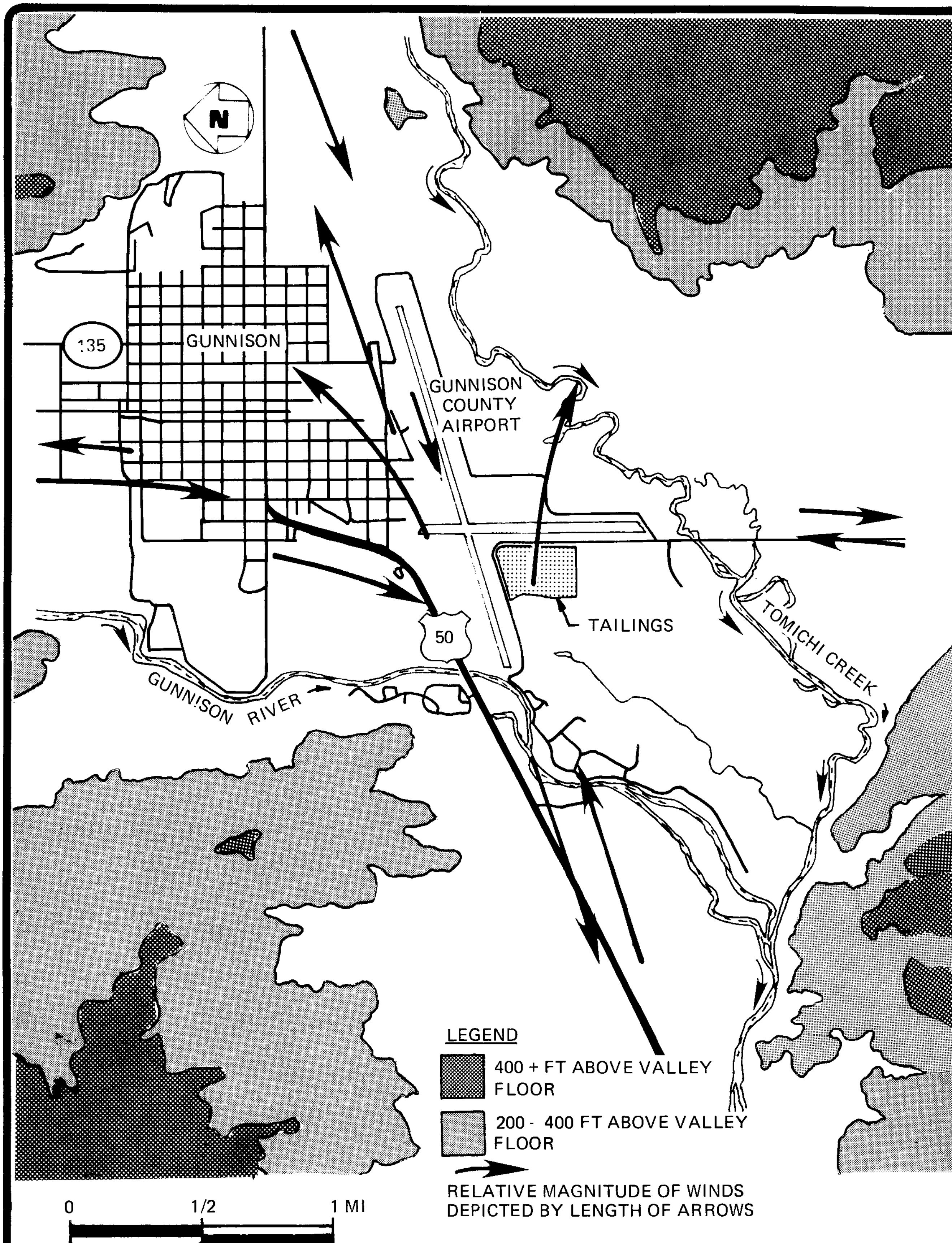

FIGURE 2-6. WIND MAP

130-12

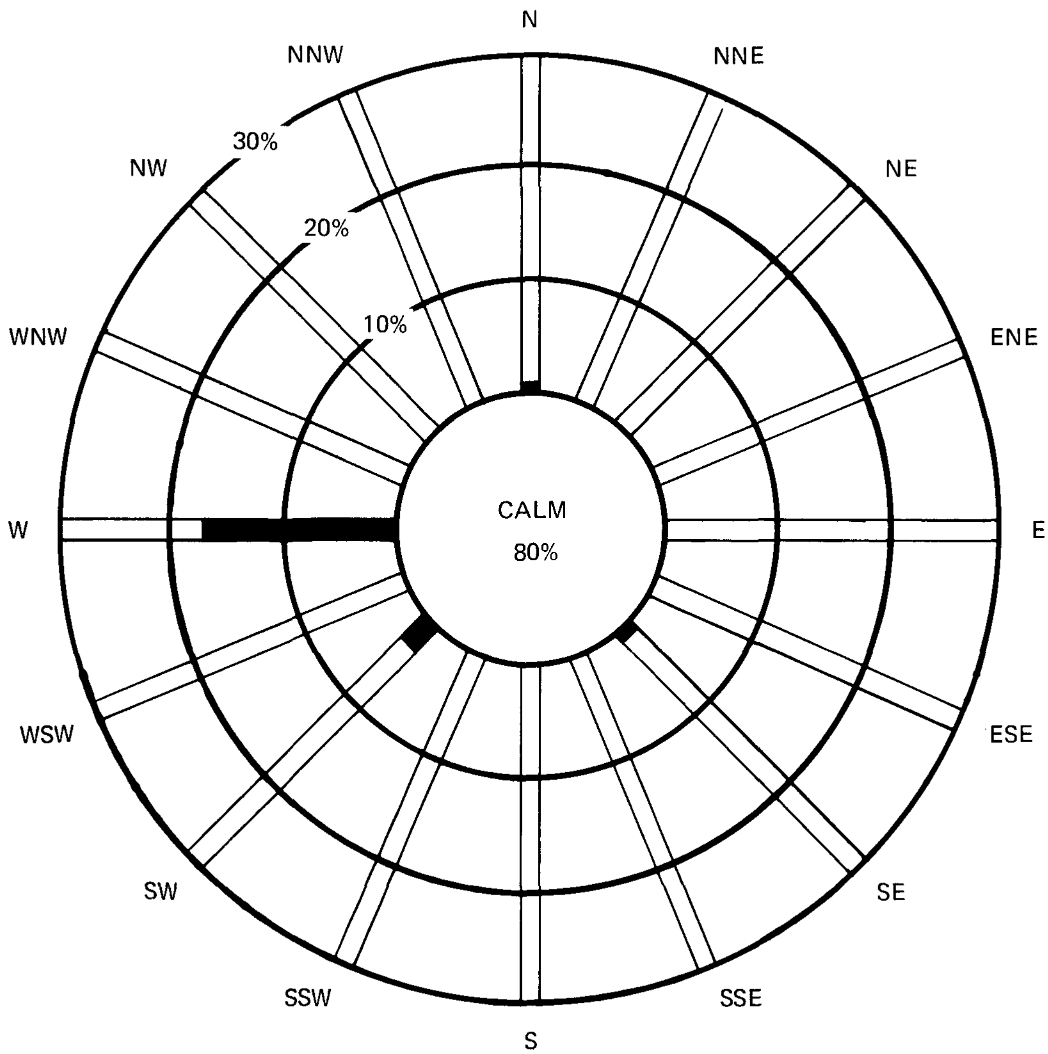

FIGURE 2-7. AIRPORT SURFACE WIND ROSE
(CUMULATIVE DATA FOR 1974 AND 1975)

130-12

TABLE 2-1

QUANTITIES OF MATERIALS IN TAILINGS PILE

Material	Volume (yd^3)	Weight (tons)
Tailings	345,000	540,000*
Dikes	17,800	32,500
Stabilization Material	30,600	55,800
Total	393,400	628,300

* Weight based on average existing field densities which include moisture.

TABLE 2-2

PHYSICAL PROPERTIES AND pH OF THE URANIUM TAILINGS

Sample Location*	Percent Moisture	Bulk Density (lb/ft^3)	pH of Soil (5% water by wt)
GC-2	17.67	114.6	2.95
GC-5	18.18	115.8	3.40
GC-9	6.91	127.5	2.55

* See Figure 2-3.

CHAPTER 2 REFERENCES

1. "Phase I Reports on Conditions of Uranium Millsite and Tailings at Gunnison, Colorado"; AEC; Grand Junction, Colorado; Oct 1974.

2. R. C. Merritt; The Extractive Metallurgy of Uranium; Colorado School of Mines Research Institute; Golden, Colorado; 1971.

3. A. W. Miller, D. K. Fuhriman, and L. F. Hintze; "Hydrology and Geology of Uranium Tailings Site at Gunnison, Colorado"; Center for Health and Environmental Studies, Brigham Young University; Provo, Utah; 1976.

4. "Radium-226, Uranium, and other Radiological Data Collected from Water Quality Surveillance Stations Located in Colorado, Utah, New Mexico, and Arizona"; 8SA/TIB-24; EPA, Region VIII; Jul 1973.

5. "Meteorology Affecting Uranium Tailings at Durango, Colorado"; unpublished report; URS Company; Denver, Colorado; Jun 1976.

CHAPTER 3

RADIOACTIVITY AND POLLUTANT IMPACT ON THE ENVIRONMENT

CHAPTER 3

RADIOACTIVITY AND POLLUTANT IMPACT ON THE ENVIRONMENT

The principal objective of the assessment in this chapter is to determine the magnitude and characteristics of the radiation emitted from the Gunnison uranium tailings pile and the resulting potential exposure to the population residing and working in the vicinity of Gunnison, Colorado. In addition, this chapter describes briefly the potential radioactive and chemical pollutants and their pathways in the environment. The notations and abbreviations used are given in Table 3-1.

3.1 RADIOACTIVE MATERIAL CHARACTERISTICS

Many elements spontaneously emit subatomic particles; therefore, these elements are radioactive. For example, when the most abundant uranium isotope, ^{238}U undergoes radioactive decay, it emits a subatomic particle called an alpha particle; the ^{238}U after undergoing decay becomes ^{234}Th, which is also radioactive; and ^{234}Th subsequently emits a beta particle and becomes ^{234}Pa. As shown in Figure 3-1, this process continues with either alpha or beta particles being emitted, and the affected nucleus thereby evolves from one element into another. It is noted in Figure 3-1 that ^{230}Th decays to ^{226}Ra, which then decays to ^{222}Rn, an isotope of radon. Radon, a noble gas, does not react chemically. The final product in the chain is ^{206}Pb, a stable isotope that gradually accumulates in ores containing uranium. Uranium ore contains ^{226}Ra and the other daughter products of the uranium decay chain. One of the daughters of ^{226}Ra is the isotope ^{214}Bi, which emits a significant amount of electromagnetic radiation known as gamma radiation. Gamma rays are very similar to X-rays, only more penetrating. The ^{214}Bi is the principal contributor to the gamma radiation exposure in the uranium-radium decay chain.

Besides knowing the radioactive elements in the decay chain, it is also important to know the rate at which they decay. This decay rate, or activity, is expressed in curies (Ci) or picocuries (pCi), where 1 pCi equals 10^{-12} Ci or 3.7×10^{-2} disintegrations per second. The picocurie often is used as a unit of measure of the quantity of a radioactive element present in soil, air, and water.

Another important parameter used in characterizing radioactive decay is known as the "half life", $T_{1/2}$. This is the time that it takes for half of any initial quantity of the radioactive atoms to decay to a different isotope. For example, it takes 4.5×10^9 yr for half the ^{238}U atoms to decay to ^{234}Th. Similarly, half of a given number of ^{222}Rn atoms will decay in 3.8 days.

The activity and the total number of radioactive atoms of a particular type depend upon their creation rates as well as their half life for decay. If left undisturbed, the radioactive components of the decay chain shown in Figure 3-1 all reach the same level of activity, matching that of the longest-lived initiating isotope. This condition is known as secular equilibrium. When the uranium is removed in the milling process, ^{230}Th, which is not removed, becomes the controlling isotope. After processing the ore for uranium, the thorium, radium, and other members of the decay chain remain in the spent ore solids in the form of a waste slurry. The slurry is pumped to tailings ponds. The sands and slimes that remain constitute the tailings piles. Generally, as at Gunnison, the slimes constitute only 20% of solid waste material, but they may contain 80% of the radioactive elements of major concern: radium, and its daughters.

3.2 RADIATION EFFECTS

The radioactive exposure encountered with uranium mill tailings occurs from the absorption within the body of the emitted alpha and beta particles, and gamma radiation. The range of alpha particles is very short; they mainly affect an individual when the alpha emitter is taken internally. Beta particles have a much lighter mass than alphas, and have a longer range; but they still cause damage mainly to the skin or internal tissues when taken internally. Gamma rays, however, are more penetrating than X-rays and can interact with all of the tissue of an individual near a gamma-emitting material.

The biological effects of radiation are related to the energy of the radiation; therefore, exposure to radiation is measured in terms of the energy deposited per unit mass of a given material. In the case of radon and its daughter products, the principal effect is from alpha particles emitted after the radon and its daughter products are inhaled.

The basic units of measurement for the alpha particles from short-lived radon daughters are the working level (WL) and the working level month (WLM). The working level is defined as any combination of the short-lived radon daughters in a liter of air that will result in the ultimate emission of 1.3×10^5 MeV of alpha energy. The working level is so defined because it is a single unit of measure, taking into account the relative concentrations of radon daughter products which vary according to factors such as ventilation. One WLM results from exposure to air containing a radon daughter concentration (RDC) of 1 WL for a duration of 170 hr.

The basic units of measurement for gamma radiation exposure and absorption are the roentgen (R) and the rad. One R is equal to an energy deposition of 88 ergs/g of dry air, and 1 rad is the dose that corresponds to the absorption of 100 ergs/g of material. The numerical difference between the magnitude of the two units is often less than the uncertainty of the measurements, so that exposure of 1 R is often assumed equivalent to an absorbed dose of 1 rad or a gamma dose of 1 rem.

3.3 NATURAL BACKGROUND RADIATION

There are several sources of radiation that occur naturally in the environment. Natural soils contain trace amounts of uranium, thorium, and radium that give rise to radon gas and to alpha, beta, and gamma radiation. The average background value in nine off-site soil samples for each member of the uranium decay chain, assuming equilibrium, was 1.5 pCi/g.[1] The sample locations taken within a 120-mi radius of Gunnison and the corresponding ^{226}Ra concentrations are shown in Figure 3-2. No previous measurements are available for the area. Another natural source of radiation in the environment arises from the decay of ^{232}Th, the predominant thorium isotope. The half-life of ^{232}Th is 1.4 x 10^{10} yr. It is also the parent of a decay chain containing isotopes of radium and radon. The average background value in the same off-site samples for each member of the thorium decay chain, assuming equilibrium, is about 1.1 pCi/g of soil. Table 3-2 lists the major background radioactive sources. It is noted that background values of the radium and thorium chains vary with locations by a factor of 6 and 14, respectively.

Background values of radon concentrations were measured at five locations using continuous radon monitors supplied by ERDA.[2] An average background value of 1.0 pCi/l was obtained from the 24-hr samples for the city of Gunnison. However, the range of the measurements extends from 0.9 to 1.1 pCi/l.

Background gamma ray rates, as measured 3 ft above the ground, also were determined at several locations within 0.6 mi from the site by using a calibrated and energy-compensated Geiger Mueller detector. A value of 13 μR/hr was established as the average background rate, but the values ranged from 10 to 15 μR/hr.[1] Cosmic rays are part of the measured background radiations levels. The contribution from cosmic rays is generally dependent upon the altitude and is approximately 9 μR/hr in the Gunnison area,[3] or approximately 70% of the measured average background value.

3.4 RADIATION EXPOSURE PATHWAYS AND CONTAMINATION MECHANISMS

As noted previously, the principal environmental radiological implications and associated health effects of uranium mill tailings are related to radionuclides of the ^{238}U decay chain: primarily ^{230}Th, ^{226}Ra, ^{222}Rn, and ^{222}Rn daughters. Although these radionuclides occur in nature, their concentrations in tailings material are several orders of magnitude greater than in average natural soils and rocks. The major potential routes of exposure to man are:

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(1) See end of chapter for references

(a) Inhalation of the ^{222}Rn daughters, from decay of ^{222}Rn escaping from the pile; the principal exposure hazard is to the lungs.

(b) External whole-body gamma exposure directly from the radionuclides in the tailings pile (primarily from ^{214}Bi) and in surface contamination from tailings spread in the general vicinity of the pile.

(c) Inhalation of windblown tailings; the primary hazard relates to the alpha emitters ^{230}Th and ^{226}Ra, each of which causes exposure to the bones and the lungs.

(d) Ingestion by man of ground or surface water contaminated from either radioactivity (primarily from ^{226}Ra) leached from the tailings pile or from solids physically transported into surface water.

(e) Erosion and removal of tailings material from the pile by flood waters or heavy rainfall; this can create additional contaminated locations with the same problems as the original tailings pile.

(f) Physical removal from the tailings pile also provides a mechanism for contamination of other locations.

(g) Contamination of food through uptake and concentration of radioactive elements by plants and animals is another pathway which can occur; however, this pathway was not considered in this assessment.

The extent of radiation and pollution transport from the pile into the environment is discussed in the following paragraphs.

3.4.1 Radon Gas Diffusion and Transport

Radon flux measurements were not performed at Gunnison because it rained during the first 2 days of the scheduled field survey period and remained cloudy and cold during the remainder of the week. The cover material had not dried sufficiently to obtain meaningful measurements of the flux. Based upon the radium activity versus depth in the pile, as measured by gamma probe measurements in auger holes, a radon flux of 470 pCi/m^2-s was calculated.

Radon gas above background, considered to be from the pile, was detected at distances up to 0.6 mi from the site. The locations and corresponding 24-hr average radon concentrations, including background, measured during this program with the continuous radon monitors are shown in Figure 3-3. The average background radon concentration was 1.0 pCi/l and the highest 24-hr average value measured was 3.6 pCi/l on the tailings pile. The latter value may be lower than the annual average as a result of moisture in the tailings and cover material.

Variation of radon concentration at two locations during the measurement period and the available weather data are shown in Figures 3-4 and 3-5. The sample location for Figure 3-4 is 0.5 mi south of the tailings pile. Figure 3-5 illustrates the measurements on the tailings pile. A diurnal variation of ^{222}Rn concentration is evident in both figures, indicating the presence of a source of ^{222}Rn greater than background near the measurement locations. Radon concentration measurements made near the pile during this program generally indicated increased concentrations during the night, with reduced values during the day. The increase in concentration is probably the result of an inversion condition and reduced wind velocities. High winds tend to disperse the radon and generally do not result in significantly higher measurements of radon concentration downwind from the tailings pile. Data were not recorded during high winds or rainstorms.

The radon concentration measurements are plotted in Figure 3-6 as a function of distance from the edge of the tailings pile. Model calculations were also performed with annual meteorology data to provide an additional estimate of the radon concentration in the vicinity of the pile. The FB&DU model first determines radon flux and the total radon released from the pile with diffusion theory using radium soil concentrations, and pile configuration deduced from the drilling and survey data. Then the radon transport off-pile is calculated by Gaussian diffusion[4] plus wind drift conditions. Meteorology for the town of Gunnison during a 2-yr period (1974-1975) was used. The measured values are generally consistent with the model results.

The model curve of radon concentration-versus-distance was used to calculate potential health effects resulting from radon diffusing from the Gunnison tailings.

3.4.2 Direct Gamma Radiation

The external gamma radiation (EGR) levels measured on the tailings pile are shown in Figure 3-7. These measurements, which include background, were taken 3 ft above ground with calibrated, energy-compensated Geiger Mueller detectors.[1] The highest gamma radiation rate (280 μR/hr) was measured toward the center of the north edge of the tailings pile. Gross gamma measurements on the pile ranged between 2 and 21 times background. In the former mill and ore storage areas, gamma radiation rates were measured from 2 times background to 230 μR/hr near the south edge of the tailings pile.

Gamma rate measurements away from the tailings pile, taken at 100-yd intervals, reached background levels about 0.25 mi to the south and east of the pile. Towards the north and west, the gamma radiation measurements reached background levels at about 0.2 mi. In Figure 3-8, these gamma radiation rate measurements are shown. The reduction of gamma radiation as a function of distance from the pile is shown in Figure 3-9.

Towards the city of Gunnison, the gamma radiation generally decreases to background range at the airport less than 0.2 mi from the pile.

3.4.3 Windblown Contaminants

Another pathway is the result of windblown tailings. Prevailing winds are from the west.

Figure 3-10 shows iso-exposure lines due to the residual windblown tailings as determined by EPA.(5) If scattered tailings and ore are removed from inside the 10-μR/hr line (toward the pile), and if the pile is removed or covered to provide essentially complete gamma shielding, then the remaining tailings outside the line (away from the pile) would produce a new gamma exposure rate, 3 ft above ground, approximately equal to 10 μR/hr.

Tailings remain in the area between the north end of the pile and the east-west runway of the airport. These tailings are not all windblown tailings, but remain from the original pile and from tests for possible use in airport construction. The 40-μR/hr line in Figure 3-10 extends around these tailings north of the pile.

Surface soil samples were taken in the area surrounding the tailings.(1) The sample locations and ^{226}Ra concentrations are shown in Figure 3-11. Five soil and sediment samples contained ^{226}Ra above twice background; however, none of these appeared to be due to windblown contamination. The sample with the highest ^{226}Ra content was taken from the north end of the tailings and its origin was described in the preceding paragraph. The sample with the next highest ^{226}Ra content which was about 5 times background, was taken between the former millsite and the ore storage area south of the tailings. The other surface soil sample with elevated ^{226}Ra content was taken near the southwest corner of the tailings pile. This sample contained 2.6 times background. Two water sediment samples contained ^{226}Ra concentrations of 5.0 and 9.8 pCi/g; however, they appeared to be due to spills rather than windblown tailings since surface soil samples between the tailings and where the sediment was obtained were significantly lower in ^{226}Ra content.

No air particulate measurements were performed at the Gunnison site.

3.4.4 Ground and Surface Water Contamination

Seven surface water samples were taken from the vicinity of

Less than 0.05	Less than 0.01	No remedial action indicated

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*Based upon yearly average values from 6 air samples of at least 100-hr duration taken at a minimum of 4-wk intervals throughout the year.

The radiological criteria for decontamination of inactive uranium millsites and for open areas are based upon EGR readings above background, measured 3 ft above ground. Decontamination should result in residual exposures that are as low as practicable. For this assessment the following criteria were used:

(a) For the tailings piles:

(1) Tailings should be covered so that residual gamma ray levels do not exceed 0.040 mR/hr above background. The area also should be designated a control area with restricted access.

(2) Where the site is not considered suitable for long-term stabilization, remove so that residual radium concentration in the soil does not exceed twice background values.

(b) Windblown tailings in open land areas near to or adjacent to the site:

(1) If gamma levels are less than 0.010 mR/hr above background, the land may be released for unrestricted use.

(2) If gamma levels exceed 0.010 mR/hr above background, cleanup should reduce the radium soil concentration to no more than twice background.

(3) If tailings removal is not practicable, residual gamma levels should in any part of the area not exceed 0.040 mR/hr above background.

3.6 POTENTIAL HEALTH IMPACT

An assessment has been made of the potential health impact of the tailings pile. The six environmental pathways described in paragraph 3.4 were evaluated. A summary of the evaluation of each pathway is presented below:

(a) Radon Diffusion - inhalation of radon daughters from radon diffusion constitutes the most significant pathway and results in the largest estimated population dose.[1,9] Elevated concentrations were measured to 0.6 mi from the tailings pile.

(b) External Gamma Radiation - gamma radiation above background is measurable to distances up to 0.25 mi from the piles, an area with very few inhabitants. People on-site will receive some gamma exposure until the pile is covered with sufficient material to reduce the gamma radiation. Exposure to the local population within 0.25 mi from the pile has been evaluated and yields a negligible health impact compared with exposure from radon daughters.

(c) Airborne Activity - the limited, directional spread of significant quantities of windblown tailings toward inhabited areas indicates that direct inhalation or ingestion of tailings particles may be a minor component of the total population dose. This is a general result also reported at other uranium tailings piles.[10,11] Added stabilization of the Gunnison tailings against wind erosion will eliminate any gradual accumulation of tailings off the site.

(d) Water Contamination - the low ^{226}Ra activity in nearby off-site surface and ground water indicates little, if any, ^{226}Ra contamination from the tailings pile, as confirmed by measurements since 1961. However, the conditions at the site indicate a potential for contamination.

(e) Subsoil Contamination - leaching of radioactive materials into the ground beneath the pile at the millsite is on the order of 1 to 4 ft. Water analyses do not indicate significant contamination from this pathway, however.

(f) Physical Removal - tailings which have been placed near a structure or used in its construction are sources for elevated gamma levels and radon daughter concentrations in the structure. Radiation exposure to individuals living or working in these structures can be significant. (For details refer to Chapter 7.)

Only the potential health effects from the inhalation of radon daughters (pathway a) are estimated quantitatively in this assessment because this pathway constitutes the most significant pathway.[9-11] Furthermore, it is assumed that the uncertainty in the estimates of the potential health effects from this pathway far exceeds the magnitude of the health effects from the other pathways.

It is extremely difficult to predict with any assurance that a specific health effect will be observed within a given time after chronic exposure to low doses of toxic material. Therefore, the usual approach to evaluation of the health impact of low-level radiation exposures is to make projections from observed effects of high exposures on the basis that the effects are linear, using the conservative assumption of no threshold for the effects. The resulting risk estimators also have associated uncertainties due to biological variability among individuals and to unknown contributions from other biological insults which may be present simultaneously with the insult of interest. No synergistic effects are considered explicitly in this analysis. For the purpose of this engineering study, lung cancer is the potential health effect considered for RDC. The health effects were estimated using both an absolute and a relative risk model.

3.6.1 Assumptions and Uncertainties in Estimating Health Effects

Since radiation exposure from ^{222}Rn daughters is expressed in terms of working levels (WL) and working level months (WLM), total population exposures as well as health risk estimates are based upon these units, i.e. person-WLM. Exposures and resulting health effects often are expressed in terms of rems; however, estimates of the WLM-to-rem conversion factor for internal lung exposure to alpha particles from ^{222}Rn daughters vary by over an order of magnitude. Presently, there are significant differences of opinion related to the choice of an appropriate conversion factor. Consequently, disagreements of calculated health effects from RDC occur when these effects are based on the rem.

The absolute risk estimator used in this assessment is that given in the report of the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR report).(12) This report presents risk estimators for lung cancer derived from epidemiological studies conducted on two groups of miners, namely:

> 3 cancers per year per 10^6 person-WLM exposure for uranium miners
>
> 8 cancers per year per 10^6 person-WLM exposure for fluorspar miners

Therefore, the average of these two values was chosen as the risk estimator for use in this study. This estimator then is:

> 6 cancers per year per 10^6 person-WLM exposure

A dose from a given ingestion or inhalation of radionuclides varies widely due to differences in age (infants-adults), physical size, etc. This and other components of natural biological variability which exist among members of any given population, as well as the differences between exposure conditions in residences and mines, give rise to an uncertainty on the order of a factor of 3 in this parameter.(13)

The commitment, then, of 6 cancers per year has a statistical basis and relates to a total population exposure of 10^6 person-WLM. If a cancer does occur it likely will be evident during the 30-yr period following the initial exposure and latency period.[14] When the exposure is continual over an individual's lifetime, this commitment is cumulative and the risk per year increases to an ultimate value of 6 times 30, or:

180 effects per year for 30×10^6 person-WLM total cumulative exposure

This mathematical expression also can be interpreted in terms of the average annual risk to an individual per unit of exposure. For example, an individual with a continuous exposure of 1 WLM annually has about a 2×10^{-4} probability each year of developing lung cancer from this exposure. Several investigations have been reported recently concerning the association between lung cancer incidence and RDC exposures in miners.[13,15,16] These investigations yielded risk estimator values consistent with the risk estimator used in the present assessment. The relative risk estimator can be several factors larger than the absolute risk estimator.[17]

For the purposes of this assessment, equivalent working levels inside structures are determined from the radon concentration assuming a 50% equilibrium condition. This yields the following conversion factor:

$$1 \text{ pCi/l of } {}^{222}\text{Rn} = 0.005 \text{ WL}$$

It is assumed that the component of indoor radon concentration due to radon exhaled from the piles is equal to the corresponding outdoor concentration component at that point. However, the concentration of radon daughters is higher indoors owing to reduced ventilation and to other sources of radon, such as building materials.

The exposure rate in terms of WLM/yr can be obtained from a continuous 0.005 WL concentration (equivalent to 1 pCi/l Rn concentration) as follows:

$$(0.005 \text{ WL})\left(8766 \frac{\text{hr}}{\text{yr}}\right)\left[\frac{1 \text{ WLM}}{1 \text{ WL } (170 \text{ hr})}\right] = 0.25 \frac{\text{WLM}}{\text{yr}}$$

The risk estimator[12] used for continual exposure to gamma radiation is:

100 effects per year for 10^6 person-rem continuous exposure to gamma radiation

In this assessment it is assumed that a gamma exposure of 1 R in air is equivalent to a dose of 1 rem in soft tissue.

3.6.2 Health Effects

The model curve of radon concentration-versus-distance (Figures 3-6) is used to determine the health effects due to radon from the Gunnison pile. First, an indoor radon daughter concentration is deduced from the outdoor radon concentration curve using the conversion factor 1 pCi/l of ^{222}Rn outside equals 0.25 WLM/yr inside, then, the resulting RDC distribution is multiplied by the risk estimators given previously to yield the health effect risk per person as a function of distance from the pile. The estimated annual radiation-induced lung cancer risk due to the pile is given in Figure 3-15 as a function of distance from the edge of the pile for prolonged continuous exposure. The curve shown in the figure represents the sum of the estimated annual radiation-induced risk from the tailings pile plus the average lung cancer risk per year from all causes for residents of the State of Colorado.(18) It is noted that the risk for developing lung cancer from pile radon near the edge of the pile is one-half the natural occurrence risk.

No health effects were attributed to gamma radiation from the pile, because gamma population exposures are very small within 0.25 mi surrounding the pile where the gamma radiation from the pile is greater than the background range.

Health effects from total population RDC exposures for the area within 2.5 mi from the tailings pile perimeter are obtained by multiplying the health effect risk per person from the curves given in Figure 3-15, by the population distribution as a function of distance from the pile. The results are given in Table 3-3. Beyond 0.6 mi, the pile-induced radon concentration is so low that the contribution to health effects is negligible. The population was estimated using 1970 census enumeration district data for Gunnison and a 3.3% growth rate was assumed to estimate 1976 population. The population distribution as a function of distance and direction from the pile was considered in the health effects calculations. The health effect values are obtained by converting the appropriate radon concentrations in the Gunnison area to equivalent WLM/yr and multiplying by the absolute risk estimator and the population distribution.

Also shown in the table are health effects estimated from background radon concentrations. The pile-induced radon daughter health effects are approximately 5% of background values for the area within 2.5 mi of the tailings, which contains most of the Gunnison population.

If the relative risk estimator is used, the health effects estimates are correspondingly larger than the ones given in Table 3-3. The uncertainty in the health effects estimation is about a factor of 4.

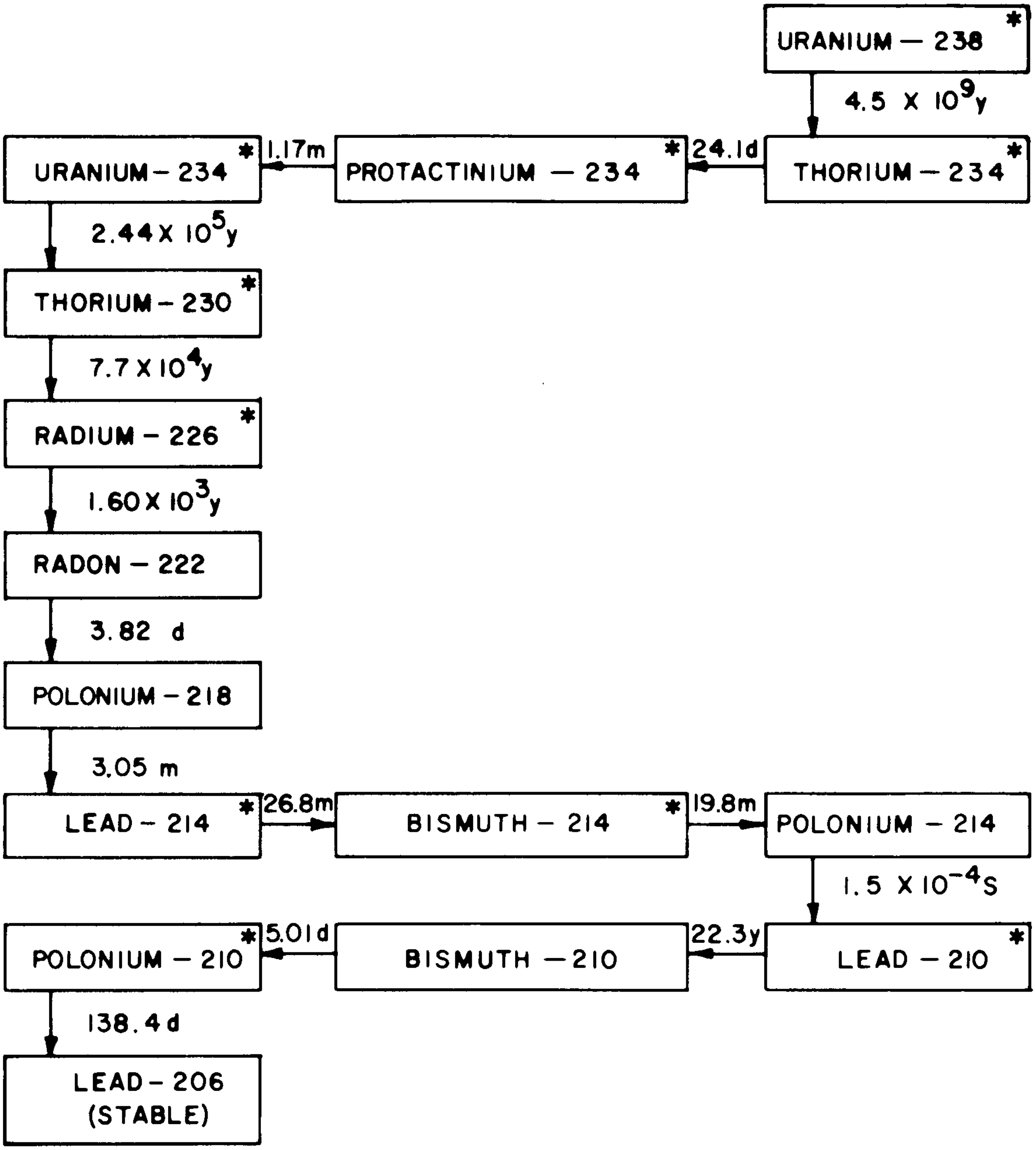
Also shown in Table 3-3 are 25-yr cumulative values based on two growth rate projections. The health effects in Table 3-3 are considered in conjunction with remedial action costs in Chapter 9.

3.7 NONRADIOACTIVE POLLUTANTS

The tailings piles contain other potentially toxic materials. Chemical analyses of tailings samples from auger holes in the Gunnison tailings pile showed barium and lead in concentrations between 30 and 150 ppm. The highest selenium concentration measured was about 1 ppm; and the arsenic ranged as high as 450 ppm. Vanadium was present in a range of concentrations from less than 0.01 to 4 ppm.

Eleven water samples were taken from the vicinity of the Gunnison tailings pile and chemically analyzed. The locations of these samples are shown in Figure 3-12 and the results of the analysis are given in Table 3-4. Four of these samples were obtained from surface water, of which two were from Tomichi Creek, one from a stream which drains the area west of the tailings, and one from a pond west of the pile. Seven of the samples were from shallow wells around the tailings pile and situated hydrologically downgradient from the pile. All samples contained elevated levels of iron. The selenium content of the sample from the fishing pond and one of the Tomichi Creek samples were well above the EPA Interim Drinking Water Standard. The contamination was very localized and cannot be definitely ascribed to the tailings pile, since neither an obvious pathway nor a general high level of contamination were found surrounding the tailings. Gunnison is an old mining district and these spots of localized contamination may be due to earlier mining activity or from ore spills during the Gunnison mill operation, particularly since one area is where the road crosses Tomichi Creek.

In summary, while there is no definitive evidence demonstrating the contamination of the surface or unconfined ground water from the Gunnison tailings, the hydrologic conditions of the site indicate a potential for contamination.



NOTE:
VERTICAL DIRECTION REPRESENTS ALPHA DECAY, HORIZONTAL DIRECTION INDICATES BETA DECAY. TIMES SHOWN ARE HALF LIVES. ONLY THE DOMINANT DECAY MODE IS SHOWN.
* ALSO GAMMA EMITTERS

FIGURE 3-1. RADIOACTIVE DECAY CHAIN OF URANIUM 238

130-12

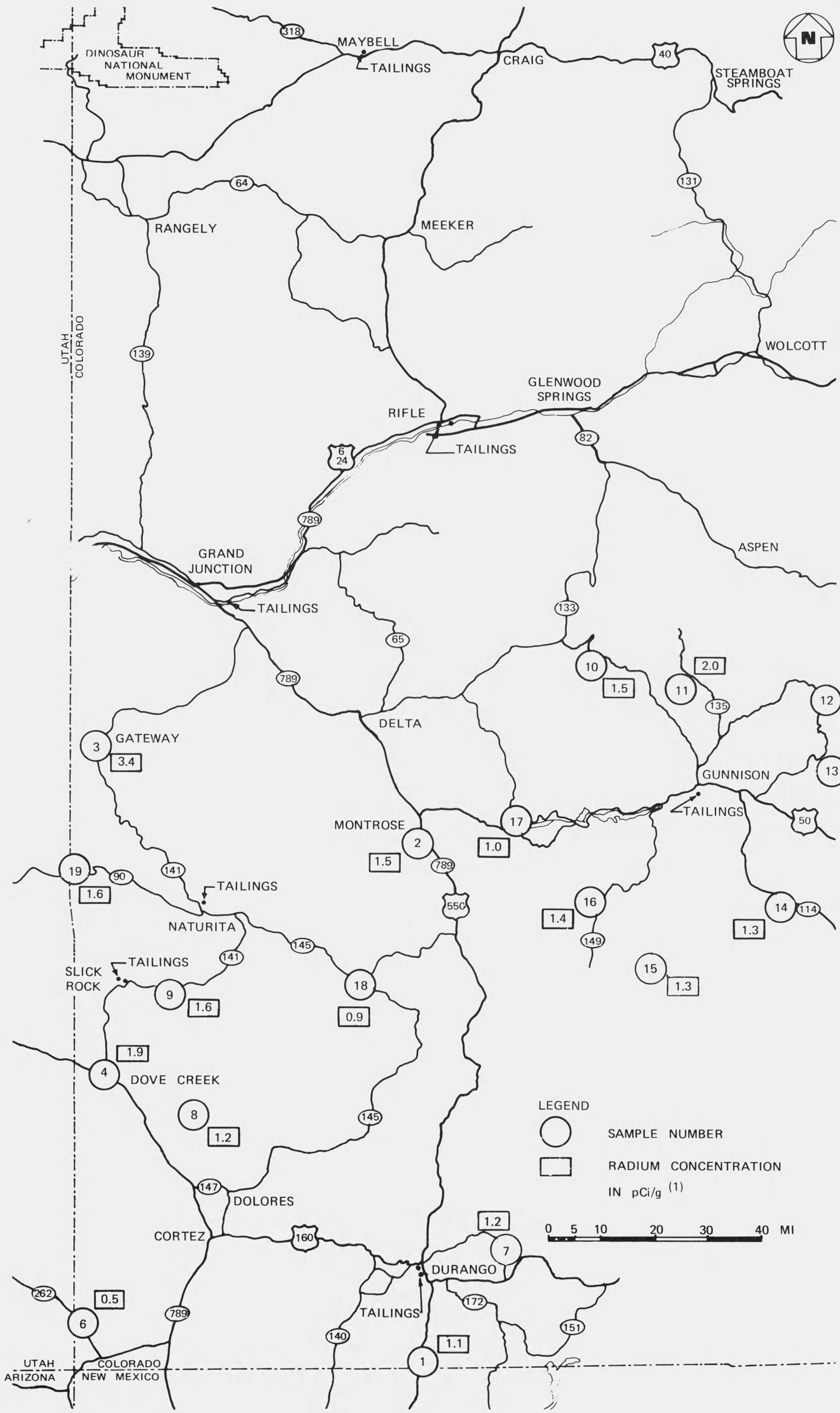
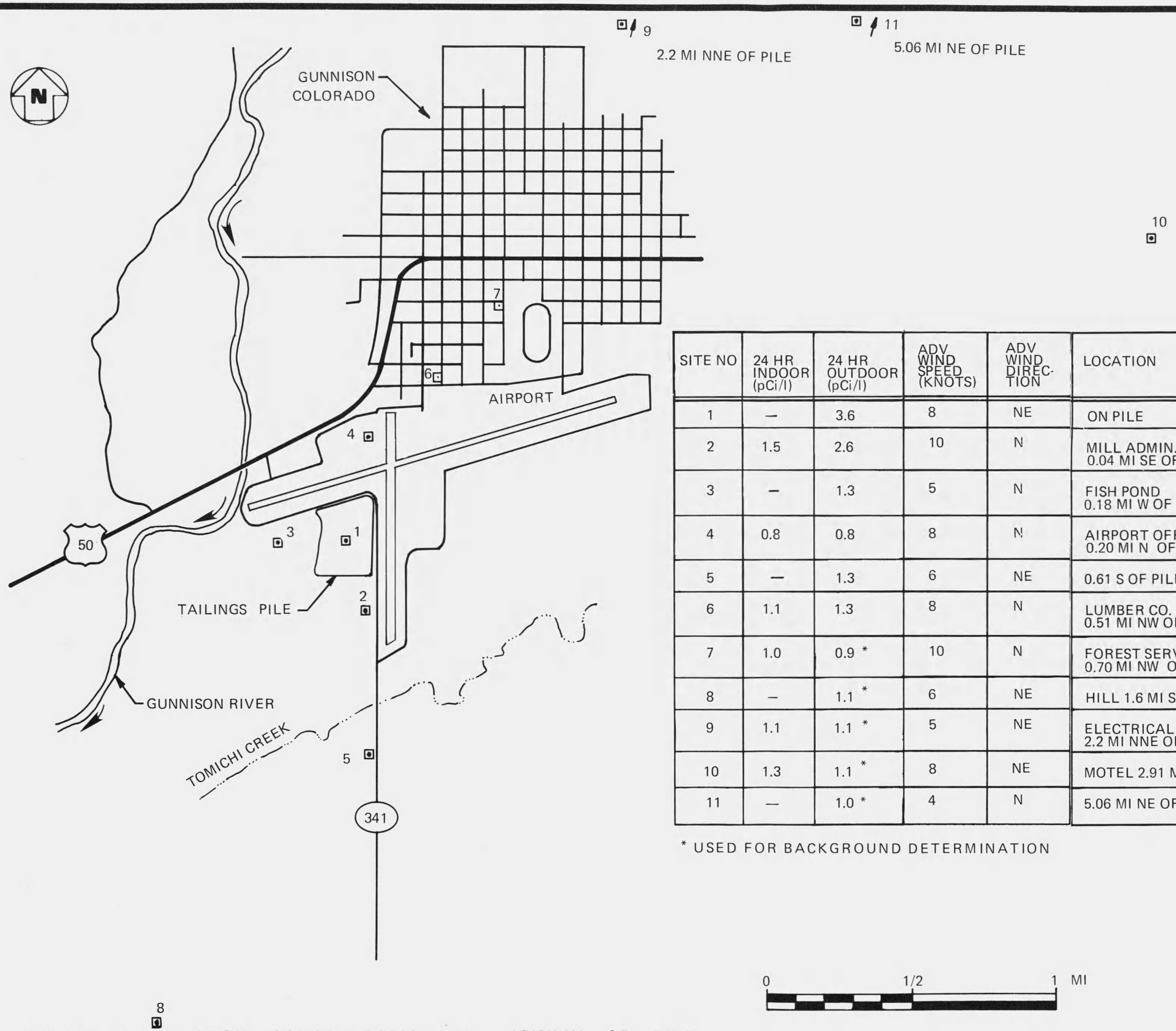


FIGURE 3-2. LOCATIONS FOR 226RA BACKGROUND SAMPLES

Ford, Bacon & Davis Utah Inc.



SITE NO	24 HR INDOOR (pCi/l)	24 HR OUTDOOR (pCi/l)	ADV WIND SPEED (KNOTS)	ADV WIND DIREC-TION	LOCATION
1	—	3.6	8	NE	ON PILE
2	1.5	2.6	10	N	MILL ADMIN. BLDG. 0.04 MI SE OF PILE
3	—	1.3	5	N	FISH POND 0.18 MI W OF PILE
4	0.8	0.8	8	N	AIRPORT OFFICE 0.20 MI N OF PILE
5	—	1.3	6	NE	0.61 S OF PILE
6	1.1	1.3	8	N	LUMBER CO. 0.51 MI NW OF PILE
7	1.0	0.9 *	10	N	FOREST SERVICE GARAGE 0.70 MI NW OF PILE
8	—	1.1 *	6	NE	HILL 1.6 MI SW OF PILE
9	1.1	1.1 *	5	NE	ELECTRICAL SHOP 2.2 MI NNE OF PILE
10	1.3	1.1 *	8	NE	MOTEL 2.91 MI E OF PILE
11	—	1.0 *	4	N	5.06 MI NE OF PILE

* USED FOR BACKGROUND DETERMINATION

FIGURE 3-3. RADON CONCENTRATION IN VICINITY OF PILE

130-12

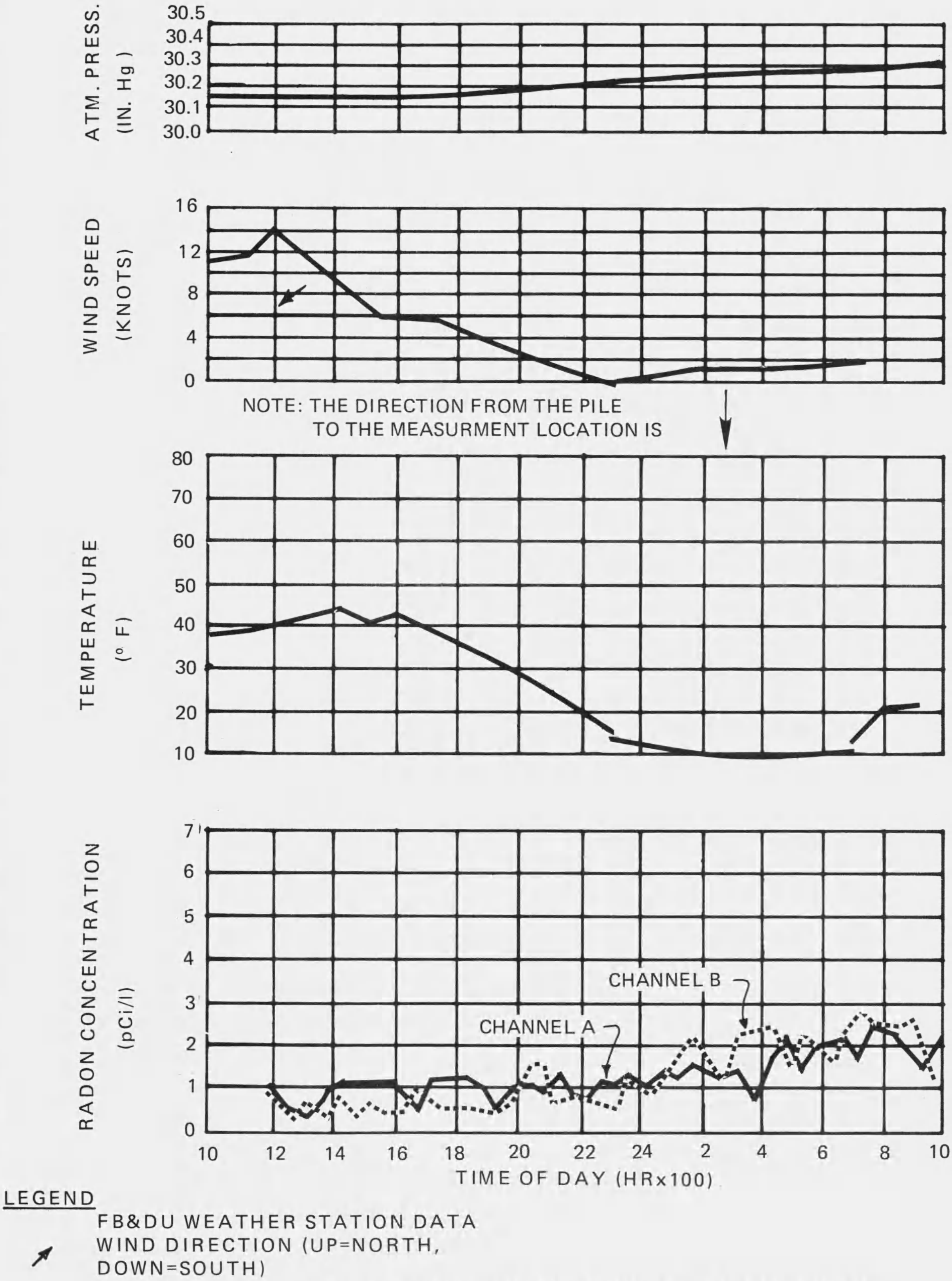


FIGURE 3-4. 222 Rn AND ATMOSPHERIC TRANSIENTS AT 0.5 MI S OF PILE ON OCT 6, 1976

130-12

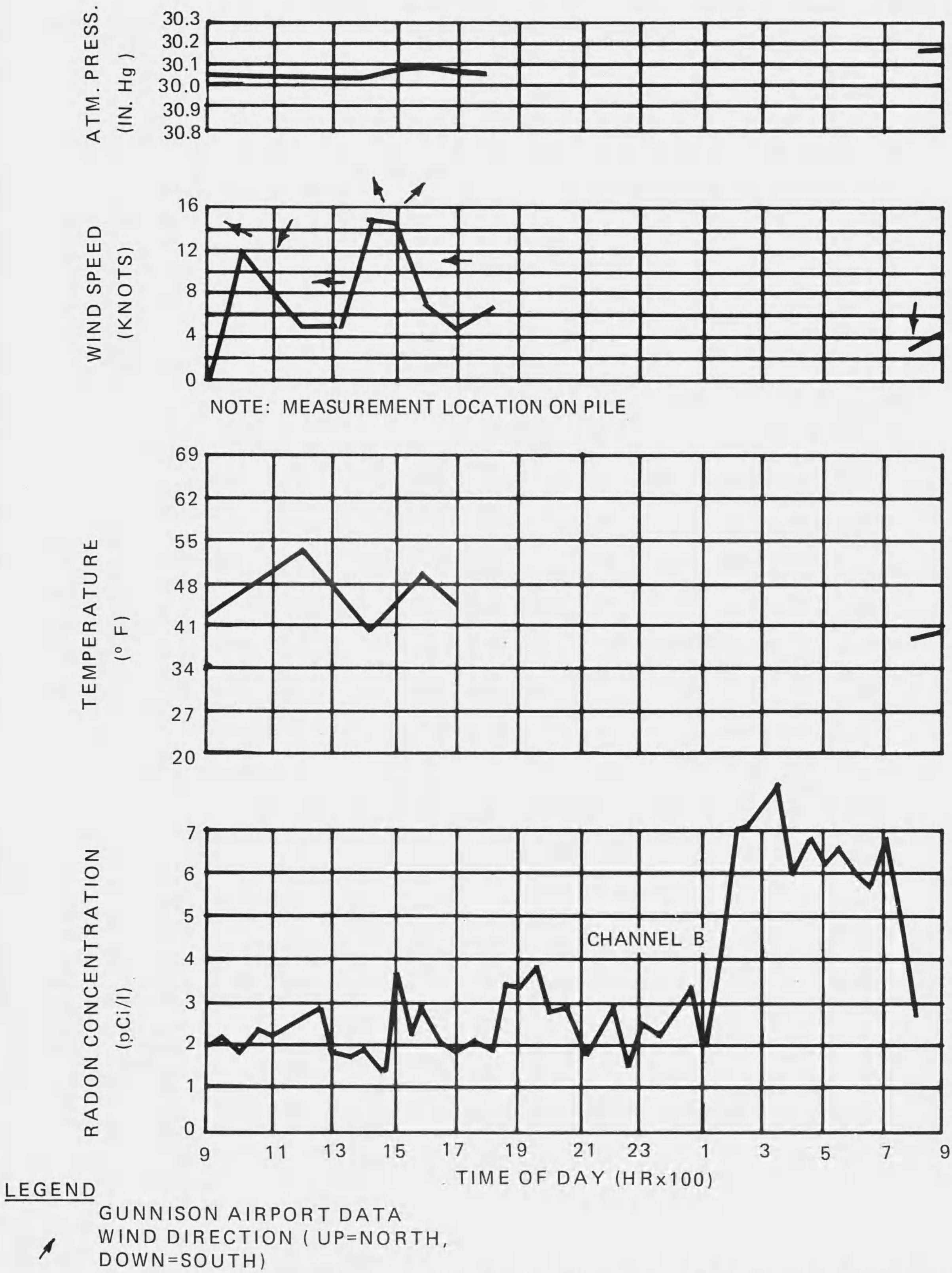


FIGURE 3–5. 222 Rn AND ATMOSPHERIC TRANSIENTS ON TOP OF TAILINGS PILE ON MAY 6, 1976

130-12

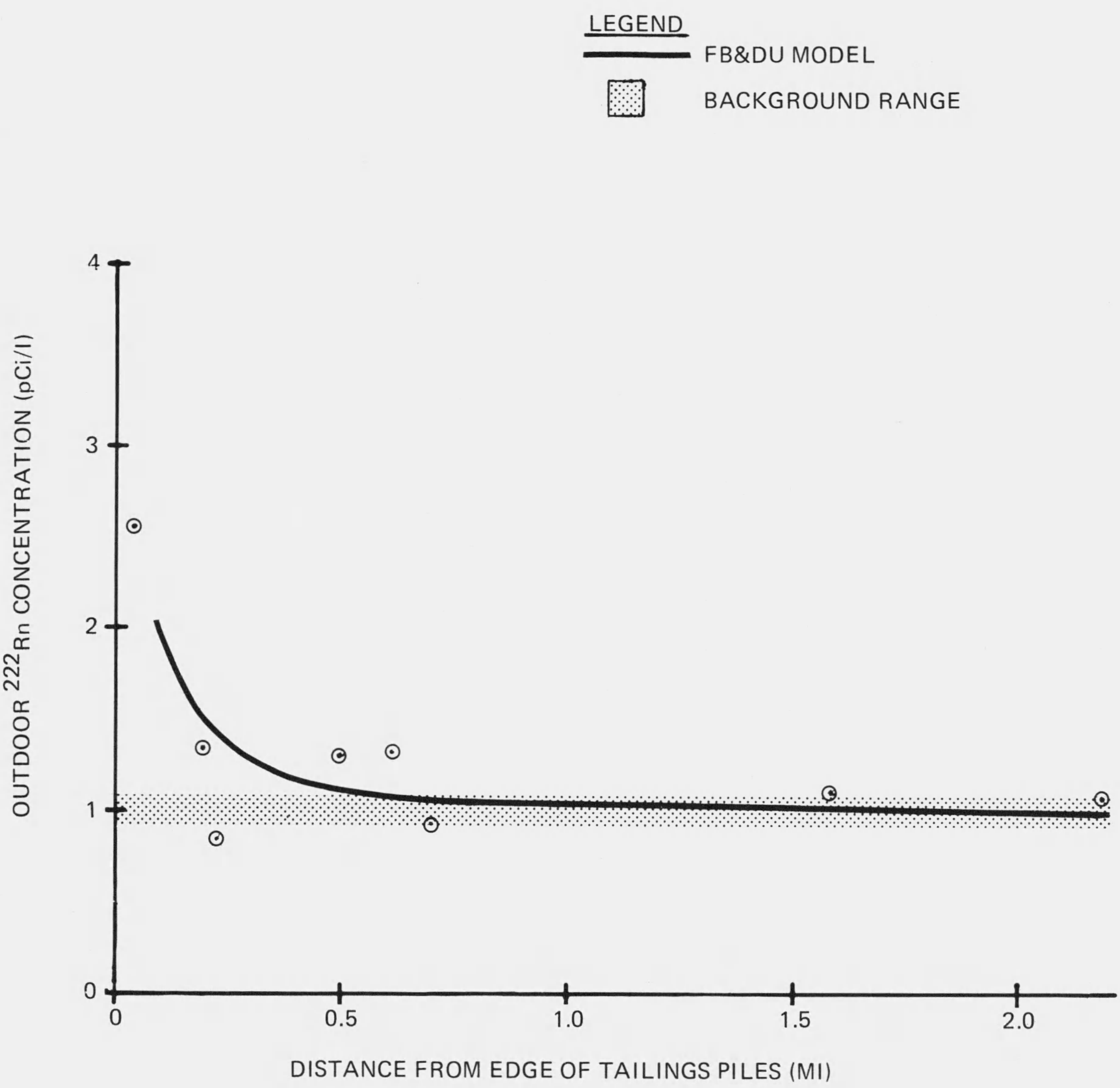


FIGURE 3-6. REDUCTION OF OUTDOOR 222Rn CONCENTRATION WITH DISTANCE FROM THE TAILINGS PILE

130-12

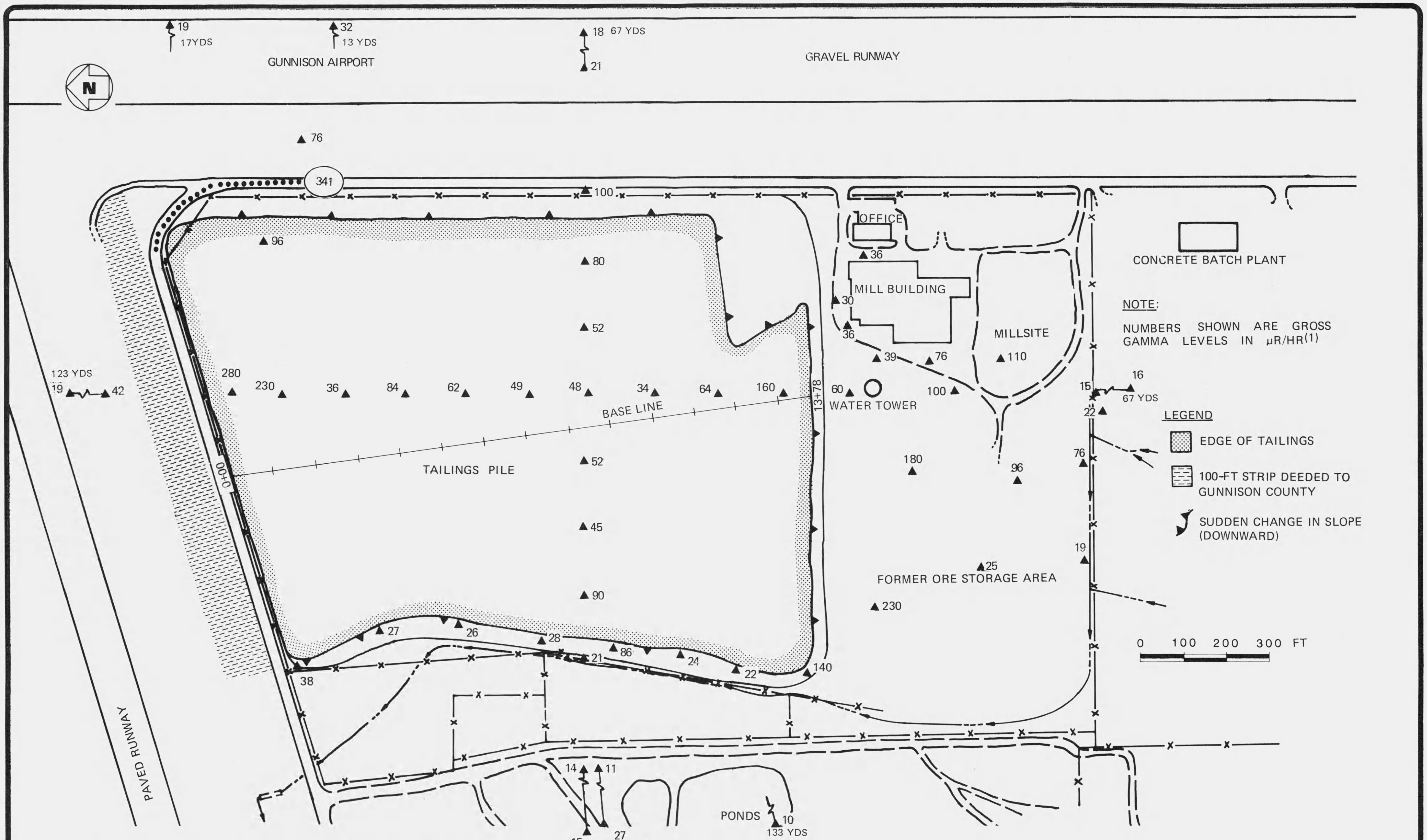
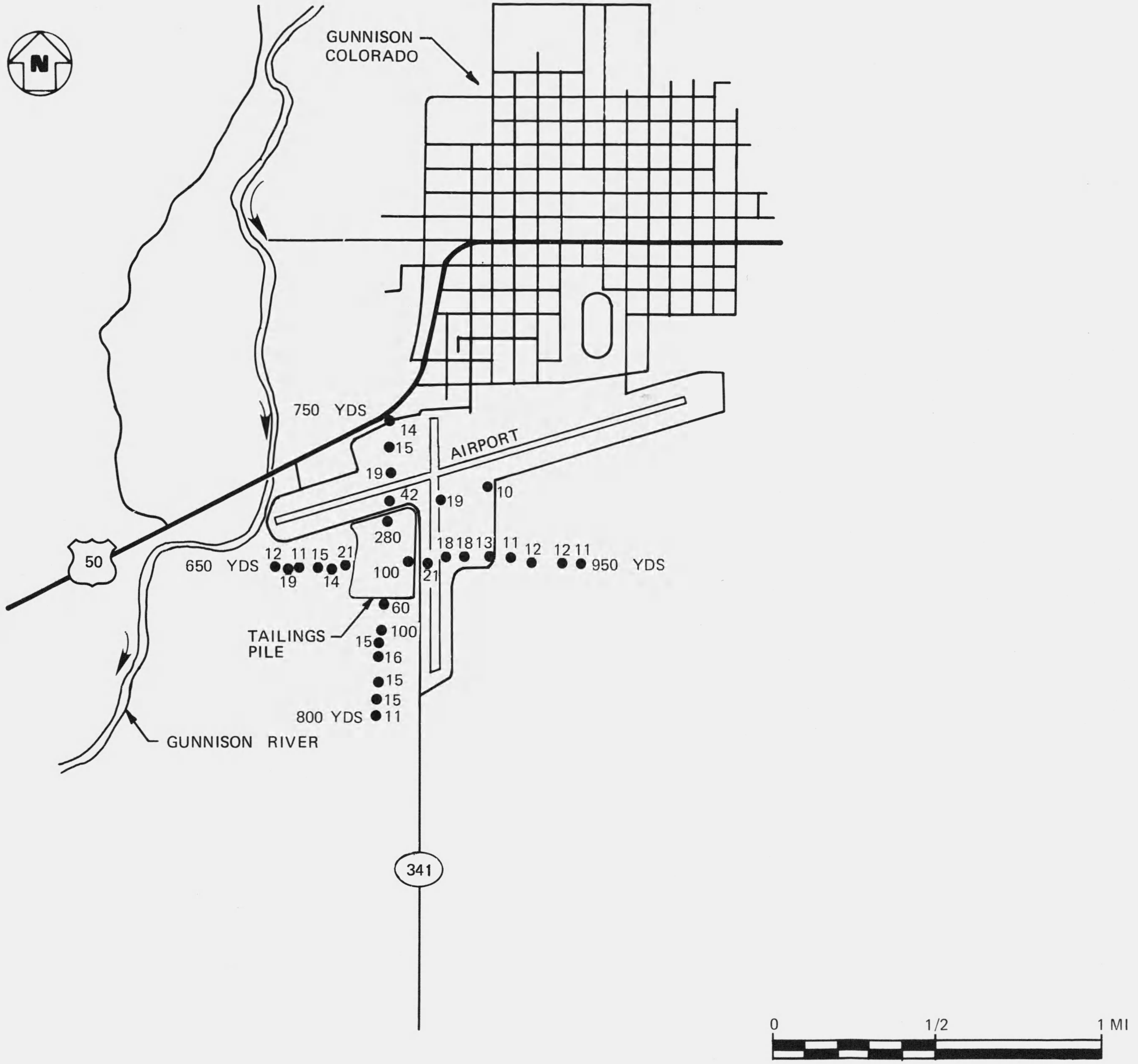


FIGURE 3–7. GAMMA LEVELS AT SITE 3 FT ABOVE GROUND



NOTE:

NUMBERS SHOWN ARE GROSS GAMMA LEVELS IN μR/HR(1)

FIGURE 3-8. GAMMA LEVELS IN VICINITY 3 FT ABOVE GROUND

130-12

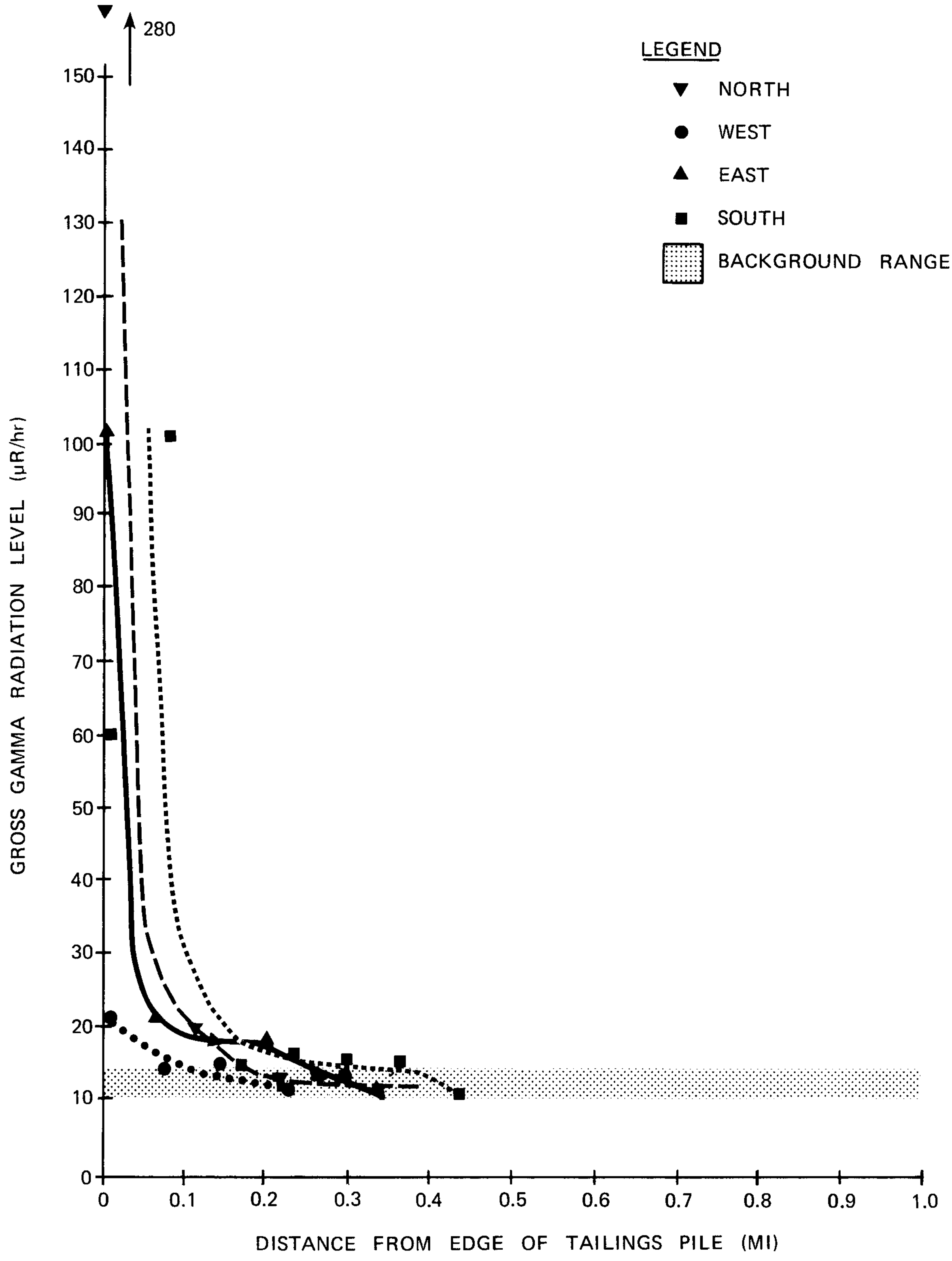
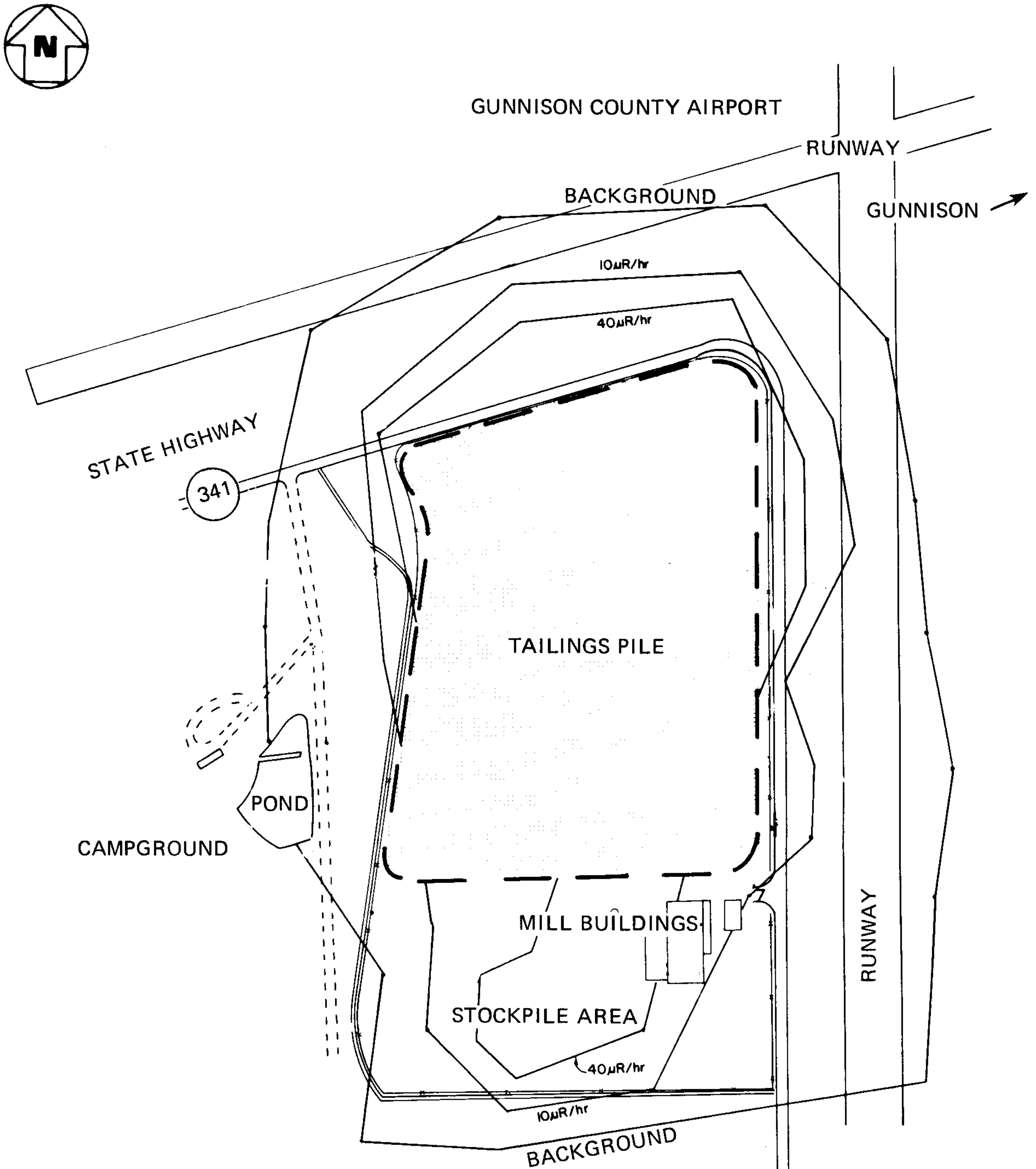


FIGURE 3-9. REDUCTION OF EXTERNAL GAMMA RADIATION LEVELS WITH DISTANCE FROM THE TAILINGS PILE

130-12



NOTE:

REFERENCE; TECHNICAL NOTE ORP/LV-75-5, "GAMMA RADIATION SURVEYS AT INACTIVE URANIUM MILLSITES", USEPA , LAS VEGAS, NEVADA, AUGUST 1975
FIG. 5 PAGE 45

0 200 400 600 800 FT

FIGURE 3-10. EPA GAMMA SURVEY SURROUNDING MILLSITE

130-12

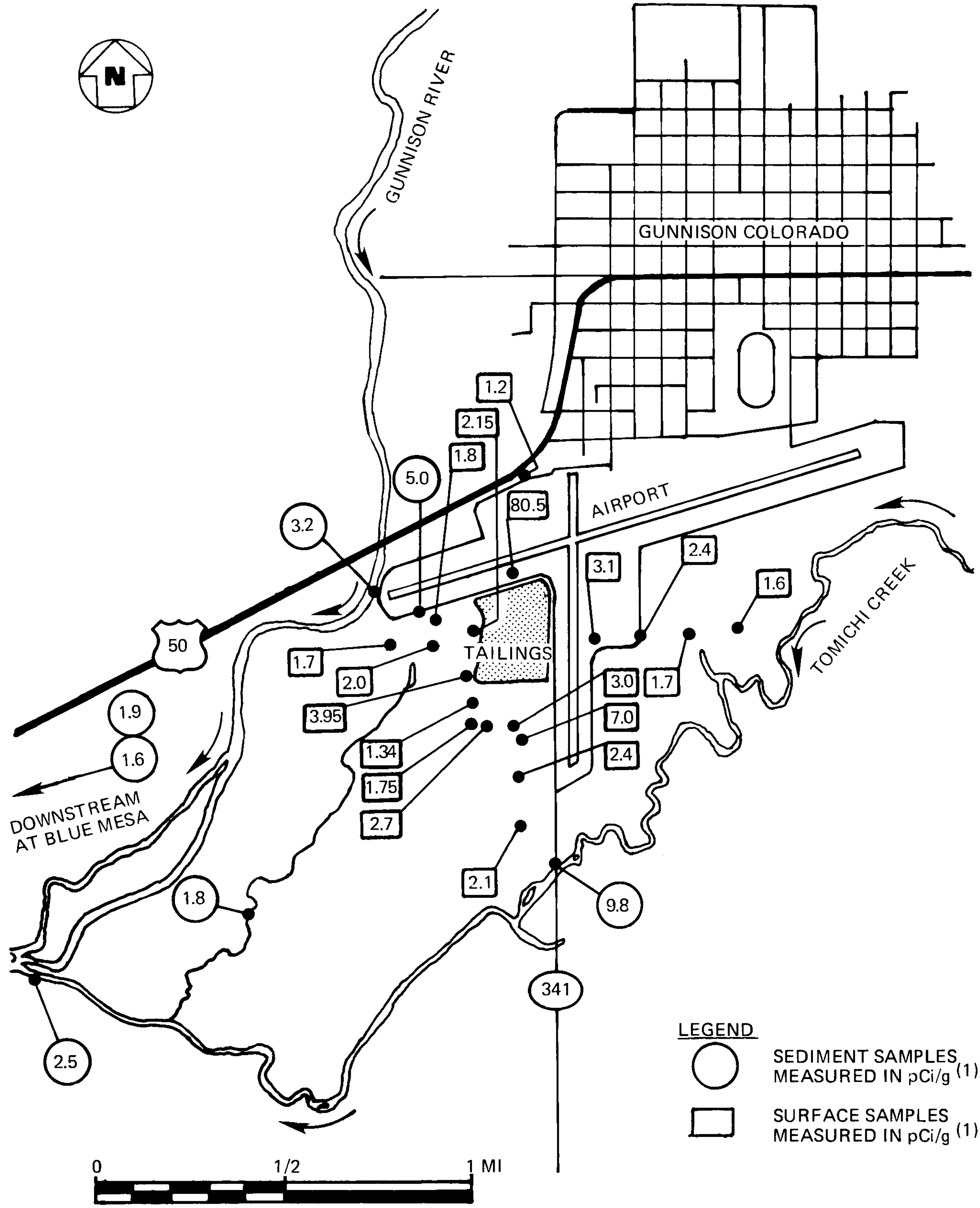


FIGURE 3-11. SURFACE RADIUM CONCENTRATIONS

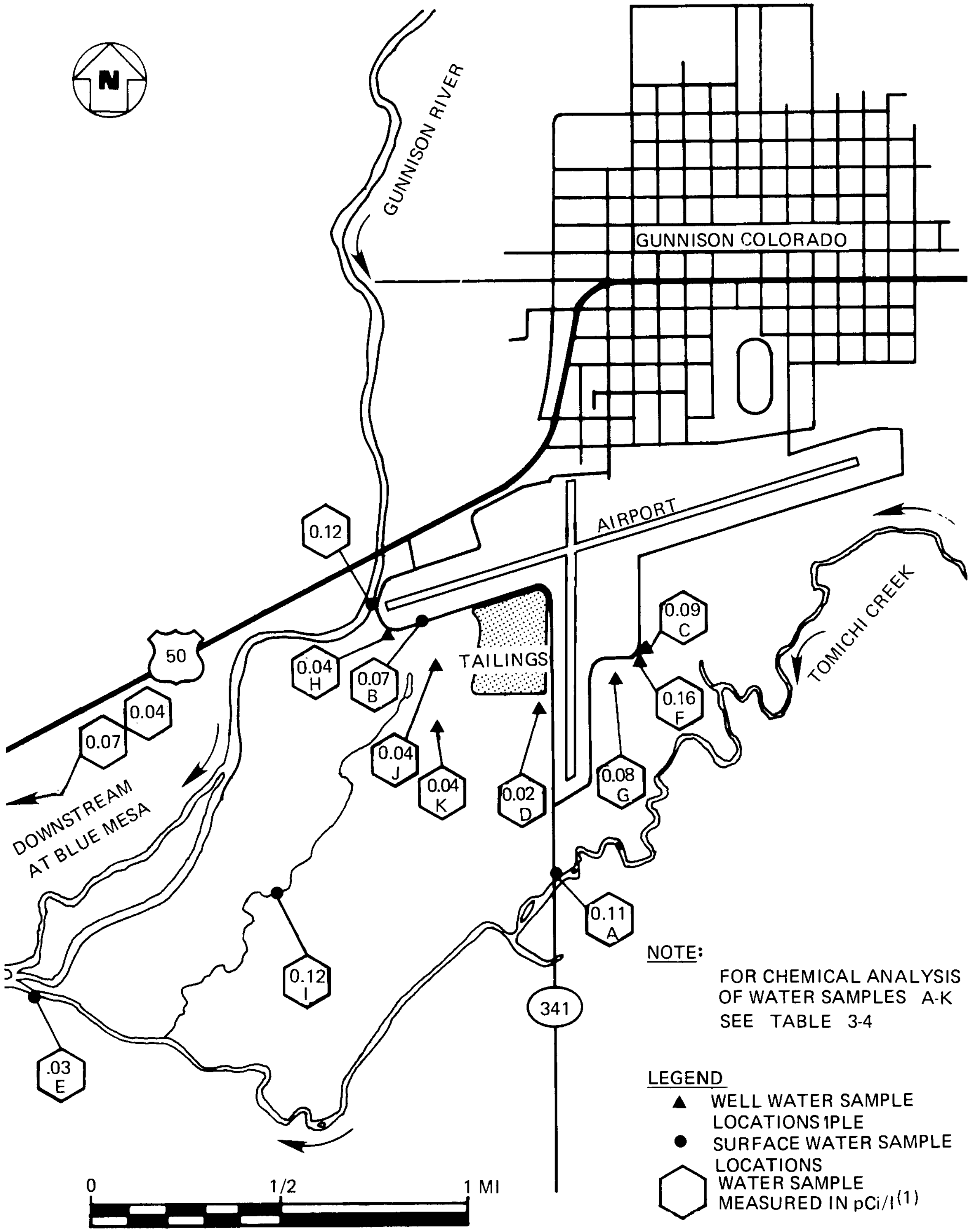


FIGURE 3-12. SURFACE AND GROUND WATER RADIUM CONCENTRATIONS

130-12

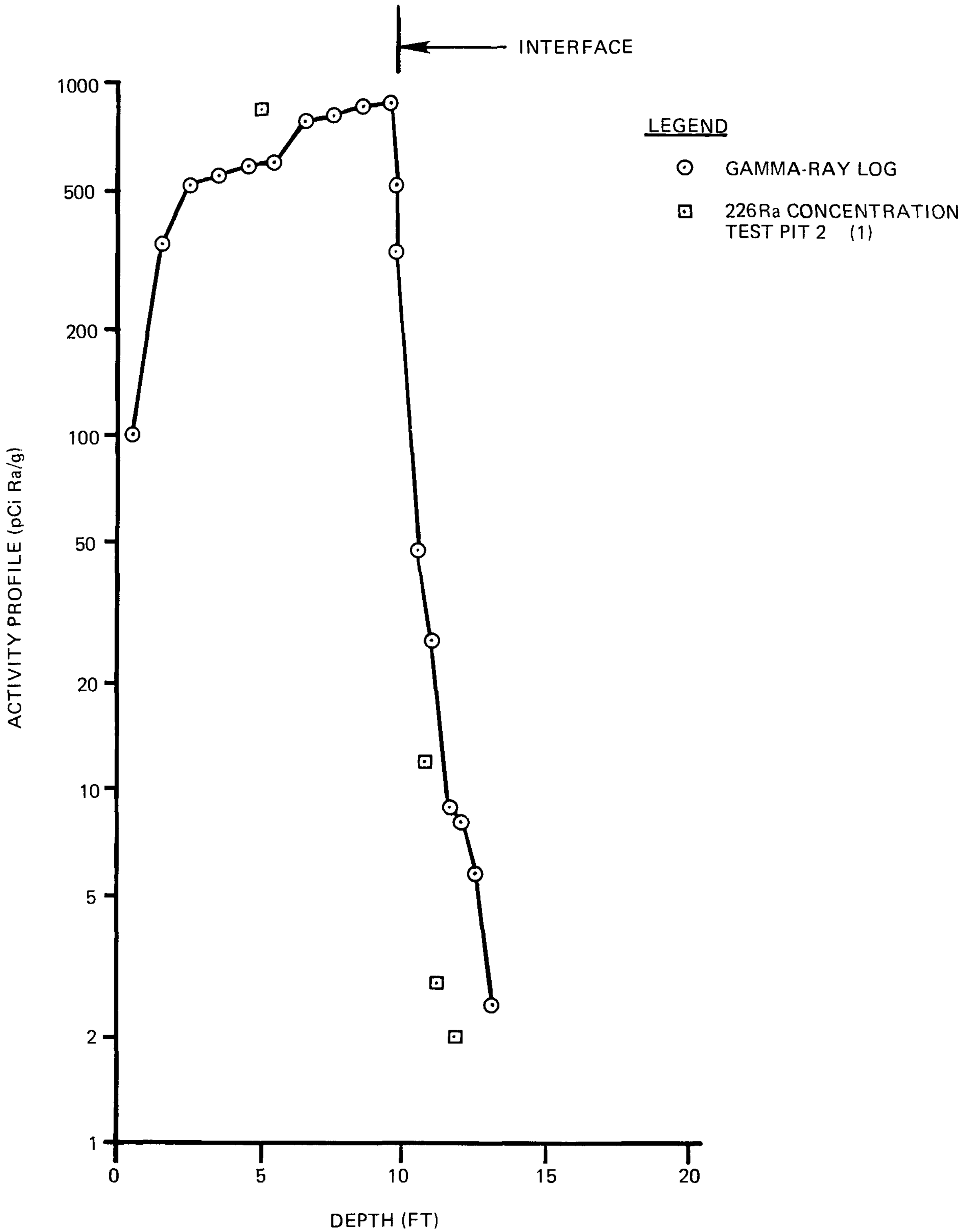


FIGURE 3-13. RADIOMETRIC PROFILE AT DRILL HOLE GC-2

130-12

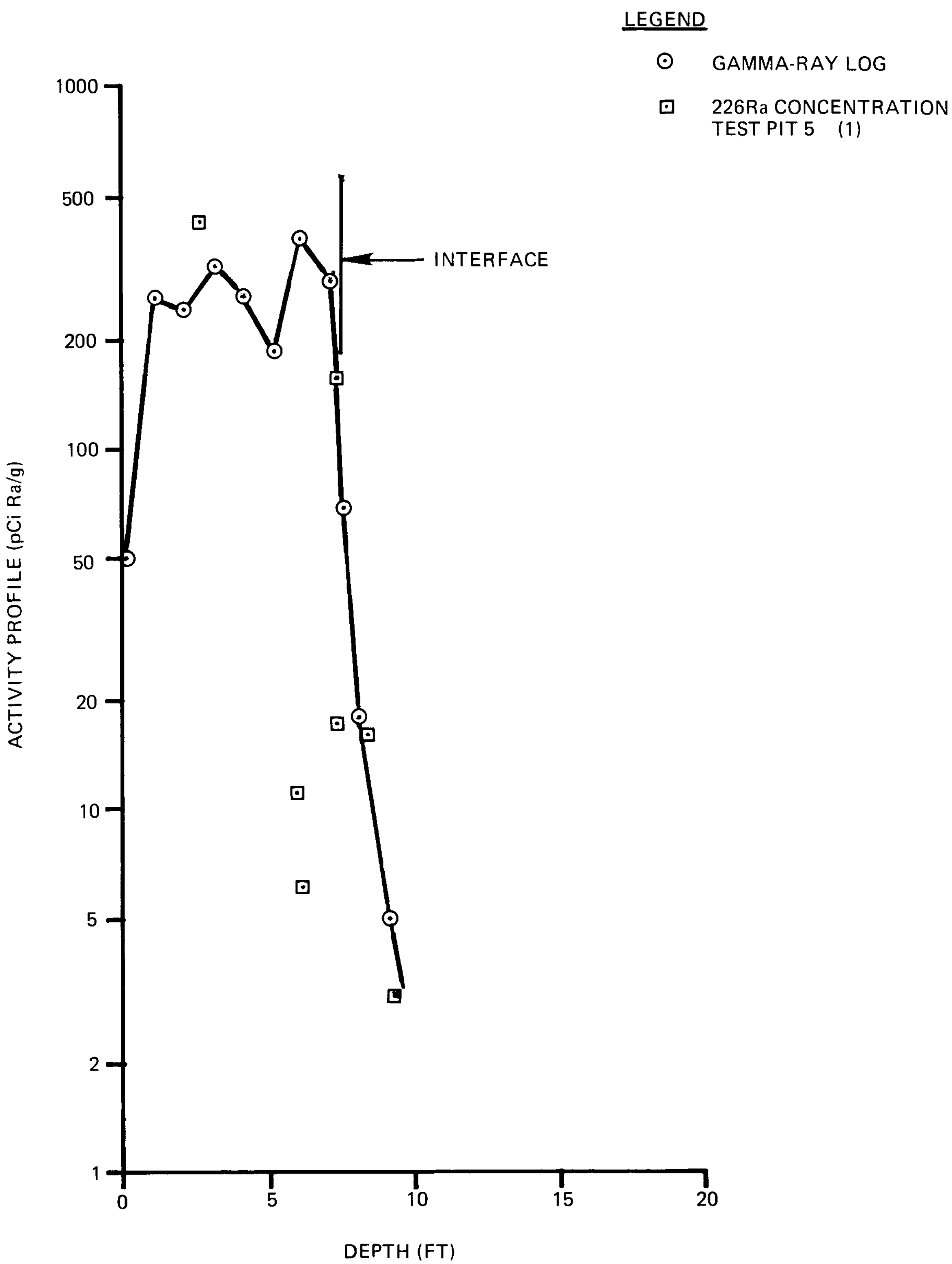


FIGURE 3-14. RADIOMETRIC PROFILE AT DRILL HOLE GC-5

130-12

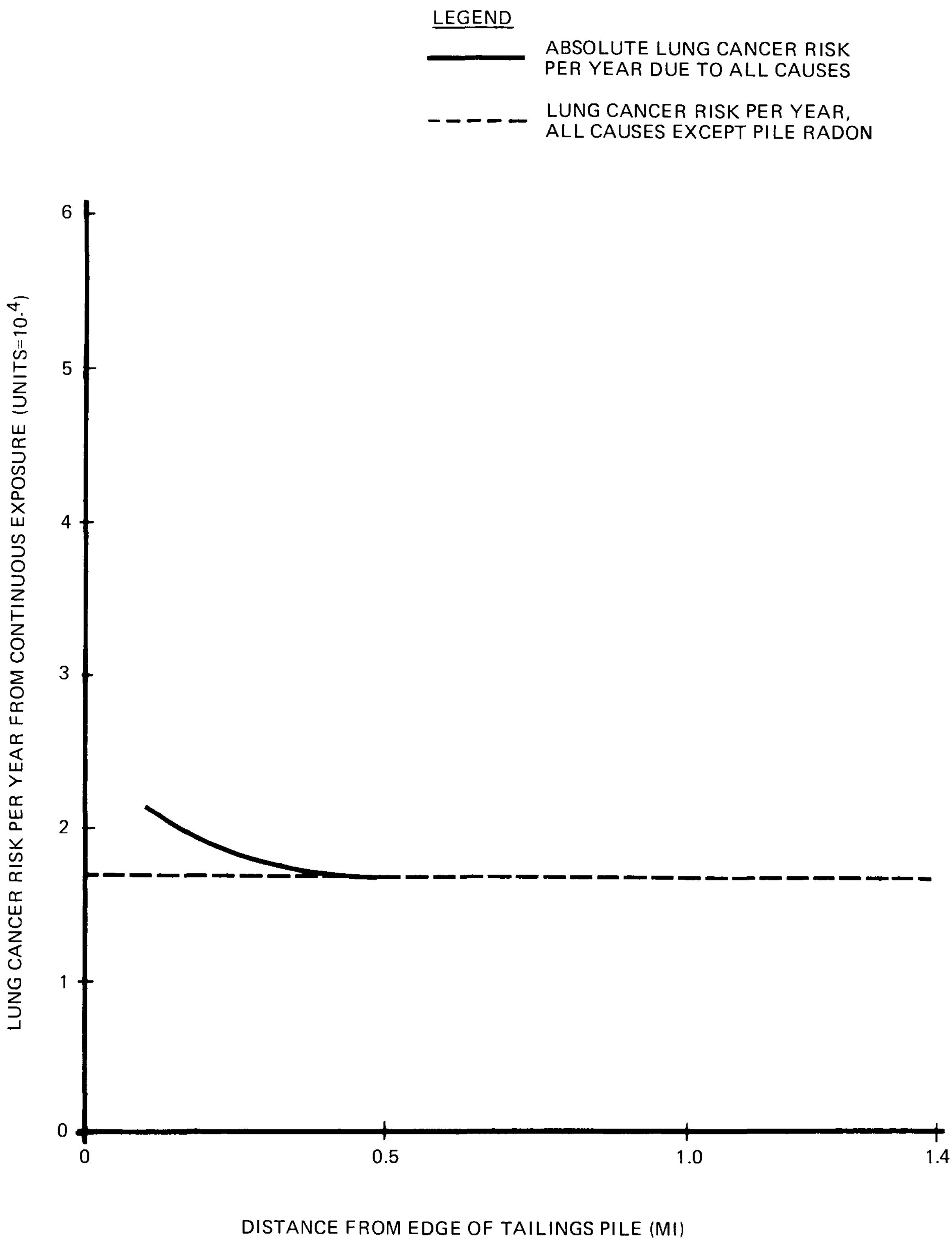


FIGURE 3-15. LUNG CANCER RISK FROM CONTINUOUS EXPOSURE TO RADON DIFFUSION

130-12

TABLE 3-1

NOTATIONS AND ABBREVIATIONS USED IN CHAPTER 3

Isotope - A particular type of element, differing by nuclear characteristics, identified by the atomic mass number given after the element name, e.g. radium-226.

Isotope Abbreviations:

^{238}U = Uranium-238

^{234}Th = Thorium-234

^{232}Th = Thorium-232

^{234}Pa = Protactinium-234

^{226}Ra = Radium-226

^{222}Rn = Radon-222

^{218}Po = Polonium-218

^{214}Pb = Lead-214

^{214}Bi = Bismuth-214

^{40}K = Potassium-40

Radiations:

alpha particle - helium nucleus; easily stopped with thin layers of material, all energy deposited locally.

beta particle - electron; penetrates about 0.2 g/cm^2 of material.

gamma rays - electromagnetic radiation; similar to X-rays, and highly penetrating.

Half-Life ($T_{1/2}$) - time required for half the radioactive atoms to decay.

TABLE 3-1 (Cont)

Working Level (WL)	- measure of potential alpha energy per liter of air from any combination of short-lived radon daughters (1 WL = 1.3 x 10^5 MeV of alpha energy).
One Working Level Month (WLM)	- WLM-Exposure to air containing a RDC of 1 WL for a duration of 170 hr.
Roentgen (R)	- that quantity of gamma radiation which yields a charge deposition of 2.58 x 10^{-4} coul/kg air. This is equal to the energy deposition of 88 ergs/g of dry air or 93 ergs/g of tissue.
μR/hr	- 10^{-6} Roentgen/hr.
Rad	- energy deposition of 100 ergs/g of material
Picocurie (pCi)	- unit of activity (1 pCi = 0.037 radioactive decays/sec or 2.2/min).
MeV	- unit of energy - 1 MeV = 1.6 x 10^{-6} erg.
Rem	- unit of energy deposition in man. 1 rem = 1 rad x quality factor. The quality factor = 20 for alpha particles.

TABLE 3-2

BACKGROUND RADIATION SOURCES IN SOIL FROM SOUTHWEST COLORADO[1]

Isotope (Decay Chain)	Average Value (pCi/g)	Range (pCi/g)
^{226}Ra (^{238}U)	1.48±0.63	0.54-3.4
^{232}TH (^{232}Th)	1.11±0.32	0.10-1.46

TABLE 3-3

ESTIMATED HEALTH IMPACT FROM GUNNISON TAILINGS FOR AN AREA 0-2.5 MILES FROM TAILINGS EDGE

Time Period	Population (Persons)	Total Pile-Induced RDC Health Effect/yr	Background RDC Health Effects/yr
1976	7,100	0.015	0.3
2001 (2% growth rate)	11,600	0.024	0.5
2001 (3.3% growth rate)	15,900	0.033	0.7

25-yr Cumulative Effect	Pile-Induced RDC	Background RDC
2% growth rate	0.8	17
3.3% growth rate	1.3	27

TABLE 3-4

CHEMICAL ANALYSES OF GUNNISON WATER SAMPLES (mg/l)

Sample[a]	As	Ba	Cd	Cr	V	Fe	Pb	Se
A - Tomichi Creek at State Highway 341	0.006	0.090	<0.001	<0.001	<0.01	0.94	0.011	0.095
B - Fishing Pond	0.007	0.072	<0.001	<0.001	<0.01	1.17	0.026	0.084
C - Well	0.028	0.037	<0.001	<0.001	0.02	1.19	0.018	0.011
D - Well	0.023	0.072	<0.001	<0.001	0.03	1.15	0.024	0.009
E - Tomichi Creek at Confluence with Gunnison River	0.016	0.003	<0.001	<0.001	<0.01	1.94	0.004	0.007
F - Well	0.013	<0.001	<0.001	<0.001	0.04	1.31	0.012	0.010
G - Well	0.010	0.214	<0.001	0.05	0.03	0.76	0.009	0.011
H - Well	0.009	0.046	<0.001	0.05	<0.01	9.20	0.028	0.008
I - Stream west of Pile Above Confluence with Tomichi Creek	0.009	0.002	<0.001	<0.001	<0.01	1.67	0.011	0.007
J - Well	<0.001	<0.001	<0.001	0.05	<0.01	0.329	0.016	0.012
K - Well	<0.001	<0.001	<0.001	<0.001	<0.01	1.12	0.027	0.013
EPA Interim Drinking Water Standards[b]	0.05	1.0	0.01	0.05	--	0.3[c]	0.05	0.01

[a]See Figures 3-12 for locations

[b]Federal Register, Dec 24, 1975

[c]Recommended limit from Manual for Evaluating Public Drinking Water Supplies, U.S. Public Health Service, 1969

CHAPTER 3 REFERENCES

1. F. F. Haywood, et al; "Assessment of Radiological Impact of the Inactive Uranium Mill Tailings Pile at Gunnison, Colorado"; ORNL (in preparation).

2. M. E. Wrenn, H. Spitz, and N. Cohen; "Design of a Continuous Digital-Output Environmental Radon Monitor"; IEEE Transactions on Nuclear Science; Vol NS-22; Feb 1975.

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5. R. L. Douglas and J. M. Hans, Jr.; "Gamma Radiation Surveys at Inactive Uranium Mill Sites"; Technical Note ORP/LV-75-1; EPA; Las Vegas, Nevada; Aug 1975.

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7. Office of the U. S. Surgeon General, Department of Health, Education and Welfare; Jul 1970.

8. "Radiological Criteria for Decontamination of Inactive Uranium Mill Sites' EPA/ORP; Washington, D.C.; Dec 1974.

9. F. F. Haywood, et al; "Assessment of Radiological Impact of the Abandoned Uranium Mill Tailings Pile at Salt Lake City, Utah"; ORNL-TM-5251 (in preparation).

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12. "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation"; Report of Advisory Committee on Biological Effects of Ionizing Radiation; NAS, National Research Council; Nov 1972.

13. W. Jacobi; "Interpretation of Measurements in Uranium Mines: Dose Evaluation and Biomedical Aspects"; NEA Specialist Meeting; Elliot Lake, Canada; Oct 4-8, 1976.

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17. "Health Effects of Alpha-Emitting Particles in the Respiratory Tract"; Report of the Advisory Committee on the Biological Effects of Ionizing Radiation; EPA/ORP; EPA-520/4-76-013; Washington D.C.; Oct 1976.

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CHAPTER 4

SOCIOECONOMIC AND LAND USE IMPACTS

CHAPTER 4

SOCIOECONOMIC AND LAND USE IMPACTS

The Gunnison tailings and millsite are located south of the Gunnison airport immediately south of the city limits. Gunnison is the commercial, political, and transportation center of Gunnison County. The boundaries of Gunnison County are shown in Figure 4-1.

4.1 SOCIOECONOMIC BACKGROUND

Gunnison was founded in 1878 as a gold miner's boomtown and supply point for mining camps. The Denver and Rio Grande Railroad reached Gunnison in 1881 and the town's economy diversified to include farming, commerce, and the hotel business. The State Normal School at Greeley opened a branch in Gunnison in 1911. This school, now called Western State College of Colorado, is a major employer of city residents. Mining and raising stock continue as principal industries of the area, although tourism and education are gaining importance.

The future demographic and economic conditions of Gunnison can be projected by extrapolating statistical data obtained for the four census records of 1940 through 1970.(1) The population of the City of Gunnison has grown steadily since 1940 although Gunnison County experienced a population decrease from 1940 to 1960, followed by a population increase from 1960 to 1970. The population of Gunnison is one of the youngest in the state. The median age of county residents declined from 29.7 in 1940 to 22.3 in 1970, and city residents are even younger (21.2 in 1970). The city's male population, in marked contrast to Colorado as a whole, has increased from 49.4% in 1940 to 52.3% in 1970.

Ethnically, the population of Gunnison is predominantly Caucasian, 1.2% are Indian, Black, or Asian Americans. Educational attainment is high and noticeably above average among the area's farmers. Compared with the state as a whole, however, the median income in Gunnison is low. Most workers now are employed as professionals, clericals, craftsmen, and service providers. Farming, transportation, mining, and forestry have been displaced by education as the major employer. Today, Gunnison is a community with a diversified economy based on education, agriculture, tourism, and, to a lesser extent, mining.

4.2 POPULATION ESTIMATES

The 1970 census figures of 4,613 city residents and 7,578 county residents are used as the population base. A modified population base is used in the health effects assessment (see

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(1) See end of chapter for references.

Chapter 3). Residents of unincorporated areas to a distance of 2.5 mi were included with the city population for health effects calculations, resulting in a 1970 population of 5,827 and a projected 1976 population of 7,100 The general population distribution near Gunnison is shown in Figure 4-2, with the highest population density northeast of the tailings.

Several factors must be considered in determining population projections and future growth patterns for Gunnison. First, tourism offers a potential for future growth. Second, extensive industrialization except for energy development is unlikely due to long distances from major markets. Third, continued growth based on long-term expanding university enrollment is unlikely.

Considering these factors, three rates of growth were employed. The highest assumes a 3.3% annual growth rate, which assumes a continuation of current growth rates. The second rate is 2.6%, which assumes a growth rate similar to Colorado as a whole. The third rate employed is 2.0%, which is approximately the growth rate of the Mountain States for 1974. Population growth projections for constant growth rates are presented in Figure 4-3.

Assumptions of a steady rate of growth may be highly unrealistic. For the reasons given above, the rate of growth could decline and approach zero by some future date. Also presented in Figure 4-3 are the population projections for a steady growth rate for 10 yr followed by a declining rate to zero growth at 25 yr. This is referred to as a "declining rate of growth".

The slowest constant rate (2.0%) indicates there will be 1.64 times as many inhabitants in the year 2000 and 2.7 times as many in 2025 as at present. If the most rapid constant rate (3.3%) is assumed, there will be 2.56 persons in the year 2000 and 5.8 persons in the year 2025 in Gunnison for every person now there. This most rapid constant rate produces results which may be tenable over the short run, but the carrying capacity of the land, and the area's available water supply make sustaining this rate unlikely. The 3.3% declining rate of growth indicates that in the year 2025 there will be 2.02 times as many residents as now.

4.3 LAND USE

The area south of the Gunnison tailings is primarily grazing and pasture land although due south of the tailings are the old processing mill, associated buildings, and a gravel operation. The Gunnison airport is on the north and east sides of the tailings. The City of Gunnison is located north and northeast of the airport. Figure 4-2 summarizes a land use survey of the area within a mile of the tailings.

The land immediately north of the airport is devoted to light industry but includes junkyards and trucking operations. Further east and north to U.S. Highway 50, there are several vacant lots, the fairgrounds, and housing for students and other residents. The land on both sides of U.S. Highway 50 is commercial as are the areas along Colorado Highway 135. Residential areas and services such as the courthouse, churches, and schools are located north of U.S. Highway 50. Western State College is located to the northeast of the survey area. The land west of the tailings area is primarily agricultural land although there are trailer camps, motels, residences, condominium units, a garage, and a drive-in movie theatre located along the highway.

The land use of the area surrounding the tailings is shifting from agriculture to transportation and light industry. The availability of plentiful ground water within a few feet of the surface, the proximity to transportation routes, and the level land are several attractive features of the area. The city has zoned the area north of the tailings for industrial use and the county has zoned the tailings site for industrial use as well. The presence of the tailings cannot be demonstrated to have had a direct impact on the use of surrounding lands, but if industrial development takes place south of the airport, there will be strong pressures to use the tailings site and surrounding land.

4.4 IMPACT OF THE TAILINGS ON LAND VALUES

Figure 4-4 summarizes the 1975 assessed values of land in Gunnison based on the listed value which is 30% of assessed value without improvements. Most land is privately owned, the major exception being the airport.

The land on which the tailings are located is listed at less than $10/acre, as is much of the nearby land between the Gunnison River and Tomichi Creek. The mill buildings on the adjacent site were assessed at $12,140 at the time of survey early in 1976. More valuable property lies northwest of the airport and is being developed for recreation and condominium use. In general, the land surrounding the tailings site has market values ranging from $1,500 to $8,000/acre. The presence of the tailings at the Gunnison site influences the use of the site itself and probably its land value. With further development of the surrounding industrial-zoned corridor, the impact on land values will become more noticeable.

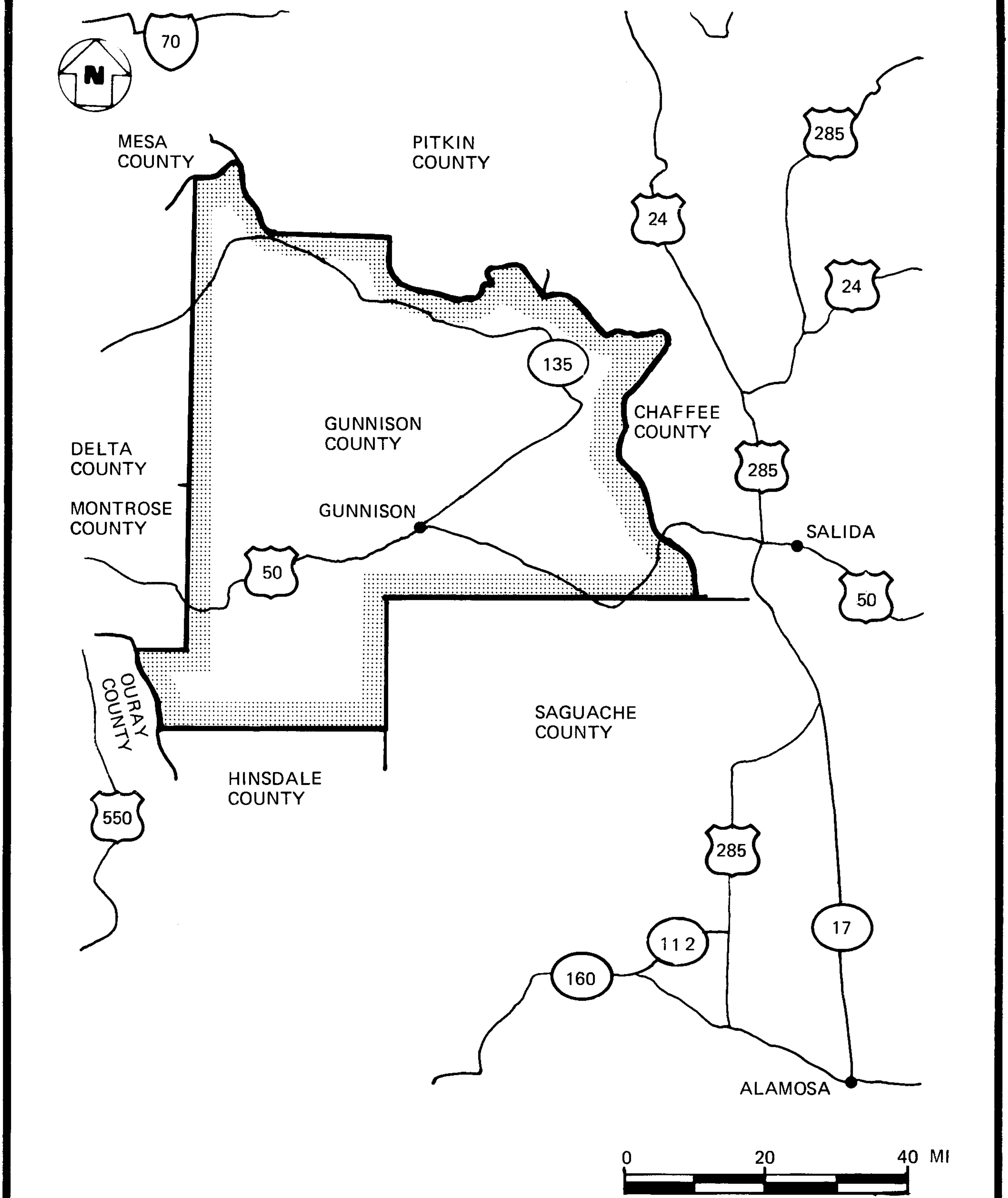

FIGURE 4-1. MAP OF GUNNISON COUNTY BOUNDRIES

130-12

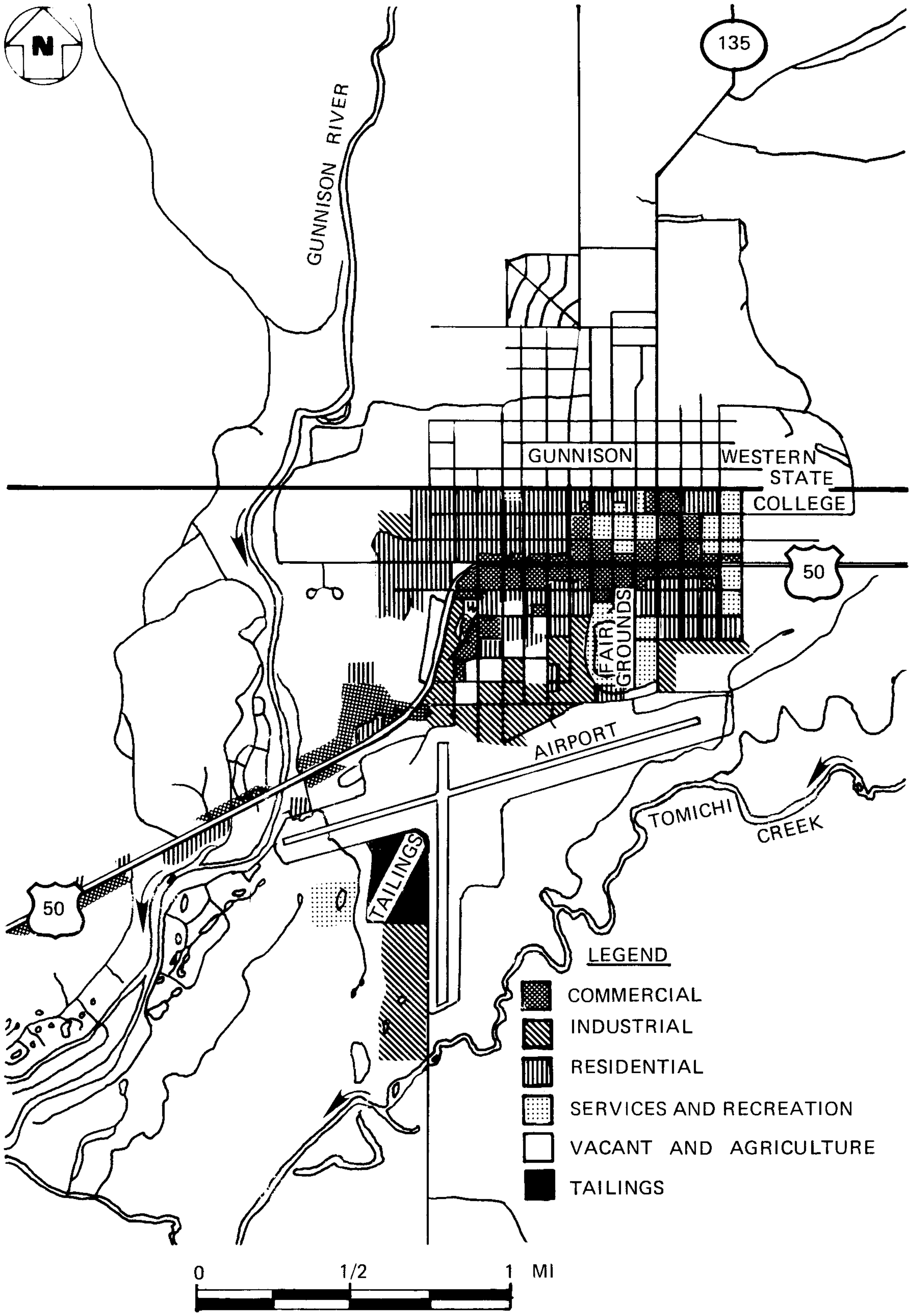

FIGURE 4-2. VICINITY LAND USE

130-12

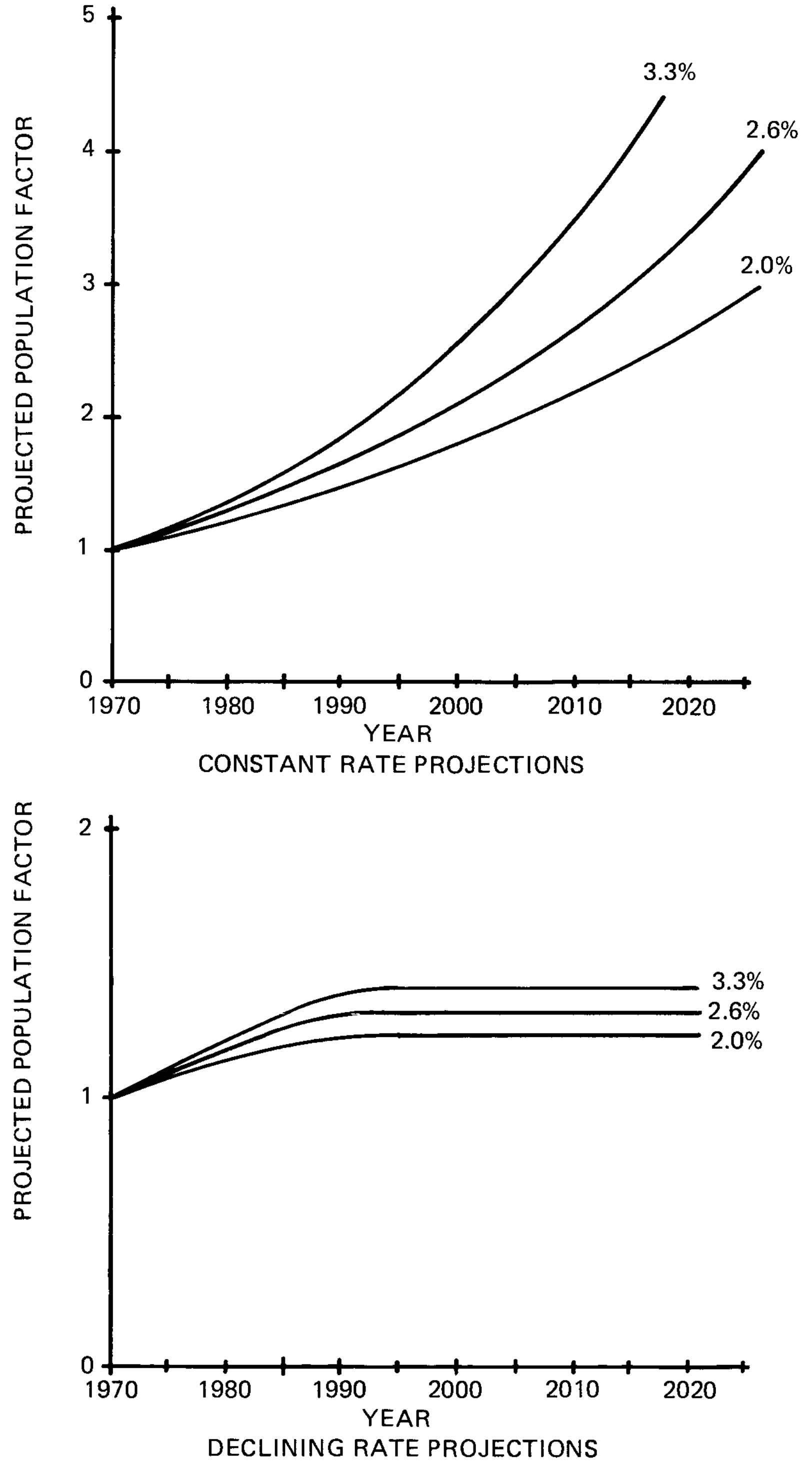

FIGURE 4–3. POPULATION PROJECTIONS

130-12

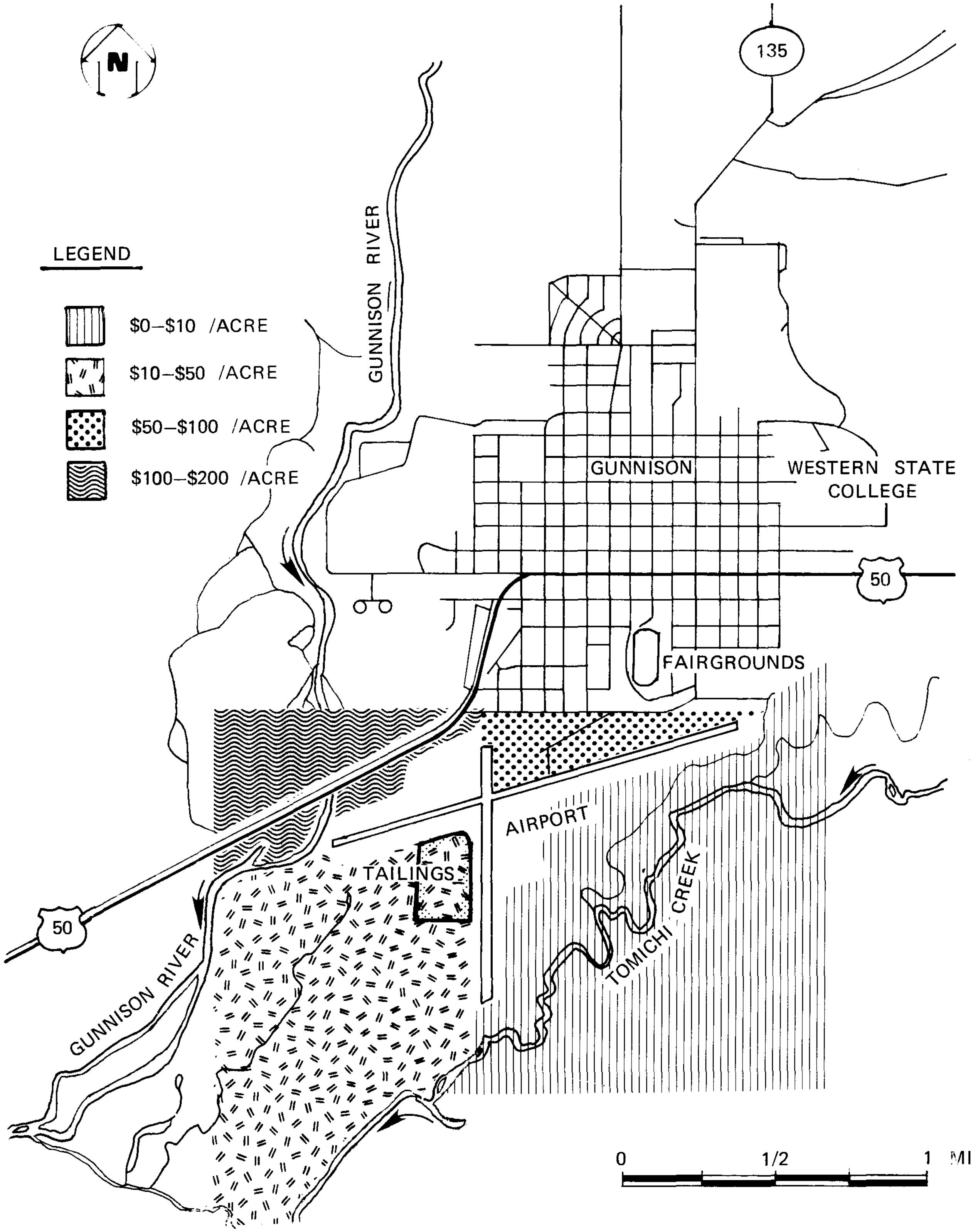

FIGURE 4-4. ASSESSED VALUE OF LAND (30%LEVEL)

130-12

CHAPTER 4 REFERENCES

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CHAPTER 5

RECOVERY OF RESIDUAL VALUES

CHAPTER 5

RECOVERY OF RESIDUAL VALUES

The principal purpose of this chapter is to address questions such as the following:

(a) Does the Gunnison tailings pile represent a future uranium resource?

(b) Should the pile be reprocessed?

The feasibility of economic recovery at each millsite is a function of:

(a) Total mineral recovery

(b) Reprocessing costs

(c) Market price

5.1 PROCESS ALTERNATIVES

Three alternative methods of treating uranium tailings to recover uranium are: (a) placing the tailings on a prepared pad and heap leaching, (b) treating at an existing mill, and (c) treating at a new conventional mill.

5.1.1 Heap Leaching

In heap leaching, the mill tailings are placed on an impermeable pad for leaching with appropriate reagents. The pregnant solution is collected in the pad drainage system and processed for uranium recovery.

The percent of uranium recovery for both heap leach and conventional mill operation is given in Figure 5-1.[1] Because it is difficult to obtain optimum conditions for metal extraction in heap leaching, the uranium recovery using the heap leach method is only about 56% of a conventional mill operation. However, the construction costs of a heap leaching facility are only about 60% of the costs for a conventional uranium mill. The operating costs for a heap leach plant are also lower than for a conventional mill for plants of the size considered -- 500 to 5,000 tons/day.

The heap leaching site must be an acceptable tailings disposal site that can be readily stabilized and maintained or must be adjacent to the tailings disposal site. A heap leach site of about 13 acres of relatively flat ground would be required if the

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[1] See end of chapter for references.

540,000 tons of Gunnison tailings were to be leached and stabilized in place. The reprocessing site would also require water and power.

5.1.2 Treating in an Existing Plant

In order to consider reprocessing the tailings in an existing conventional mill, it is necessary that a mill with excess milling capacity be reasonably close to the tailings site. There are four existing uranium mills that are between 100 and 240 mi from Gunnison. Two of these have capacities exceeding 1,500 tons/day. In addition a new mill is proposed approximately 30 mi away.

Reprocessing of mill tailings at an existing uranium mill must be economically feasible and lower in cost than other acceptable remedial alternatives. The mill must have available excess capacity and the tailings must be amenable to the existing treatment process. Finally, the active mill tailings disposal site should have sufficient capacity to handle the additional tailings and to allow ready stabilization and maintenance of the tailings piles.

The major advantages of treating the uranium in an existing mill are the elimination of the construction costs of a new mill and the consolidation of two tailings piles.

5.1.3 Treating in a New Mill

The advantages of treating the tailings in a new mill are: (a) the process would be designed specifically for the tailings (crushing and/or grinding circuit may not be needed), (b) the millsite would be chosen to assure a safe and relatively low-cost disposal of the tailings, and (c) the higher recovery a conventional uranium mill provides over a heap leach facility as seen in Figure 5-1. Some industry tests have shown heap leach recoveries on tailings to be higher than the values in Figure 5-1.

The major disadvantage of a new conventional uranium mill is the higher construction costs.

5.2 GUNNISON RECOVERY ECONOMICS

The parameters discussed in this section determine the economic viability of reprocessing uranium mill tailings to recover residual mineral values.

5.2.1 Recovery

The Gunnison tailings pile consists of 540,000 tons of tailings containing 0.017% U_3O_8 as determined from AEC records.[2] In addition, auger samples from the tailings pile were obtained and were composited for analysis. The results of the analysis for this composite sample are presented in Table 5-1. Using the AEC estimate, the Gunnison pile contains 184,000 lb of U_3O_8. Further sampling would be necessary to verify this estimate. Recovery of a sufficient fraction of radium to eliminate the potential health hazards is not technically feasible at this time.

5.2.2 Reprocessing Costs

Reprocessing costs include the operating and construction costs of any new facilities.

A range of operating costs for both heap leaching and conventional uranium mills as a function of plant capacity are shown in Figures 5-2 and 5-3.[1] The operating costs of heap leach plants range from $2.65 to $4.45/ton. The operating costs of conventional uranium mills range from $2.70 to $8.50/ton, depending on the nature of the ore and the size of the plant.

Plots of construction costs of heap leach facilities and conventional uranium mills as a function of plant capacity are shown in Figures 5-4 and 5-5.[1] The construction costs of a heap leach plant range from $2.7 to $27 million for a 500- to 5,000-ton/day uranium mill, while a conventional mill costs from $3.5 to $33 million. The construction costs of a heap leach facility are obtained from the lower range of Figure 5-4.

5.3 ASSESSMENT OF GUNNISON MINERAL RECOVERY POTENTIAL

Using Figures 5-1 through 5-5, the breakdown cost of recovery for the Gunnison pile can be calculated as follows:

	U_3O_8 Recoverable (lb)	Operating Costs* ($M)	Construction Costs* ($M)	Total Cost ($M)	Cost/lb ($)
Heap Leach	41,400	1.9	2.7	4.6	111
Conventional	73,200	3.8	4.7	8.5	116
Haulage to Existing Mill	73,200	3.8	1.6**	5.4	74

* For a 500-ton/day facility
**Transportation cost for 30 mi at $0.10/ton-mi

From the economic evaluation of the reprocessing of the Gunnison tailings it can be seen that none of the three proposed options are presently economically feasible. The lowest cost for reprocessing appears to be $74/lb in an existing mill. This value is based on current dollars and includes no interest costs, inflation costs, nor allowance for profit.

While it is always possible that technological improvements may be developed to improve the basis for estimation of production costs used herein, it is unlikely that they will be of such magnitude as to affect significantly the conclusions based upon the experience in the uranium industry over the last 25 years.

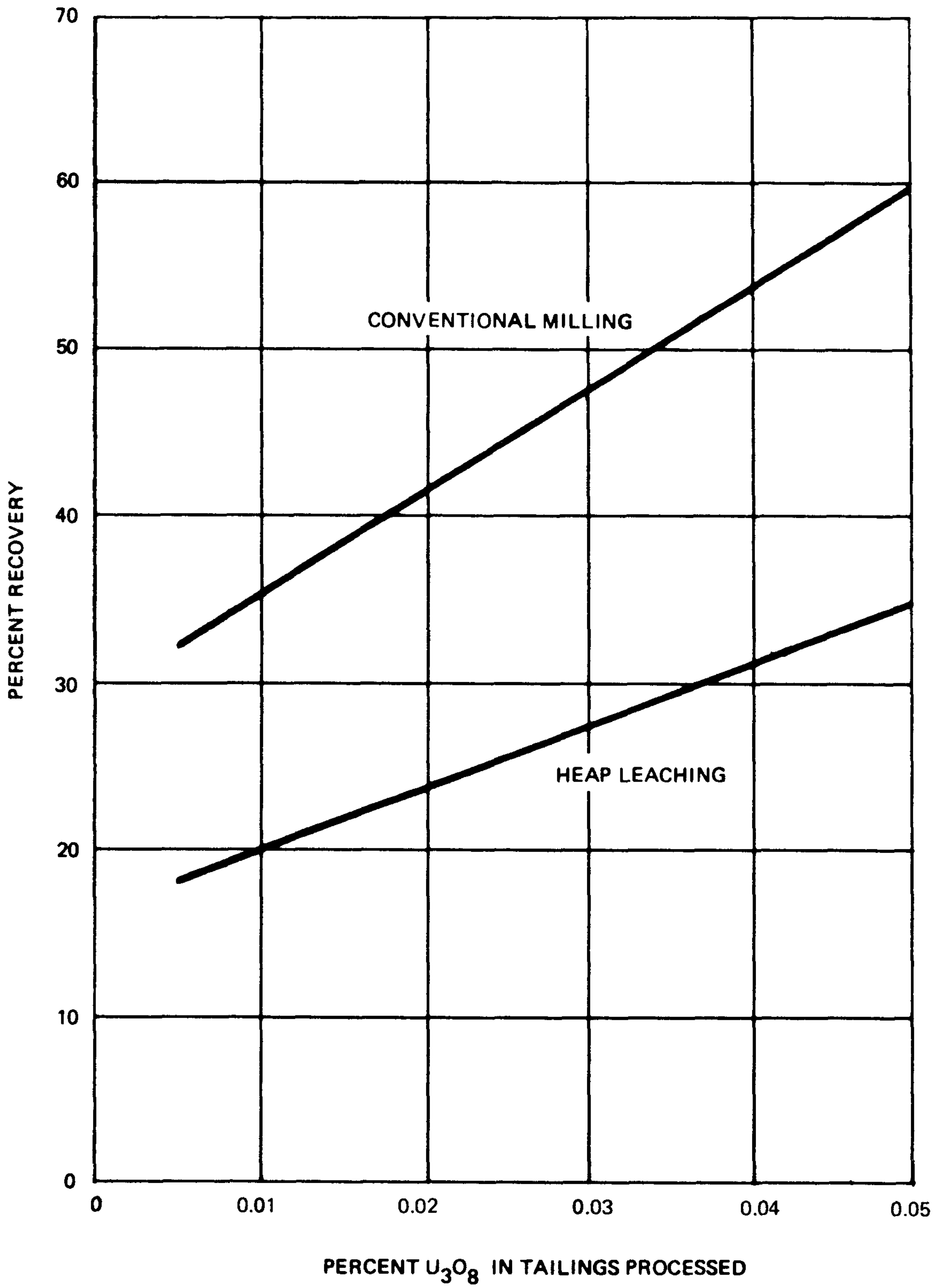

FIGURE 5-1. URANIUM RECOVERY FROM MILL TAILINGS AS A FUNCTION OF U_3O_8 CONTENT IN TAILINGS

130-12

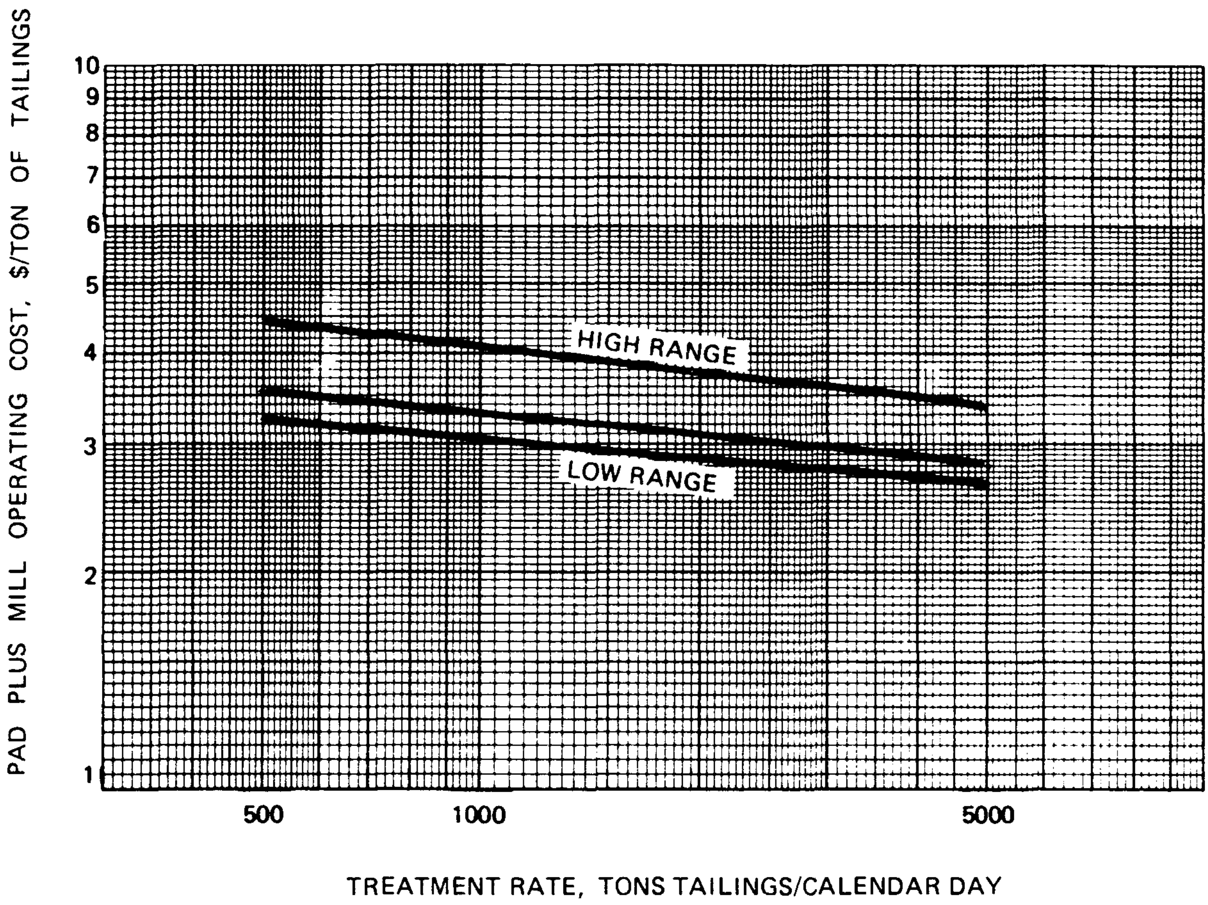

FIGURE 5-2. OPERATING COSTS OF HEAP LEACHING OF URANIUM MILL TAILINGS CONTAINING 0.01 TO 0.05% U_3O_8 WITH URANIUM RECOVERY RANGING FROM 20 TO 35% (COST ADJUSTED TO JANUARY 1977)

130-12

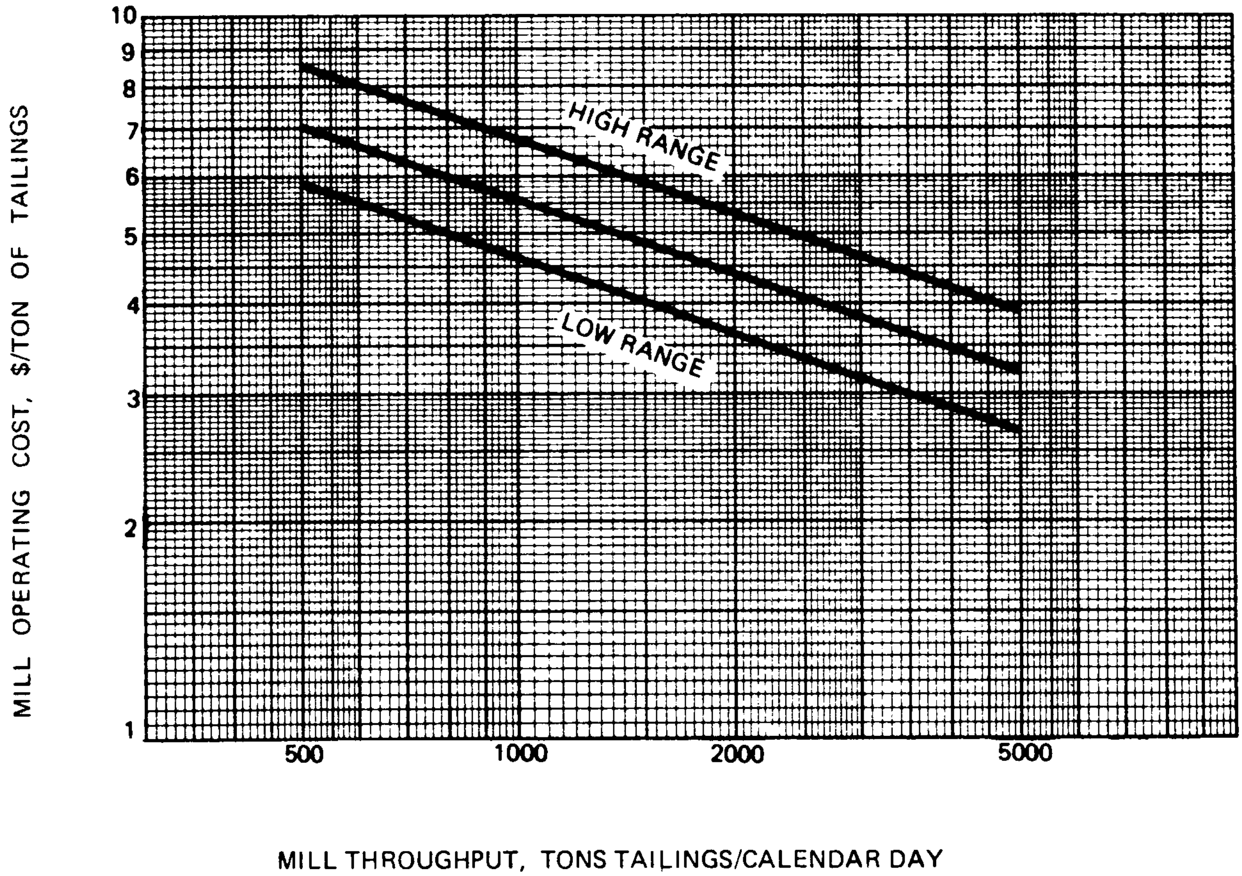

FIGURE 5-3. OPERATING COSTS OF CONVENTIONAL MILLING W/O CRUSHING AND GRINDING FACILITIES TO REPROCESS TAILINGS CONTAINING 0.01 TO 0.05% U_3O_8 WITH URANIUM RECOVERY RANGING FROM 35 TO 60% (COST ADJUSTED TO JANUARY 1977)

130-12

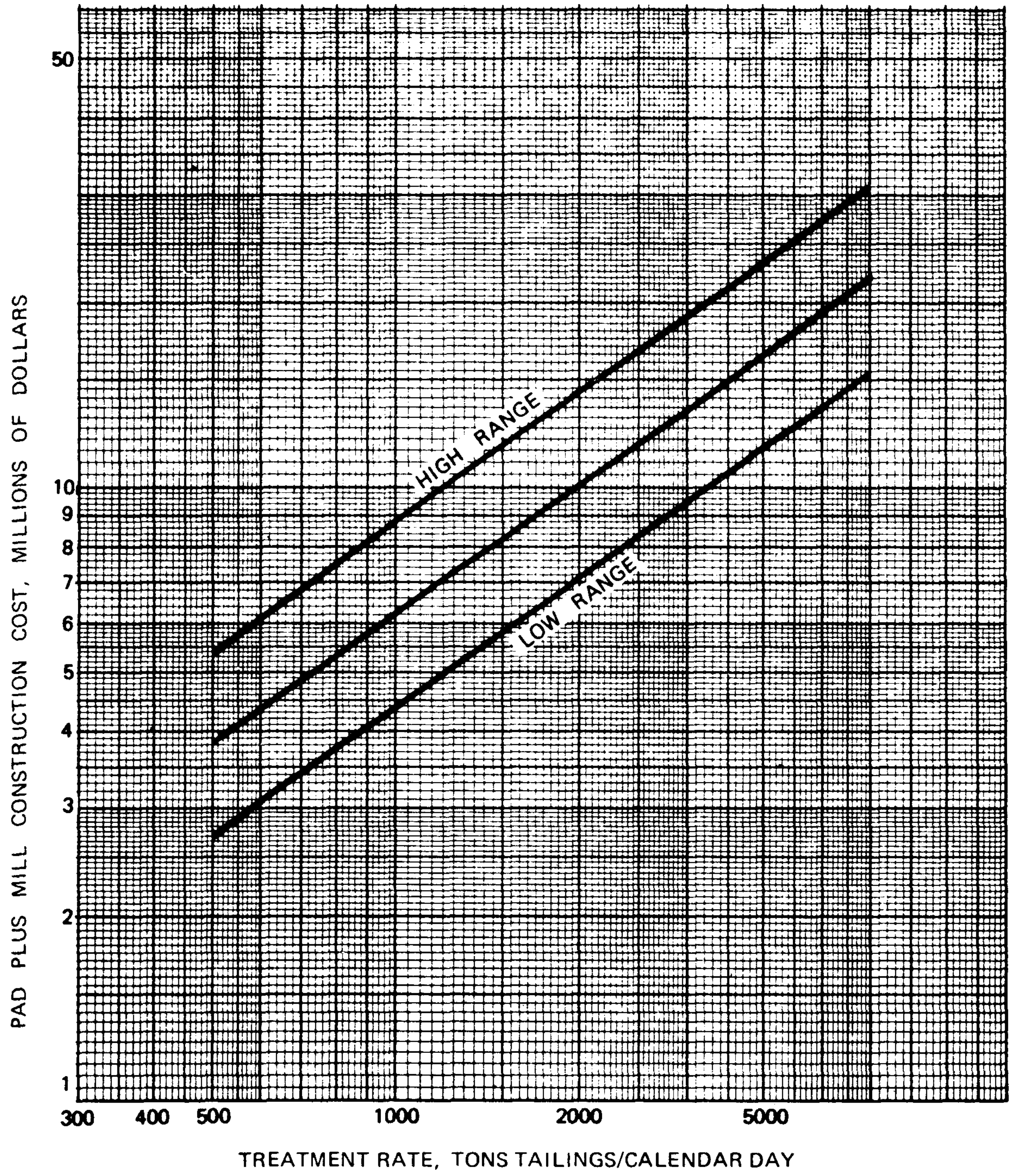

FIGURE 5-4.
CONSTRUCTION COSTS OF HEAP LEACHING PLANT TO REPROCESS URANIUM MILL TAILINGS CONTAINING 0.01 TO 0.05% U_3O_8 WITH URANIUM RECOVERY 20 TO 35% (COST ADJUSTED TO JANUARY 1977)

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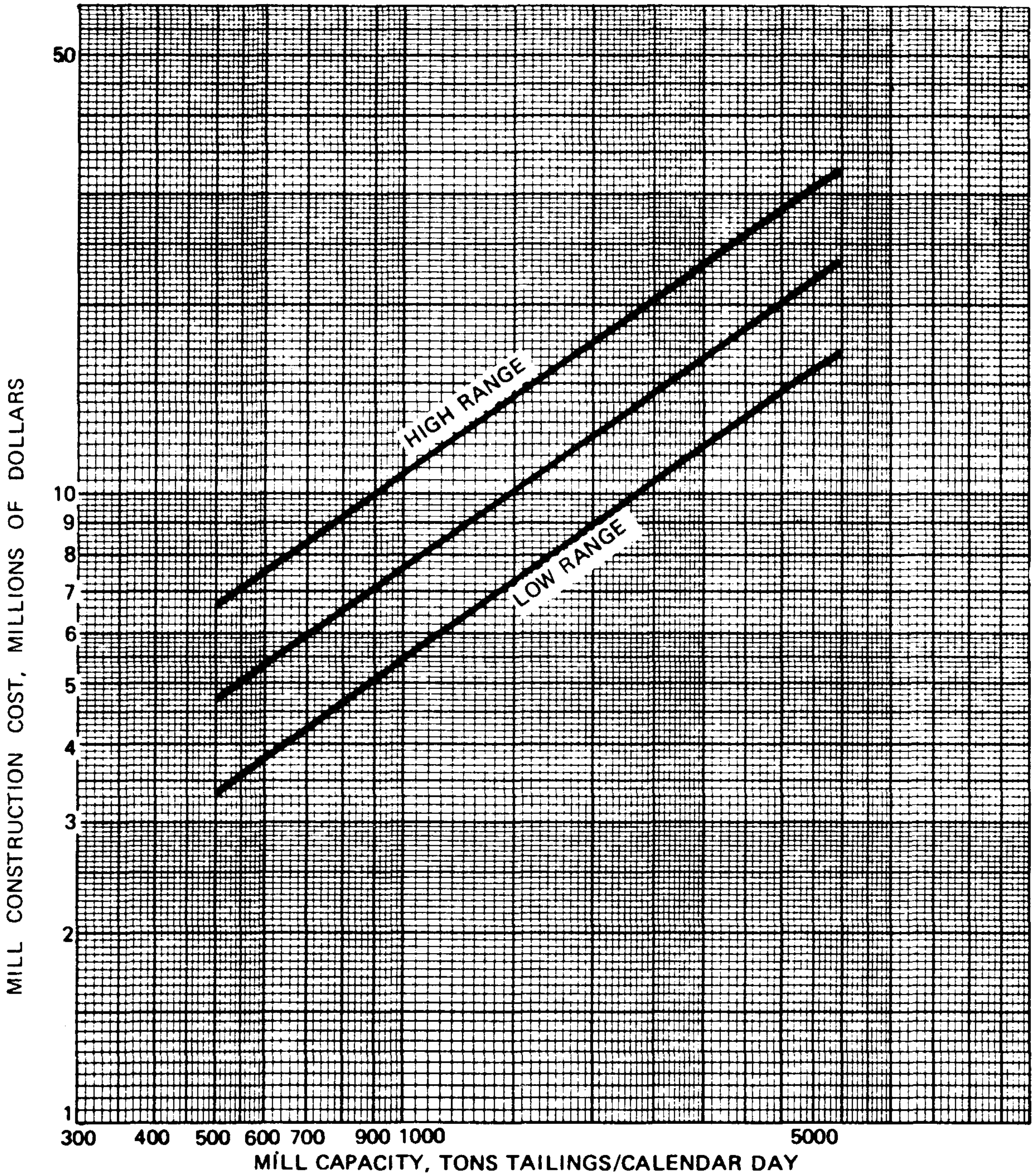

FIGURE 5-5. CONSTRUCTION COSTS OF A CONVENTIONAL URANIUM MILL W/O CRUSHING AND GRINDING FACILITIES TO REPROCESS TAILINGS CONTAINING 0.01 TO 0.05% U_3O_8 WITH URANIUM RECOVERY RANGING FROM 35 TO 60% (COST ADJUSTED TO JANUARY 1977)

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TABLE 5-1

ASSAY RESULTS OF GUNNISON COMPOSITE TAILINGS SAMPLES

	Percentage by Weight			
Element	Atomic Absorption	Spectrographic	Chemical	AEC* Estimate
Aluminum	--	1.0 - 0.1	--	--
Arsenic	0.0254	--	--	--
Barium	0.0066	--	--	--
Boron	--	<0.01	--	--
Cadmium	0.000025	--	--	--
Calcium	--	1.0 - 0.01	--	--
Chromium	0.00052	--	--	--
Cobalt	0.00373	--	--	--
Copper	0.00295	--	--	--
Cyanide	<0.000001	--	--	--
Gallium	--	<0.01	--	--
Iron	2.080	--	--	--
Lead	0.0137	--	--	--
Magnesium	--	1.0 - 0.01	--	--
Manganese	--	<0.01	--	--
Mercury	<0.0000001	--	--	--
Molybdenum	--	<0.01	--	--
Nickel	--	--	--	--
Potassium	--	1.0 - 0.01	--	--
Selenium	0.0001	--	--	--
Silicon	--	>1.0	--	--
Silver	0.000384	--	--	--
Sodium	--	1.0 - 0.01	--	--
Titanium	--	1.0 - 0.01	--	--
Uranium (U_3O_8)	--	--	.009	0.017
Vanadium (V_2O_5)	--	--	.008	--
Zinc	0.01197	--	--	--

*Calculated tails assay based on plant operation[(1)]

CHAPTER 5 REFERENCES

1. ERDA-GJO, private communication.

2. "Summary Report, Phase I Study of Inactive Mill Sites and Tailings Piles;" AEC; Grand Junction, Colorado; Oct 1974.

CHAPTER 6

MILL TAILINGS STABILIZATION

CHAPTER 6

MILL TAILINGS STABILIZATION

In most of the alternative remedial actions which have been considered, the stabilization of mill tailings is a required process. Government agencies and private industry have carried out limited research to develop economical and environmentally suitable methods of uranium tailings site stabilization. All present methods, technology, and research data on stabilization that are available were reviewed to determine the best approach. In addition, experiments are being conducted to determine the relative effectiveness of various stabilization techniques.

The objective of stabilizing the uranium mill tailings is to eliminate the pathways to the environment of the radioactive and other toxic particles as described previously in Chapter 3. Ideally, complete stabilization of radioactive tailings should permanently eliminate the possibilities of:

(a) Wind and water erosion

(b) Leaching of radioactive materials and other chemicals

(c) Radon exhalation from the tailings

(d) Gamma radiation emitted from the tailings

6.1 PREVENTION OF WIND AND WATER EROSION

Wind and water erosion can be prevented by chemical stabilization of the surface, complete chemical stabilization, physical stabilization, and vegetative stabilization.

6.1.1 Chemical Stabilization of the Surface

This process involves applying chemicals to the surface of the tailings to form a water- and wind-resistant crust. Chemical stabilizers have been used successfully as a temporary protection on portions of dikes and tailings ponds which have dried and become dusty, and in areas where water shortage or chemical imbalance in the tailings prevents the use of cover vegetation. Chemical surface stabilizers, however, are susceptible to physical breakup and gradual degradation and will not meet the long-term requirements for the Gunnison tailings pile.

Other complications also can arise in achieving satisfactory chemical stabilization in that the surfaces of tailings piles seldom are homogeneous, and variables such as particle size and moisture content affect the bonding characteristics of the chemical stabilizers.[1]

Tests were conducted by the Bureau of Mines[1] using certain chemicals (e.g. Compound SP-400 Soil Gard, and DCA-70 elastomeric polymers) on both acidic and alkaline uranium tailings. Subsequently, the chemicals DCA-70 and calcium lignolsulfonate were applied to the surfaces of the inactive uranium tailings ponds and dikes at Tuba City, Arizona, in May 1968, because low moisture conditions and high costs prohibited vegetative or physical stabilization. After 4 yr, approximately 40% of the dike surface showed disruption while the crust in pond areas was affected to a lesser extent. The major disruptions were attributed to initial penetration of the stabilizer by physical means such as vehicles, people, or animals crossing the tailings surface.

In 1969, a portion of the Vitro tailings at Salt Lake City, Utah, was sprayed with tarlike material as a Bureau of Mines experiment to achieve surface stabilization and to reduce wind erosion. The attempt was unsuccessful because the material decomposed and the tailings were exposed within 2 to 3 yr.

Since no chemical sealant has been used successfully to stabilize uranium tailings for more than a few years, this method has not been considered in the various stabilization alternatives presented in Chapter 9.

6.1.2 Complete Chemical Stabilization

This process, which has been used in other mineral industry operations, involves the addition of chemicals in sufficient quantities to a slurry to produce a chemical reaction which solidifies the slurry. Chemicals may be added in two ways: to a slurry pipeline, and in situ. The in situ method of stabilization is relatively new and extensive research is required in each individual situation to define the optimum chemical addition to produce the desired results.

One of the features claimed for this stabilization method is that all pollutant chemicals are locked in the solidified slurry and chemicals cannot be leached from the solid.

The cost of this stabilization method is expensive for the chemicals alone. A cover material, such as gravel, would be required to protect the solidified slurry from wind and water erosion. It is not known whether vegetation can be established after topsoil and other soil cover have been spread over the solidified slurry. This probably would be a function of the specific chemical makeup of the solidified slurry and would require research to identify the conditions under which vegetation could thrive.

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(1) See end of chapter for references.

6.1.3 Physical Stabilization

Physical stabilization consists of isolating the contained material from wind and water erosion by covering the tailings with some type of resistant material (e.g. rock, soil, smelter slag, broken concrete, asphalt, etc.) Thin covers of concrete or asphaltic materials have been shown to break down over relatively short periods of time; and starting within a few years after application, continuing maintenance is required. A concrete covering sufficiently thick and properly reinforced would be relatively permanent and maintenance-free, but the cost would be prohibitive for large areas.

In some arid regions, where the potential for successful vegetative stabilization is slight, physical stabilization may be the preferred alternative. In such areas, combinations of pit-run sand and gravel, soil, and riprap have been placed over the tailings and have been successful in preventing wind and water erosion. An important component of physical stabilization is the proper treatment of the finished surface by such means as contour-grading and terracing. Such treatments can reduce greatly long-term maintenance costs.

6.1.4 Vegetative Stabilization

This method involves the establishment of vegetative cover on the tailings or on a growing medium placed over the tailings.

Many species of plants are self-regenerating and require little or no maintenance after growth becomes established. Vegetation can survive providing that:

(a) Evapotranspiration is not excessive

(b) Landscapes are properly shaped

(c) Nontoxic soil mediums capable of holding moisture are provided

(d) Irrigation and fertilization appropriate to the area are applied

(e) Proper selection of plants conducive to self-regeneration under conditions anticipated over a long time

Growth of vegetation at sites receiving less than 10 in. of annual precipitation and with high evapotranspiration rates requires irrigation and fertilization. At Gunnison, precipitation averages about 11 in. annually.

After the mill was shut down in 1962, the surface of the pile was contoured, covered with 6-in. of material excavated from a nearby gravel pit and vegetated in accordance with plans approved by the Colorado Department of Health.

The pile was sprinkled for several summers, and now the vegetation is sustained by natural precipitation. The top of the pile is well vegetated and although portions of the slopes are not as well vegetated, there is no evidence of wind or surface water erosion.

One potential problem in the use of vegetative stabilization is the possibility of pickup of radioactive elements by the plants. The effect of this mechanism has not been considered in the present assessment.

6.2 PREVENTION OF LEACHING

Leaching into underground aquifers is one of the several pathways that chemicals and radioactive materials might take into the environment. There is little direct evidence that migration of radioelements from the Gunnison tailings is likely to constitute a problem. The techniques which could be employed to control leaching from the tailings piles include the following:

(a) Employ chemical stabilization to prevent leaching into underground aquifers (This is the same stabilization system discussed in paragraph 6.1.2).

(b) Physically compact the tailings to reduce the percolation of water through the materials.

(c) Contour the tailings surface, then employ appropriate chemicals (discussed in paragraph 6.1.1) to seal the surface, thus preventing water from penetrating and destabilizing the tailings.

(d) For a new site, line the storage area with an impermeable membrane (bentonitic clays and various plastic materials commonly are used for this purpose).

6.3 REDUCTION OF RADON EXHALATION

Little research has been directed toward reduction of radon exhalation from tailings piles. While there are materials that can seal or contain the gas in small quantities, none of these are suitable for permanent coverage of large areas.

From simplified diffusion theory estimates, about 13 ft of dry soil[2,3] are needed to reduce radon flux by 95%, but only a few feet of soil are needed if a high moisture content in the cover material is maintained. Figure 6-1 illustrates curves of the reduction of radon exhalation flux for three soil types versus depth of cover based upon the theory and diffusion coefficients presented in the above references. Research is under way to explore more precisely the problems associated with reducing and eliminating the exhalation of radon from radioactive tailings material. The effects of applying various chemical stabilizers and varying thicknesses of stabilizing earth covers and combinations of materials are still being investigated. The results may have an important impact in planning radon exhalation control.

6.4 REDUCTION OF GAMMA RADIATION

A few feet of cover material are sufficient to reduce gamma radiation to acceptable levels.

The reduction of gamma exposure rates resulting from a packed earth covering is given in Figure 6-2.[4,5] Two feet of cover reduces the gamma levels by about two orders of magnitude. Therefore, an average cover of 2 ft should reduce gamma levels to less than 10 μR/hr above background.

6.5 ASSESSMENT OF APPLICABILITY

Available data indicate that none of the methods used thus far to stabilize uranium tailings sites has been a totally satisfactory solution to uranium tailings site radiation problems. Some of the methods examined have exhibited short-term advantages, but no economical long-term solutions have become apparent. Consequently, new methods of stabilization may have to be developed and additional engineering research may be required. However, except for the minimum action option, the present remedial action options include physical stabilization of the tailings with at least 2 ft of cover. This action will further reduce gamma radiation and wind and water erosion.

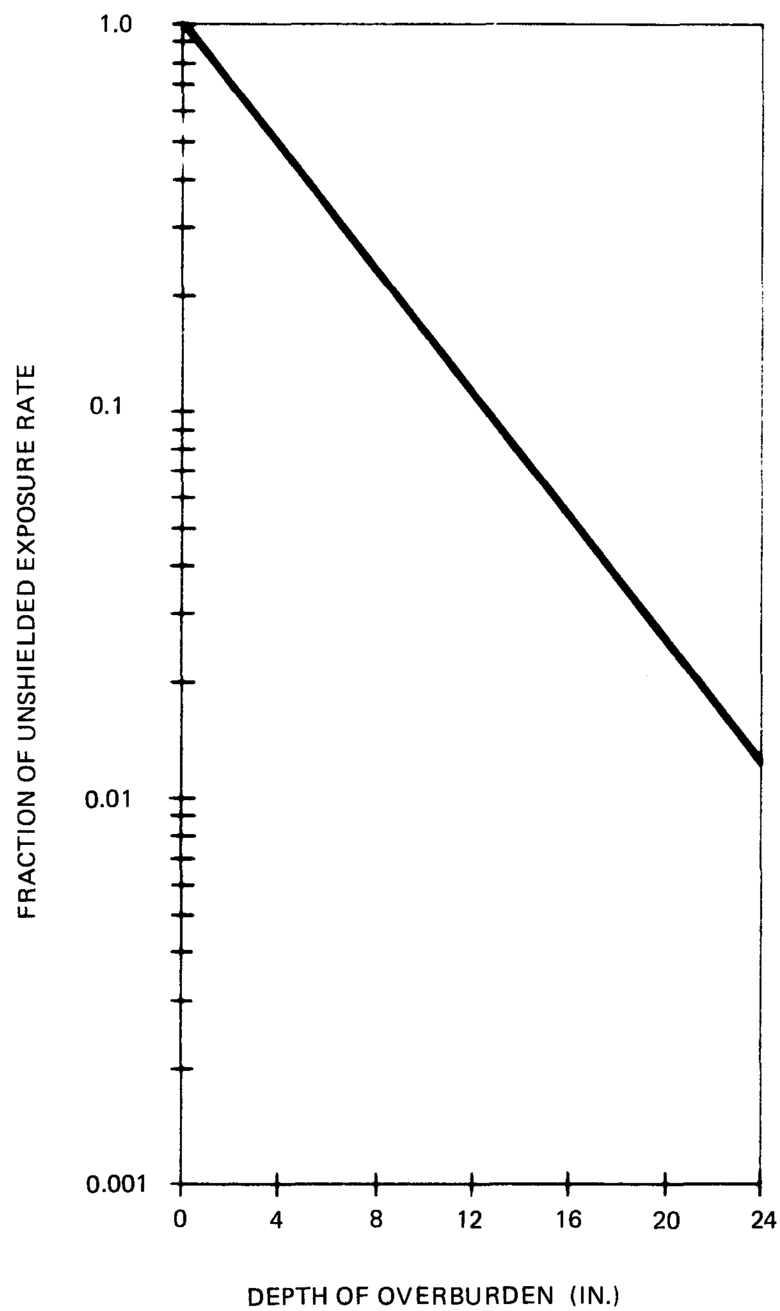

FIGURE 6-2. REDUCTION OF GAMMA EXPOSURE RATE RESULTING FROM PACKED EARTH SHIELDING

130-12

CHAPTER 6 REFERENCES

1. "Methods and Costs for Stabilizing Fine Sized Mineral Wastes"; Bureau of Mines Report of Investigation: RI7896; 1974.

2. A. B. Tanner; "Radon Migration in the Ground: A Review"; The Natural Radiation Environment; J. A. S. Adams and W. M. Lowder, eds; Universtiy of Chicago Press; pp. 161-190; 1964.

3. H. W. Kraner, G. L. Schroeder, and R. D. Evans; "Measurements of the Effects of Atmospheric Variables on Radon-222 Flux and Soil-Gas Concentrations"; The Natural Radiation Environment; J. A. S. Adams and W. M. Lowder, eds; University of Chicago Press; 1964.

4. K. J. Schiager; "Analysis of Radiation Exposures On or Near Uranium Mill Tailings Piles"; Radiation Data and Reports; Vol 15; Jul 1974.

5. "Evaluation of Various Methods, Techniques, and Materials for Stabilizing Uranium Mill Tailings"; FB&DU Report (in preparation).

CHAPTER 7

OFF-SITE REMEDIAL ACTION

CHAPTER 7

OFF-SITE REMEDIAL ACTION

Two closely related objectives of this engineering assessment are to identify those structures and land areas off-site where tailings are located and, based upon the Surgeon General's guidelines and on criteria established for this assessment, to estimate the costs of appropriate remedial action.

Some tailings have been transported off the site by individuals, others by wind and water erosion.

For the purposes of this report, the tailings that have eroded off the tailings pile to surrounding land areas both on and off the site are considered in this chapter.

7.1 DATA SOURCES

A mobile scanning unit, operated by the AEC under an interagency agreement with EPA, performed a gamma radiation survey of the Gunnison, Colorado area in 1971. Of the 1,120 structures scanned, 47 anomalies were reported. A joint team from the EPA Office of Radiation Programs, Las Vegas, Nevada (EPA-ORP-LV) and the Colorado Department of Health performed individual gamma surveys of the 47 locations to determine the source of the anomalies and, if tailings, how they had been used.[1] High and low inside and outside gamma readings were recorded. A gamma map was drawn if gamma readings inside the structures exceeded 20 μR/hr.

The EPA gamma survey[2] for windblown tailings was the data source used for consideration of the remedial action for open land areas.

7.2 REMEDIAL ACTION FOR STRUCTURES

A follow-up survey of the anomalies[1] indicated that there were only three locations with possible tailings use. Of the three locations, two were vacant lots where contamination was limited to the edge of the roads and presumably resulted from spillage from ore trucks instead of tailings use. The third location was a structure where the occupant refused to allow a detailed survey of the property but where abnormally high radiation levels dominated. For purposes of this report, this structure is assumed to require remedial action and is classed as a "tailing-under" structure.

Of the remaining 44 anomalies identified by the 1971 scanning survey, 9 were caused by the presence of radioactive material in instruments or ore, 28 resulted from natural radioactive mate-

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[1] See end of chapter for references.

rials, and 7 resulted from indeterminate sources or could not be verified as anomalies above background. Additional tailings use may be identified during future work.

The cost for remedial action at the one off-site structure has been estimated at $13,000, based upon available information, primarily the follow-up gamma survey results. (1)

An extended series of measurements, such as required in the full application of the Grand Junction remedial action criteria, might modify the actual number of locations included in the remedial action. The location at which tailings are on vacant lands or are greater than 10 ft from structures could constitute a problem in the future. Costs for this category are not included in this assessment because they are not covered under the Grand Junction remedial action criteria.

7.3 REMEDIAL ACTION FOR OPEN LANDS

The extent of windblown tailings is indicated by the EPA data (2) in Figure 3-10, Chapter 3. Decontamination of windblown tailings consists of removing the off-pile contaminated soil and returning it to the tailings pile. The Phase II criteria (Appendix A.2) state that the area for windblown soil removal is determined by residual radium concentration in the soil of no more than twice background radium concentration in the vicinity. All areas would be decontaminated by moving the top 4 in. of soil, gravel roads, lawns, etc. to the pile. After decontamination, the affected areas would be restored with additional clean material and removed vegetation would be reestablished. Tailings adjacent to the airport runway would be moved back to the pile as part of the off-site decontamination effort. All structures would be decontaminated by either wet or dry vacuum procedures.

The estimated cost for off-site decontamination of structures, and open lands and on-site cleanup around the pile is $40,000 exclusive of engineering costs and contingency, which have been included in the total cost for each option discussed in Chapter 9.

CHAPTER 7 REFERENCES

1. "Summary Report of the Radiation Surveys Performed in the State of Colorado at Gunnison, Colorado"; EPA; Office of Radiation Programs; Las Vegas, Nevada; Mar 1973.

2. R. L. Douglas and J. M. Hans, Jr.; "Gamma Radiation Surveys at Inactive Uranium Mill Sites"; Technical Note ORP/LV-75-5 EPA; Office of Radiation Programs; Las Vegas, Nevada; Aug 1975.

CHAPTER 8

LONG-TERM STORAGE SITE SELECTION

CHAPTER 8

LONG-TERM STORAGE SITE SELECTION

In several of the alternative remedial actions considered in this assessment, the Gunnison tailings would be moved to an alternate site isolated from the populace for long-term (greater than 50 yr) storage.

8.1 CRITERIA FOR LONG-TERM STORAGE

The State of Colorado and federal and local agencies, concerned individuals, and personnel in industry were contacted to locate possible alternative storage sites for the long-term storage of the Gunnison tailings. In addition to the sites suggested by these information sources, other sites that could meet the federal and state criteria specified for long-term storage of radioactive tailings were sought and identified. In all, 13 disposal sites were considered and a reconnaissance survey was made of each. Of these, six sites were selected for cost estimate studies and included as options. These locations are considered in Options IV through IX. Table 8-1 gives the name of each alternate storage site studied and the distance of each from the present Gunnison tailings. Figure 8-1 shows the locations of the proposed storage sites.

Of the sites considered, seven were omitted as options for a variety of reasons, primarily because of excessive haul distance; steepness of terrain; possibility of encroachment on the site; difficulty of handling surface hydrology (too much upslope drainage); and lack of sufficient available ground cover as stabilization cover.

Each site was evaluated on the basis of hydrology, meteorology, geology, ecology, and economics. The site evaluations consisted of literature surveys and limited on-site investigations. The hydrologic and meteorologic conditions were assessed with regard to such factors as wind and water erosion, water contamination, flooding and drainage characteristics, precipitation, access to bedrock, and location of confined aquifers. Special consideration was given to drainage basin configuration, subsurface and surface drainage, and natural storage basin features. The geologic examination addressed stability problems and soil characteristics such as evidence of slides or faults and types of unconsolidated and bedrock materials. The ecological study evaluated land use potential, animal habitats, proximity to population centers, and aesthetic considerations. Economic considerations included preliminary estimates of support facilities such as highways, distance from the Gunnison site, and the extent of site preparation and long-term maintenance required at the site. Because of transportation costs, only sites within 10 mi of Gunnison were considered. Private, state, and federal lands were included in searching out acceptable alternate sites.

8.2 GENERAL DESCRIPTION OF ALTERNATE STORAGE SITE AREAS

Rolling hills, mainly sagebrush covered, rise from the valley floors to the surrounding National Forests. There are many locations in these unforested areas, which have basin or horseshoe-like configurations, which could be developed into ideal storage sites for the tailings. Sites having north or east exposures were sought. Many hills slope from the valleys to the mountain peaks in an almost unbroken plane. In these areas storage sites could be developed, but the cost of site preparation and the water run-off problems from higher elevations ruled out their inclusion.

Industrial and commercial centers are developing mainly alongside the main highways in the area (U.S. 50 and Colorado State Highway 135) which generally parallel the Gunnison River and Tomichi Creek in the Gunnison area. To haul the tailings by truck to any areas north or east of the pile would require a routing through the urban area of Gunnison. To haul by truck to the south, west or northwest would be much easier than travel through heavy-use or populated areas. Railroad facilities were not considered in that there are no such services in the area.

The Blue Mesa Reservoir area west of Gunnison with its surrounding recreational and forested areas was not considered as a potential storage site location.

There is some irrigation in the valleys surrounding Gunnison. No land now being used for irrigation or farming was considered, nor were potential irrigatable areas.

The storage sites suggested are all quite similar. They are located at the head of drainage areas in naturally formed horseshoe-shaped depressions, and the sites have little or no evidence of current erosion. The average annual rainfall at all sites is about 11 in. and the vegetation on the sites is between 30% and 80%, mostly in short shrubs like sagebrush. There are no trees or even tall bushes on any of the sites. Access to all of the sites selected as options would be over paved or graveled public roads and then on specially constructed haul roads. Where dirt roads are to be traversed by trucks carrying tailings, the estimates involve the construction of a gravel-based surface sufficient to handle the heavy loads and traffic. Dust control costs are also included. All of the lands upon which suggested storage sites are located are under the jurisdiction of the U.S. Bureau of Land Management (BLM).

Transportation, site preparation and maintenance costs are discussed more fully in Chapter 9.

8.3 RETURN TO ORIGINAL MINE SOURCES

Returning the Gunnison tailings to the mines from which the ores were obtained is not feasible. The ore refined at the mill came from mines which are farther from the site than are any of the storage sites. These mines are not available for long-term storage.

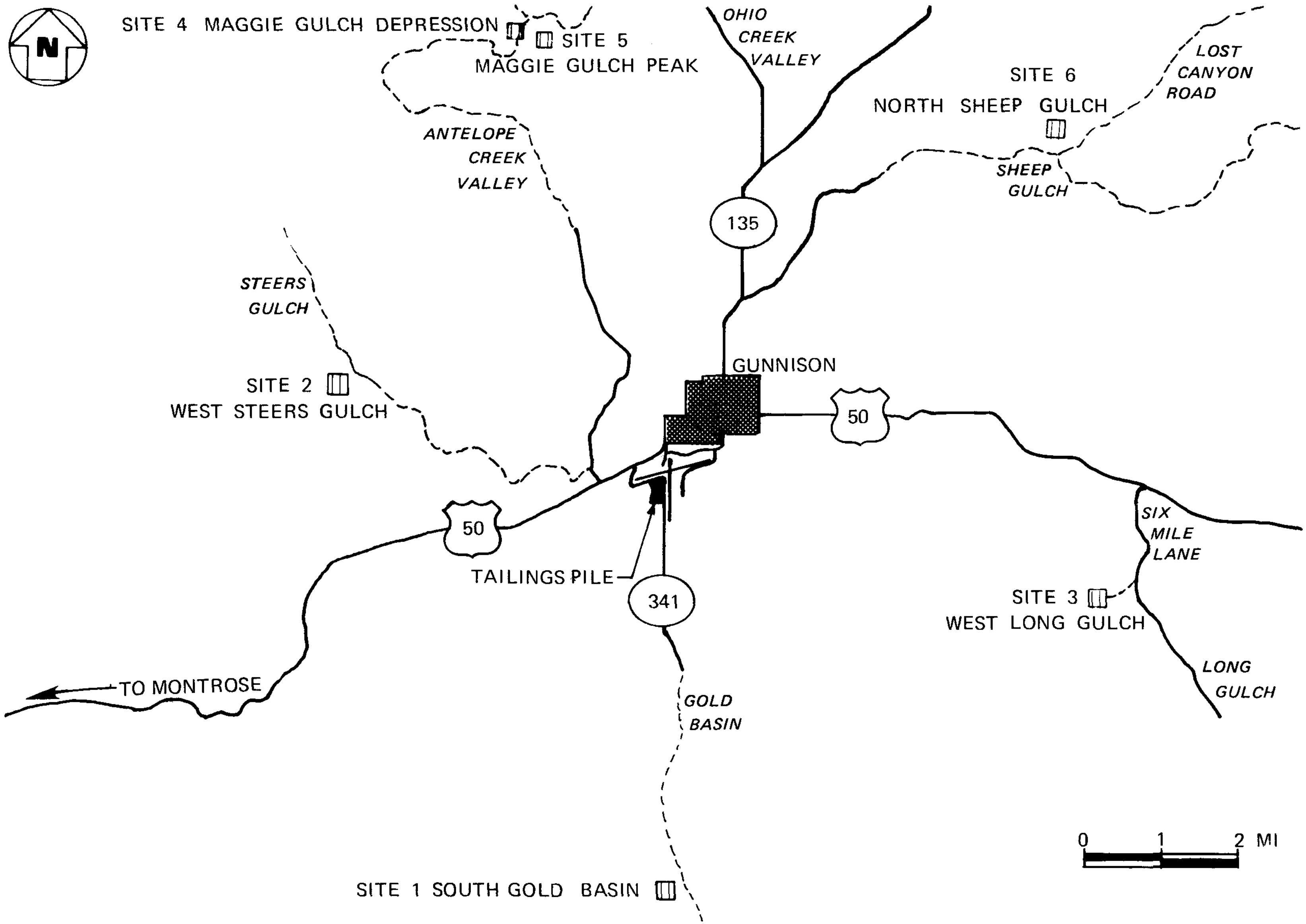

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FIGURE 8-1. LOCATION OF PROPOSED STORAGE SITES

Ford, Bacon & Davis Utah Inc.

TABLE 8-1

SITES EVALUATED FOR STORAGE OF THE GUNNISON TAILINGS

Site Identification No.	Cost Option No.	Road Distance From Pile, Mi	Site Name or Location
1	IV	5.8	South Gold Basin Creek
2	V	4.5	West Side, Steers Gulch
3	VI	7.5	West Side, Long Gulch
4	VII	9.5	Maggie Gulch Depression
5	VIII	9.0	Maggie Gulch Peak
6	IX	7.0	North Side, Sheep Gulch
7		3.4	East Side, Gold Basin Creek
8		4.0	West Side, Gold Basin Creek (Mesa)
9		6.0	West Beaver Creek
10		10.3	N-W Almont
11		6.5	Hartman Gulch
12		12.5	West Slope of Flat Top
13		4.5	West Side, Chance Gulch

CHAPTER 9

REMEDIAL ACTIONS AND COST-BENEFIT ANALYSES

CHAPTER 9

REMEDIAL ACTIONS AND COST-BENEFIT ANALYSES

Various remedial actions for the tailings were identified and investigated. The alternatives presented are those considered to be the most realistic and practical when evaluated in regard to the present technology, equipment, and transportation facilities available. Remedial measures for the site can be separated into two basic categories:

(a) Stabilization at the Gunnison site

(b) Removal of the tailings and stabilization at alternative sites

Several of the remedial measures are common to all the alternative approaches costed; these measures were considered in estimating the total cost of each option. For example, in all of the options, fencing would be required around the tailings. The standard fencing included in all options is 6-ft-high chainlink fence with three strands of barbed wire along the top. Also, radiation warning signs would be displayed prominently on the fence, gates, and in other appropriate areas and facilities. The off-site remedial action described in Chapter 7 is included in all options.

Another measure considered in all options except Option I is the stabilization of the tailings with at least 2 ft of pit-run earth, sand, and gravel. This action would greatly reduce gamma radiation and wind and water erosion.

Long-term maintenance also would be required for all of the options. The maintenance would generally include periodic monitoring and repair of fences, signs, and stabilizing cover. Provision for the annual maintenance costs for an extended period of time is included in the form of an endowment fund which, at 7% annual interest, would provide the money necessary for projected inspection and maintenance functions. The endowment fund is a mechanism to indicate the long-range control and financing needed to maintain the integrity of the inactive pile.

The two remedial action options proposed for on-site stabilization are based on various levels of radon exhalation reductions to be achieved. Six options are presented for removal of the tailings to an alternate storage site. For these six options, the proposed procedures outlined in this chapter are intended to meet the temporary criteria for stabilization specified by the State of Colorado. Applicable portions of the regulations are included in Appendix B.

A discussion of the concepts involved in tailings stabilization and their applicability to the Gunnison site have been detailed in Chapter 6.

No acquisition costs for alternate long-term storage areas are included in the cost estimates.

9.1 MINIMAL REMEDIAL ACTION (OPTION I)

The principal objective of this option is to decontaminate the area of the site not occupied by the tailings, to clean up off-site and windblown contamination as described in Chapter 7, and to provide for security fencing and maintenance. In addition, the mill building would be decontaminated.

Any loose and unstabilized tailings in the site area would be gathered up along with plant debris and contaminated soil, including that in the area where the old ore storage area was located. The average depth of soil to be removed would be 6 in., and contaminated earth would be placed at the southwest corner of the tailings pile along with the material collected from the remedial actions of Chapter 7. The tailings and contaminated earth located on the 3.5 acres owned by Gunnison County would be relocated onto the surface of the pile. This material would then be stabilized with the addition of a minimum of 6 in. of earth cover. The cavity left by the removal of the material from the ore storage area would be filled with locally available clean earth fill material.

9.1.1 Security and Maintenance

Based on the radiometric levels present at the site and on Phase II criteria, the tailings pile area of the site would be designated as a "control area". A 6-ft-high chainlink fence topped by three strands of barbed wire would be installed on all sides of the pile. Radiation warning signs would be posted around the perimeter of the tailings. Periodic monitoring and physical maintenance of the stabilized pile would be required. Fences, gates, and signs would be maintained. No irrigation of the tailings for dust control and vegetation would be required.

9.1.2 Resulting Impacts

Under this option the release of some radioactive materials from the tailings pile would continue. The projected exposure of the public to contamination is described in Chapter 3, paragraph 3.6. The site would have no commercial, industrial, or residential use.

9.1.3 Costs

As shown in Table 9-1, the $480,000 cost is the lowest-cost option, considering initial costs only. The major cost components are as follows:

(a)	Engineering (10% of item b)	$ 30,000
(b)	Remedial action	300,000

(c)	Environmental assessment and EIS preparation	40,000
(d)	Contingency (15% of items a, b, and c)	55,000
(e)	Endowment fund	55,000
	Total Cost	$480,000

The endowment fund at 7% annual interest will provide $3,850 for the annual monitoring and maintenance required.

9.2 TAILINGS STABILIZATION WITH 2-FT COVER (OPTION II)

In addition to the actions taken in Option I, this option would provide more stabilization cover on the tailings by the addition of 1.5 ft of earth, making a total cover thickness of 2 ft. The finished surface of this stabilization cover would be contour-graded with terraces to encourage retention of moisture, prevention of erosion, and growth of vegetation. The entire tailings cover would be revegetated with plants and grasses natural to the area. Irrigation would be required through at least one summer season to establish growth.

9.2.1 Security and Maintenance

Fencing and the posting of radiation warning signs under this option would be the same as that for Option I. Physical maintenance would be that necessary to assure the integrity of stabilization and the fencing. No continual irrigation program is specified.

9.2.2 Resulting Impacts

Stabilization as proposed in Option II would be more effective than the existing cover in preventing the spread of tailings by wind and water. The 2 ft of cover material would reduce the gamma radiation to near background levels, but would not reduce significantly the exhalation of radon from the pile (no more than 25%). The greater depth of stabilization cover would offer greater resistance to wind and water erosion and would increase the stability of the pile, decreasing maintenance requirements versus Option I.

The site would have limited use as a result of the physical presence of the pile and the associated radiation.

9.2.3 Costs

The cost of this option is estimated at $850,000. The major cost components are as follows:

(a)	Engineering (9% of item b)	$ 54,000

(b)	Remedial action	600,000
(c)	Environmental assessment and EIS preparation	40,000
(d)	Contingency (15% of items a, b, and c)	106,000
(e)	Endowment fund	50,000
	Total Cost	$850,000

The endowment fund at 7% interest would provide approximately $3,500/yr for monitoring and maintenance. The expected maintenance would be less than that of Option I by about $350/yr primarily because of the ease of maintenance on a more adequately stabilized pile and of the ability of natural vegetation to establish itself on the pile.

9.3 TAILINGS STABILIZATION WITH 13-FT COVER (OPTION III)

This option is identical to Option II except 12.5 ft of cover are applied to the pile. With this cover, gamma radiation would be reduced to background levels and radon exhalation reduced by about 95%. The area around the pile would be available for unrestricted use. The tailings area would continue as a controlled area. The volume of stabilization cover required would approximate the volume of the tailings.

As shown in Table 9-1, the estimated cost for this option is $2,730,000. The major cost components are as follows:

(a)	Engineering (7% of item b)	$ 150,000
(b)	Remedial action	2,140,000
(c)	Environmental assessment and EIS preparation	40,000
(d)	Contingency (15% of items a, b, and c)	350,000
(e)	Endowment fund	50,000
	Total Cost	$2,730,000

Monitoring and maintenance costs would be the same as for Option II.

9.4 REMOVAL OF TAILINGS AND ALL CONTAMINATED MATERIAL FROM THE SITE (OPTIONS IV-IX)

These six options provide for the complete removal of all tailings, contaminated soil, stabilization cover, buildings, materials, and rubble from the site to a long-term storage area. Also included would be all of the contaminated material gathered from the off-site remedial actions described in Chapter 7.

To comply with decontamination criteria for tailings piles (as described in Chapter 3, paragraph 3.5), the contaminated soils beneath the pile must be removed. The amount of soil to be removed depends on the depth of contamination, as indicated in Figure 9-1. In this figure, radium concentration is given as a function of depth below the interface. The approximate cost to remove and dispose of the subsoil for the tailings removal options is also presented. The removal of an average of 3 ft of subsoil beneath the tailings area would assure that the residual concentration in the remaining soil is less than twice the background value of 1.5 pCi/g.

9.4.1 Excavation and Loading of Tailings and Soils

Based upon site examination, a review of the physical analysis of the tailings, and a discussion with general engineering (earthmoving) contractors in the area, it appears as though there would be no difficulty in loading the tailings for removal purposes. The contractor performing this work can use any one of a number of conventional loading methods; e.g. front-end tractor loaders, conveyor belt feed to overhead loading, etc. There is room on the site for loading and easy truck ingress and egress. The moisture content of the tailings should cause no problems.

Fugitive dust emissions during material moving at the tailings sites and long-term storage sites, if used, could constitute significant sources of airborne particulates, both radioactive and otherwise. The fugitive dust provisions of Colorado Air Pollution Regulation No. 1, Section II.D.6. relate to "open mining activities" to the extent that the land disturbed involves more than one acre. The list of fugitive dust abatement and preventive measures (minimum requirements) is set forth in Regulation No. 1, Section II.D.6.

Washdown facilities for equipment would be provided. The lack of moisture in the tailings and native earth during certain seasons of the year would require the use of dust preventive methods in the excavation and loading process.

Any backfill material that might be used would be material available locally, and all of which must be hauled onto the site. No special treatments of the final surface are considered in this assessment. The cost to excavate, then backfill subsoil for various depths below the interface, is given in Table 9-1.

9.4.2 Transportation of the Material

All the radioactive tailings and materials to be removed from the present site must be transported to the selected alternate long-term storage site. Slurry pipeline technology was evaluated, but because of the high costs involved was not considered feasible. Use of a conveyor system was deemed impractical because of the geographic location of the tailings with respect to rivers, bridges, public and private land ownership, and the urban areas of Gunnison. The relatively small amount of tailings also would make a conveyor system economically unfavorable.

Truck transportation is the most economical means to haul the material to all of the storage sites. Trucks could move the materials at the rate of about 3,500 tons/day. At this rate, on a 5-days-a-week basis, all the material could be removed in approximately 12 months. This method assumes the use of conventional trailer trucks. Dust control measures, such as covers and washdown facilities for the trucks, are included in the trucking costs. No costs are included for repair and maintenance of public roads. Costs include development of access roads and road maintenance where required.

9.4.3 Storage at Alternative Sites

A general description and list of the proposed storage sites are given in Chapter 8.

All of these storage sites are located within 10 mi of the tailings pile. Vegetation cover does not exceed 80%, and average annual rainfall at all of the storage areas is approximately 11 in. All are accessible by using a combination of paved, gravel, and in some cases dirt roads.

The storage sites selected can be isolated from drainage basins naturally or by dikes and drainage ditches. The deposit procedure would involve removing topsoil from the site, constructing containment dikes or dams (preferable with a clay core), depositing the tailings, and covering the tailings with the removed topsoil to a depth of at least 2 ft. The relocated and stabilized tailings would have gently angled slopes and be contour-graded to minimize water erosion. Figure 9-2 illustrates in a schematic representation how these long-term storage sites would be developed.

Of the alternative sites evaluated, those in the following tabulation were selected as most suitable when compared with criteria for long-term storage:

Option	Name	Road Mileage from Tailings	Site No.
IV	South Gold Basin	5.8	1
V	West Steers Gulch	4.5	2
VI	West Long Gulch	7.5	3
VII	Maggie Gulch Depression	9.5	4
VIII	Maggie Gulch Peak	9.0	5

Option	Name	Road Mileage from Tailings	Site No.
IX	North Sheep Gulch	7.0	6

As shown in Table 9-1, the relative cost differences between the six options, where relocation for storage is the principal objective, is minor. The major cost factors are haul distance, routing, and preparation of the storage site.

9.4.3.1 Option IV - South Gold Basin (Site No. 1)

This site is located south of Gunnison, 5.8 mi from the tailings pile on the west side of the gulch formed by Gold Basin Creek. It is near the top of the ridge which separates Gold Basin from South Beaver Creek, on the Gold Basin side, which would give the storage site an easterly exposure. The site is at an elevation of 8,440 ft and is in a basin that, with the construction of a tailings retention dam, would make an ideal storage site. About 24 acres would be required. The site is in a remote area, yet has easy, direct access to the tailings pile without the associated traffic problems of going through the city of Gunnison. A 0.25-mi haul road would have to be constructed to provide access to the site west from the gravel road in Gold Basin. The closest residence is 1.3 mi north in Gold Basin. The canyon is sparsely populated with but three homes. The storage site is on the side of a relatively steep canyon and is not used for any purpose at present, nor does it appear that any growth or development will infringe on its isolation. Vegetative cover is about 30%. The soil would provide good stabilization cover and be ideal for dam and/or dike construction.

Advantages include the ease of access through unpopulated areas, the present and future isolation characteristics, and the ability to keep any surface drainage from entering the site. Disadvantages are the requirement for a fairly high (30 ft) containment dike and the steep haul road required to get the tailings into the site from the gravel road of Gold Basin Gulch.

As shown in Table 9-1, the estimated total cost is $5,009,000. The major cost components are as follows:

(a)	Engineering (7% of item b)	$ 256,000
(b)	Remedial action	3,656,000
(c)	Environmental assessment and EIS preparation	400,000
(d)	Contingency (15% of items a, b, and c)	647,000
(e)	Endowment fund	50,000
	Total Cost	$5,009,000

This cost includes all of the decontamination work, the cost of tailings and contaminated material removal to this storage site, site preparation, fencing, monitoring, and maintenance. An endowment fund for the monitoring and physical maintenance of the fencing and stabilized pile is included in an amount that will provide approximately $3,500 annually for the projected work.

9.4.3.2 Option V - West Steers Gulch (Site No. 2)

This site is located west of Gunnison on the west slope of an area known as Steers Gulch and on the west side of the ridge which divides Beaver Creek from Steers Gulch. Its exposure would be to the east. It is 4.5 mi from the tailings pile, 2 mi of which would be over paved roads, and 2.5 mi over an existing jeep trail which would have to be developed into a haul road. The site is at an elevation of 8,400 ft. About 28 acres would be required for the storage site, including a containment dike. Vegetative cover is approximately 80%, mainly sagebrush. There are no trees on the site. The closest residence is 2.3 mi south, along the Gunnison River. Site isolation appears to be assured, and should development occur along the river valley, the site would still be at least 1.5 mi from any commercial or residential installations. At present, the site is used for seasonal grazing.

Advantages include the short haul distance, the availability of ideal stabilization cover and the exposure, which would enable the site to become easily revegetated.

Disadvantages are the necessity of a specially built haul road and of moving the tailings through the west end of the Gunnison urban area.

As shown in Table 9-1, the estimated total cost is $5,200,000. The major cost components are as follows:

(a)	Engineering (7% of item b)	$ 267,000
(b)	Remedial action	3,810,000
(c)	Environmental assessment and EIS preparation	400,000
(d)	Contingency (15% of items a, b, and c)	673,000
(e)	Endowment fund	50,000
	Total Cost	$5,200,000

This cost includes all of the work described in Option IV including the same costs for monitoring and annual maintenance.

9.4.3.3 Option VI - West Long Gulch Area (Site No. 3)

The site is located east of Gunnison on the east-facing side of a ridge that runs north and south. The ridge divides two drainage basins: Chance Gulch on the west side of the ridge, and Long Gulch on the east side of the ridge. Thus, the tailings site, at 8,000 ft above sea level, faces eastward into Long Gulch. Six Mile Lane is 1 mi east of the proposed site.

The tailings could be trucked to the site over two routes: east on U.S. Highway 50 to Six Mile Lane, then south 1.5 mi on Six Mile Lane, then west 1 mi on a jeep road to the site; or, by permission, over BLM and private lands, on gravel or jeep roads, from the tailings east to the proposal site. This latter route would bypass urban traffic and pass south of Tenderfoot Mountain. Using either route the haul distance is 7.5 mi.

Approximately 30 acres would be required on the disposal site, which has no trees but is covered by sage brush. The closest residence is a ranch house 1.4 mi east at the entrance of Long Gulch.

The advantages of this location are the availability of excellent stabilization cover and the natural basin formation into which the tailings would be placed.

Disadvantages are the haul through downtown Gunnison along one route, or over specially built haul roads along another.

As shown in Table 9-1, the estimated total cost is $5,309,000. The major cost components are as follows:

(a)	Engineering (7% of item b)	$ 273,000
(b)	Remedial action	3,900,000
(c)	Environmental assessment and EIS preparation	400,000
(d)	Contingency (15% of items a, b, and c)	686,000
(e)	Endowment fund	50,000
	Total Cost	$5,309,000

This cost includes all of the work described in Option IV including the same costs for monitoring and annual maintenance.

9.4.3.4 Option VII - Maggie Gulch Depression (Site No. 4)

This site is located north of Gunnison 9.5 mi from the tailings pile at an elevation of 8,350 ft. It is in a 10-acre natural depression facing westward located on the Antelope Creek side of the ridge which separates the Ohio Creek drainage basin from Antelope Creek. It is on the west side of the gravel road which connects the two valleys and which runs along Maggie Creek. Access would be through urban Gunnison, on State Highway 135, north on the Ohio Creek paved road, then west on the gravel road which connects into Antelope Valley. Another possibility would be to obtain approval to go directly up Antelope Valley over private and public (BLM) lands to the site. This route would require the construction of at least 1.5 mi of access road, although it would eliminate hauling the tailings through the traffic and signal lights of Gunnison. The closest residence is 1.3 mi east, at the entrance to Maggie Gulch. The vegetative cover at the storage site is about 50%. The intent would be to enlarge the natural basin by excavation to about 20 acres, sufficient to store the tailings. The excavated material later would be used for stabilization cover.

The advantages are the use of a natural depression well protected from winds, and the site's isolation. Disadvantages include the difficult haul route and the grading required to protect the pile from upslope water runoff in that it is not at the head of a drainage basin.

As shown in Table 9-1, the estimated total cost is $5,470,000. The major cost components are as follows:

(a)	Engineering (7% of item b)	$ 282,000
(b)	Remedial action	4,031,000
(c)	Environmental assessment and EIS preparation	400,000
(d)	Contingency (15% of items a, b, and c)	707,000
(e)	Endowment fund	50,000
	Total Cost	$5,470,000

This cost includes all of the work described in Option IV, including the same costs for monitoring and annual maintenance.

9.4.3.5 Option VIII - Maggie Peak (Site No. 5)

This site is located north of Gunnison, 9 mi from the tailings site. It is just 0.5 mi southeast of the ridge between Antelope Creek and Ohio Creek. It is located in a basin which is at the very top of the ridge. There are no trees on the site and the vegetative cover is about 80%, mostly sage. A very steep haul road 0.25 mi in length would have to be constructed to gain access to the site from the gravel road connecting Antelope Creek Valley and Ohio Creek Valley. The closest residence is 0.65 mi. There is some residential development along the west slope of the ridge which parallels and faces into the lower Ohio Creek Valley. No housing would be closer to the site than the aforementioned 0.65-mi distance. Access to the site from the tailings would be via the same two alternatives as described for Site No. 4 (Option VII). The site is at an elevation of 8,400 ft, and would require about 15 acres. It has an eastern exposure, and is well protected from the wind.

The advantages include the naturally shaped storage basin, the availability of stabilization and dike materials, and its location at the very head of a drainage basin.

Disadvantages would be the steep haul over the last 0.25 mi of the route, the haul distance through the business district of Gunnison, and the scar to the hillside which dike construction would leave although in time this scar would be remedied through the natural revegetative process.

As shown in Table 9-1, the estimated total cost is $5,733,000. The major cost components are as follows:

(a)	Engineering (7% of item b)	$ 297,000
(b)	Remedial action	4,245,000
(c)	Environmental assessment and EIS preparation	400,000
(d)	Contingency (15% of items a, b, and c)	741,000
(e)	Endowment fund	50,000
	Total Cost	$5,733,000

This cost includes all of the work described in Option IV, including the same costs for monitoring and annual maintenance.

9.4.3.6 Option IX - North Sheep Gulch Area (Site No. 6)

This site is located northeast of Gunnison in an area known as Sheep Gulch. It is on the north side of Lost Canyon Road, 1 mi west of Biebel Springs and 7 mi from the tailings site. The closest house is 1.75 mi west. The storage basin is at an elevation of 8,480 ft. Its exposure would be to the east. A steep haul road of just under 0.5 mi would need to be constructed north from Lost Canyon Road in order to reach the site. About 20 acres would be required for the storage site including a containment dam. The area is steep; vegetative cover is approximately 80%, mainly sage brush. There are no trees on the site. It is on the side of a mountain which reaches an elevation of 10,655 ft, but it is in an area which would receive little upslope drainage because of the ridges which are located on the side slope. The only use that is made of the site at present is for seasonal grazing of sheep or cattle.

The advantages of the site are its remoteness and its location in an area where continued isolation is assured.

The disadvantages are the long haul distance from the existing site, the need of hauling the tailings through the business district of Gunnison, and the steepness of the last portion of the haul.

As shown in Table 9-1, the estimated total cost is $5,890,000. The major cost components are as follows:

(a)	Engineering (7% of item b)	$ 306,000
(b)	Remedial action	4,372,000
(c)	Environmental assessment and EIS preparation	400,000
(d)	Contingency (15% of items a, b, and c)	762,000
(e)	Endowment fund	50,000
	Total Cost	$5,890,000

This cost includes all of the work included in Option IV, including the same costs for monitoring and annual maintenance.

9.5 ANALYSES OF COSTS AND BENEFITS

As summarized in Table 9-1, the total estimated costs for the nine remedial options vary from a low of $480,000 to a high of $5,890,000. The purpose of this section is to compare the costs of the various alternatives with the corresponding anticipated benefits.

9.5.1 Health Benefits

Each of the remedial action alternatives considered in this chapter has an associated number of health effects that would be avoided as a result of the action. These avoided health effects are referred to as health benefits. In Chapter 3 the estimated number of health effects was determined for the Gunnison tailings pile in its present condition. In order to estimate the number of health benefits attributable to a particular remedial action, the effect of that remedial action on radon exhalation from the pile must be determined, because the health effects calculated in Chapter 3 were associated with radon and its daughters. Although there are some benefits associated with actions such as fencing, these have not been quantified in this assessment of health benefits, because under present conditions the associated benefits are small compared with those resulting from the reduction of radon exhalation.

In this evaluation, the health benefit of each option is calculated from the reduction in radon exhalation that is expected for that option. For example, if the radon exhalation and, hence, the number of health effects, are reduced by 60% for a particular remedial action, there will be a corresponding health benefit. This health benefit is equal to 60% of the number of health effects that would be expected had the remedial action not been implemented. The radon exhalation is reduced by cover material or by physical removal of the tailings to an isolated location. In the case of cover material of thickness t, the reduction in radon exhalation is given in Figure 6-1, Chapter 6, as the function: [1 - exp(-0.2t)]. Physical removal of the tailings results in a 100% reduction in exposure to the population of concern.

The results of the determination of potential cancer cases avoided (health benefits) for each option are given as a function of time in part A of Table 9-2. While there is a small health benefit predictable from decontamination, it has not been included in these analyses. Therefore, Option I is shown to have a negligible health benefit. However, Options II and III have higher health benefits due to a corresponding reduction in radon exhalation; and Options IV through IX result in the avoidance of all pile radon-induced potential health effects. The cost per potential cancer case avoided for each option is included as part B in Table 9-2.

As an alternative to the presentation in Table 9-2 the numbers of potential cancer cases avoided per million dollars expended were calculated and plotted in Figure 9-3. Option III yields the maximum health benefit per unit cost. In contrast, Option I yields a zero benefit per unit cost.

9.5.2 Land Value Benefits

The Gunnison tailings site has considerable potential for future use because of its location along U.S. Highway 50 in the southwestern portion of Colorado and because of its proximity to the business district and airport of Gunnison. The present site is conveniently located to almost any place in Gunnison. The land surrounding the tailings site has values ranging from $1,500 to $8,000/acre.

Proposed remedial action under Option I would not change the value of the south portion of the tailings site property, nor of any of the surrounding land. Under the two varying degrees of stabilization thickness cover of Options II and III, the site value would increase in proportion to the utilization permitted. The approximately 26 acres of the site not covered by tailings could increase from a current estimated value of $500/acre to approximately $1,500/acre if Option II were implemented, and to $2,000/acre if Option III were implemented.

Under Options IV through IX, where the tailings would be removed and the area decontaminated, the total site would be available for unlimited use with a resulting average market value of $30,750 ($500/acre) to $369,000 ($6,000/acre).

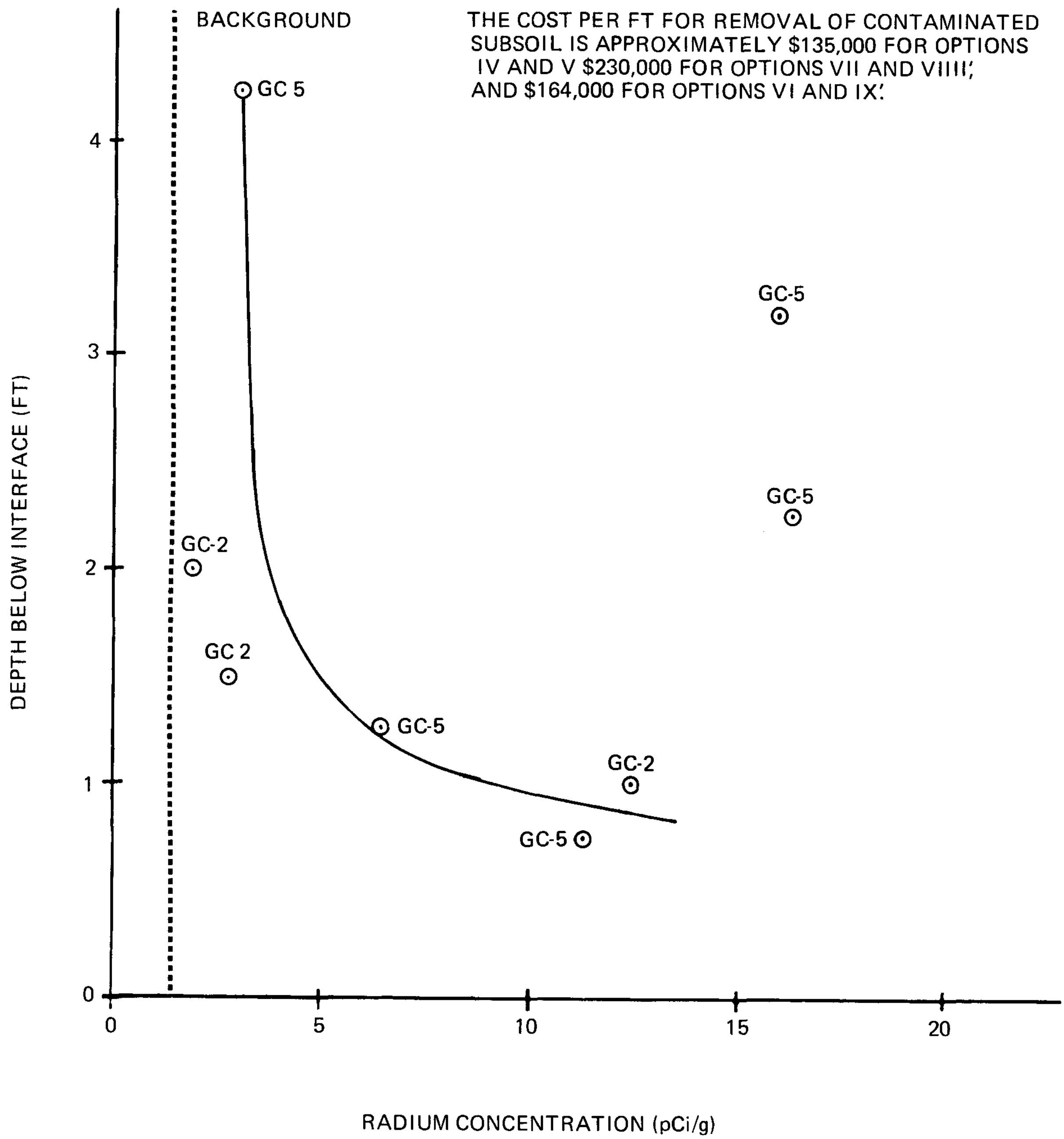

FIGURE 9-1. RADIUM ACTIVITY CONCENTRATION IN CONTAMINATED SUBSOIL

130-12

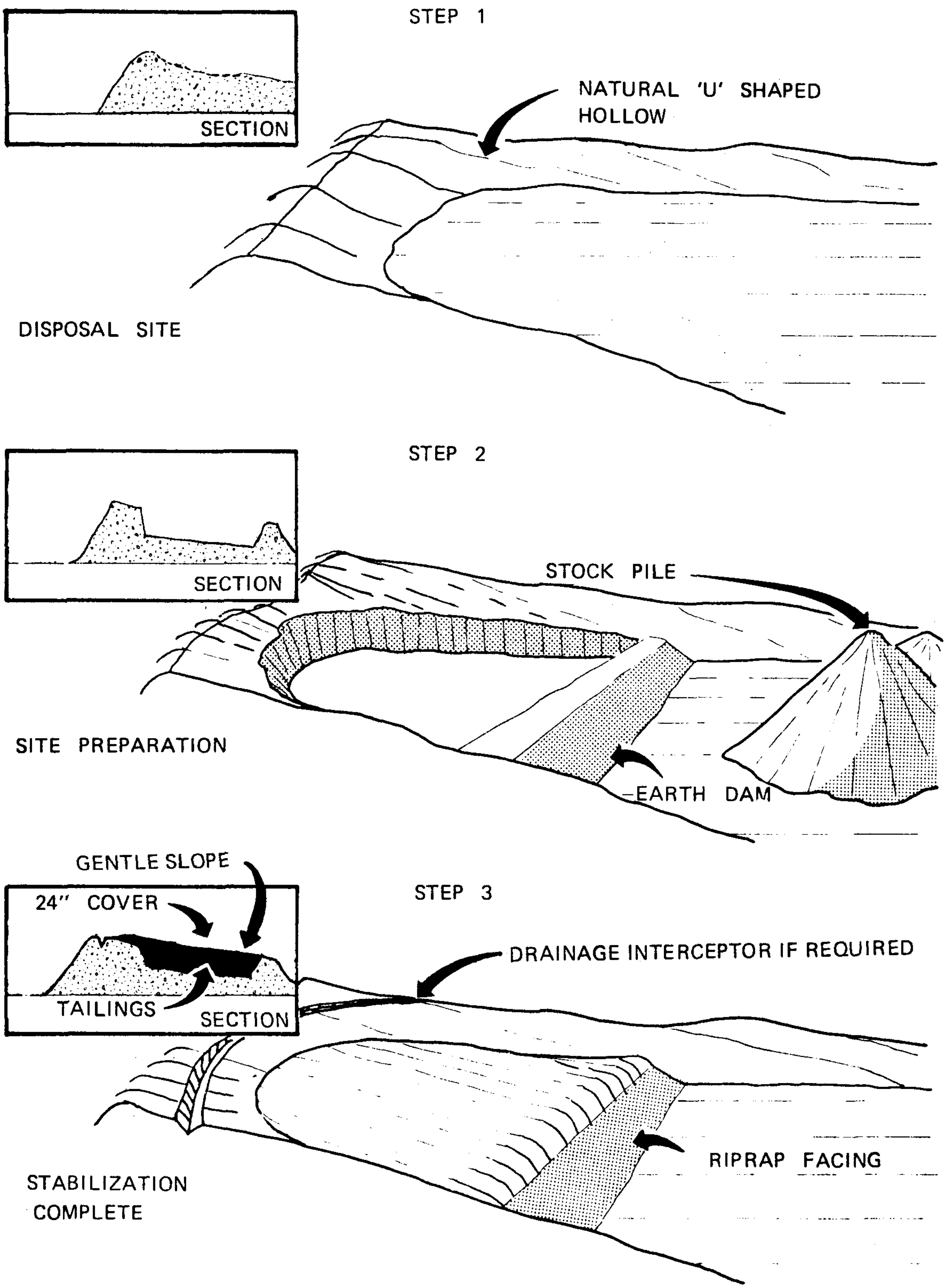

FIGURE 9-2. SCHEMATIC OF TYPICAL LONG-TERM TAILINGS STORAGE SITE

130-12

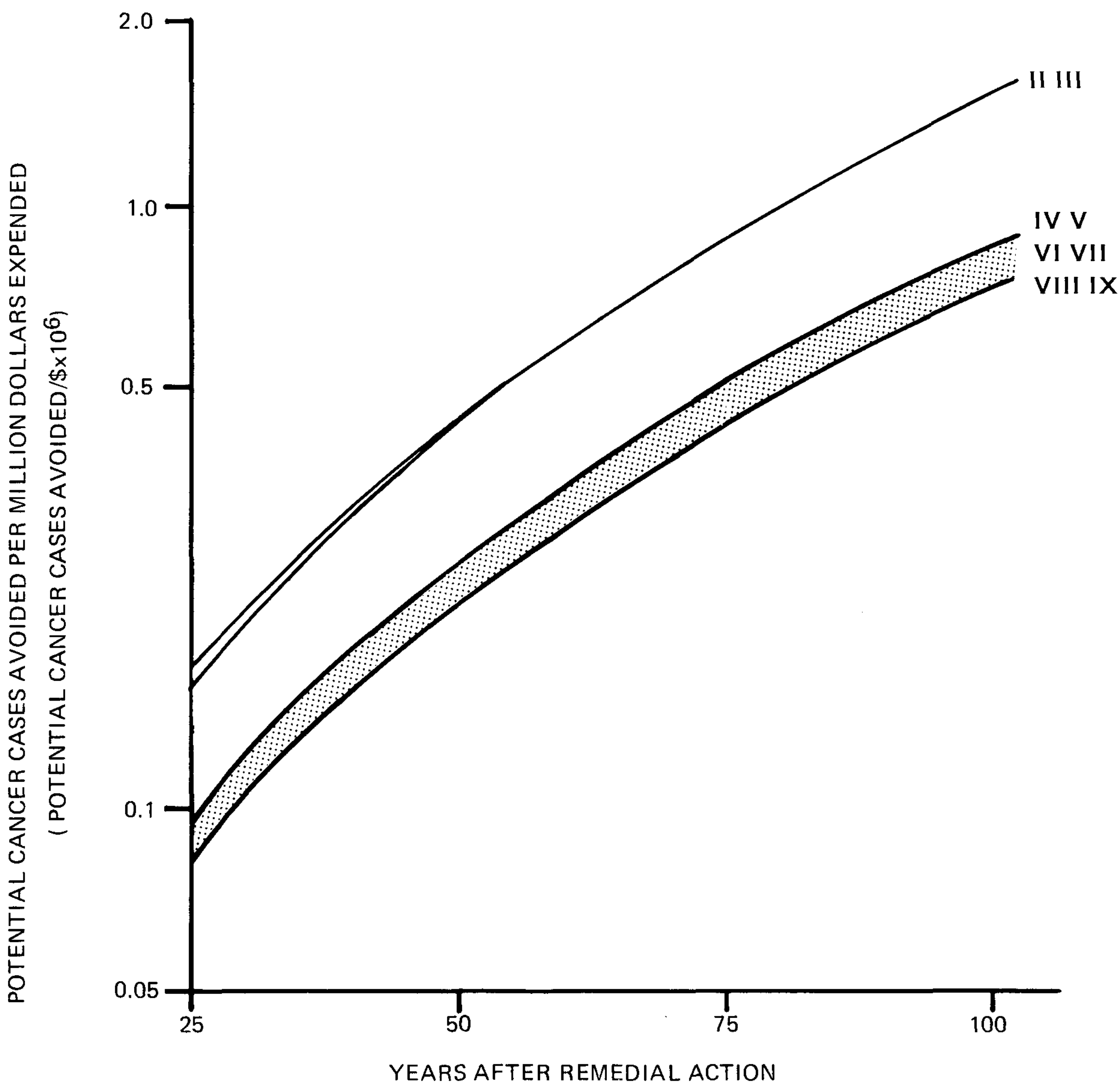

FIGURE 9-3. POTENTIAL CANCER CASES AVOIDED PER MILLION DOLLARS EXPENDED

130-12

TABLE 9-1

COST ESTIMATE SUMMARY[a]

GUNNISON OPTIONS

	TAILINGS REMAIN AT THE SITE			TAILINGS MOVED TO OTHER SITES					
COST OPTION NUMBER	I	II	III	IV	V	VI	VII	VIII	IX
DESCRIPTION	Decontamination	2-ft stabilization	13-ft stabilization	Tailings stored at South Gold Basin Area	Tailings stored at West Steers Gulch Area	Tailings stored at West Long Gulch Area	Tailings stored at Maggie Gulch Depression	Tailings stored at Maggie Gulch Peak Area	Tailings stored at North Sheep Gulch Area
				Site No. 1	Site No. 2	Site No. 3	Site No. 4	Site No. 5	Site No. 6
OPTION COSTS[b] includes removal of 3 ft of subsoil	480	850	2,730	5,009	5,200	5,309	5,470	5,733	5,890
REMOVAL COSTS:									
Option cost except for removal of 2 ft of contaminated subsoil				4,657	4,839	4,938	5,080	5,324	5,462
Option cost except for removal of 4 ft of contaminated subsoil				5,361	5,561	5,680	5,860	6,142	6,318
Option cost except for removal of 5 ft of contaminated subsoil				5,713	5,922	6,051	6,250	6,551	6,746
Option cost except for removal of 6 ft of contaminated subsoil				6,065	6,283	6,422	6,640	6,960	7,174

TABLE 9-1 (Cont)

COST OPTION NUMBER	I	II	III	IV	V	VI	VII	VIII	IX
REMOVAL PLUS BACKFILL COST:									
Option cost plus cost to backfill site to surrounding property surface				5,843	6,034	6,143	6,304	6,607	6,724
Option cost except for removal of 2 ft of subsoil and backfill to surrounding property surface				5,213	5,395	5,494	5,636	5,880	6,018
Option cost except for removal of 4 ft of subsoil and backfill				6,473	6,673	6,792	6,972	7,254	7,430
Option cost except for removal of 5 ft of subsoil and backfill				7,103	7,312	7,441	7,640	7,941	8,136
Option cost except for removal of 6 ft of subsoil and backfill				7,733	7,951	8,090	8,308	8,628	8,842

[a]All costs are total costs presented in 1977 thousands of dollars, and rounded to the nearest $100,000, and in Options IV through IX includes removal of all material from Gunnison including 3 ft of soil below interface with tailings.

[b]Costs used in cost-benefit analyses.

TABLE 9-2

POTENTIAL CANCER CASES AVOIDED AND COST PER POTENTIAL CANCER CASE AVOIDED

A. NUMBER OF POTENTIAL CANCER CASES AVOIDED

Options:	I	II	III	IV	V	VI	VII	VIII	IX
Option Costs (in million $)	0.48	0.85	2.73	5.01	5.2	5.31	5.47	5.73	5.89
Years After Remedial Action									
25	--	0.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5
50	--	0.4	1.2	1.3	1.3	1.3	1.3	1.3	1.3
75	--	0.8	2.4	2.6	2.6	2.6	2.6	2.6	2.6
100	--	1.4	4.5	4.7	4.7	4.7	4.7	4.7	4.7
Potential Cancer Cases After 100 yr	4.7	3.3	0.2	0	0	0	0	0	0

B. COST PER POTENTIAL CANCER CASE AVOIDED (Million $)

Options:	I	II	III	IV	V	VI	VII	VIII	IX
Option Costs (in million $)	0.48	0.85	2.73	5.01	5.2	5.31	5.47	5.73	5.89
Years After Remedial Action									
25	--	6.1	5.9	10.4	10.8	11.1	11.4	11.9	12.3
50	--	2.2	2.3	3.9	4.1	4.2	4.3	4.5	4.6
75	--	1.1	1.2	2.0	2.0	2.1	2.1	2.2	2.3
100	--	0.6	0.6	1.1	1.1	1.1	1.2	1.2	1.3

APPENDIX A

REMEDIAL ACTION CRITERIA

A.1 Surgeon General's Guidelines

A.2 Radiological Criteria for Decontamination of Inactive Uranium Mill Sites

A.3 Grand Junction Remedial Action Criteria (10CFR712)

APPENDIX A

REMEDIAL ACTION CRITERIA

The remedial action criteria used for the Phase II assessment of the cleanup of mill tailings are presented in the following documents:

A.1 SURGEON GENERAL'S GUIDELINES

DEPARTMENT OF HEALTH, EDUCATION AND WELFARE,
PUBLIC HEALTH SERVICE,
Washington, D. C., July 1970.

DR. R. L. CLEERE,
Executive Director, Colorado State Department of Health, 4210 E. 11th Avenue, Denver, Colorado

DEAR DR. CLEERE: I am pleased to respond to your letter of January 29 in which you asked Dr. M. W. Carter, Director of our Southwestern Radiological Health Laboratory, for Public Health Service and/or U. S. Atomic Energy Commission assistance in providing exposure guidelines applicable to homes with high concentrations of radon progeny.

The enclosed graded recommendations for action have been developed within the framework of existing Federal Radiation Council guidance for occupational exposure to airborne concentrations of radon and its daughters (progeny). Also, graded action levels applicable to external gamma radiation are included.

You will note in the accompanying Explanatory Notes that these recommendations apply specifically to dwellings constructed with or on uranium mill tailings. Further qualifications in the Explanatory Notes should be consulted before these recommendations are applied.

The specific information which your Department is developing on the variability of radon daughter concentrations in dwellings and on optimum control measures will be essential towards making those decisions necessary in applying the recommendations.

These recommendations have been directed to the Atomic Energy Commission for comment. Because of the urgency attached to your receiving the recommendations as soon as possible, they have been forwarded to you in advance of receiving AEC views and comments. We will advise you of the AEC response when received.

Sincerely yours,

PAUL J. PETERSON,
Acting Surgeon General

Enclosure:

RECOMMENDATIONS OF ACTION FOR RADIATION EXPOSURE LEVELS IN DWELLINGS CONSTRUCTED ON OR WITH URANIUM MILL TAILINGS

External gamma radiation:

Level:	Recommendations
Greater than 0.1 mR/hr . . .	Remedial action indicated.
From 0.05 to 0.1 mR/hr . . .	Remedial action may be suggested.
Less than 0.05 mR/hr . .	No action indicated.

Level:	Recommendations
Greater than 0.05 WL	Remedial action indicated.
From 0.01 to 0.05 WL	Remedial action may be suggested.
Less than 0.01 WL	No action indicated.

EXPLANATORY NOTES

1. These recommendations are written specifically for dwellings constructed on or with uranium mill tailings. This situation may involve continuous exposure of members of the public to radon daughter product activities and whole-body gamma irradiation levels in excess of the background radiation levels found within dwellings in the area not constructed with or on uranium mill tailings.

2. Although the initial concern was the presence of radon daughter product activities within these dwellings, preliminary surveys have indicated that in some instances, the gamma radiation levels were of prime importance. Thus, recommendations are made concerning both types of radiation. The recommendations applicable to a particular dwelling will be determined by whichever type of radiation has the high level.

3. Three levels for action are recommended for both external gamma and radon daughter product exposures. This graded system of actions is proposed to allow latitude in the middle ranges for the judgment of the on-site investigators.

4. The external gamma and radon daughter product levels proposed constitute exposures which are in addition to the natural background levels found within dwellings in the area not constructed on or with uranium mill tailings. In the Grand Junction, Colorado, area these levels are approximately 0.01 mR/hr (approximately 90 mrem/yr) and 0.004 Working Levels (WL) (approximately 0.2 CWLM/yr) respectively (1).

5. The expected health effects of concern will be different for the two types of radiation; i.e., leukemia for whole-body gamma radiation exposure and lung cancer for exposure to inhaled radon daughter products. This expectation is based, in part, on findings derived from population studies such as the Japanese atomic bomb

survivors and uranium miners. These specific health effects are considered to be mutually exclusive. The basis for this assumption is that the expected radiation contribution to whole-body exposure from inhaled radon and daughter products would be considerably less than the direct exposure from external gamma radiation at the levels encountered in the dwellings. Conversely, the external gamma radiation contribution to the lung dose is considered to comprise a negligible additional risk of lung cancer.

6. (a) A Working Level (WL) is the term used to describe radon daughter product activities in air. This term is defined as any combination of short-lived radon daughter products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy (2). The numerical value of the WL is derived from the alpha energy released by the total decay through Ra C' of the short-lived radon daughter products, Ra A, Ra B and Ra C, at radioactive equilibrium with 100 pCi of ^{222}Rn per liter of air (3).

6. (b) A Working Level Month (WLM) is the term used to express the occupational exposure incurred in one working month of 170 hours by a uranium miner laboring in an atmosphere containing radon daughter products; i.e., one working month in a mine atmosphere containing 1 WL of radon daughter products equals 1 WLM.

6. (c) Cumulative Working Level Months (CWLM) is the term used to express the total accumulated occupational exposure to radon daughter products in air; i.e., an air concentration of radon daughter products of 1 WL would, in one working month, equal 1 WLM, and in 1 year or 12 months would equal 12 CWLM.

6. (d) Since occupational exposures are based upon 170 hours per month and continuous exposure involves approximately 170 hours per week, then an occupational exposure to an air concentration of 1 WL is equivalent to continuous exposure to 0.025 WL.

7. These recommendations are based on the assumption of a linear, non-threshold dose-effect relationship. The lack of definitive information precludes allowances for possible differences in radio-sensitivity due to age, sex, or other biological characteristics.

8. No action is indicated when the external gamma exposure rate is less than 0.05 mR/hr and the radon daughter product activity is less than 0.01 WL since under conditions of continuous exposure these levels would result in maximum annual exposures of approximately 400 mrem and 0.5 CWLM, respectively. The maximum annual value of 400 mrem is less than the dose limits recommended for an individual body exposure to external gamma irradiation.

The ICRP (5) recommends that the annual dose limit for members of the public shall be 1/10 of the corresponding annual occupational maximum permissible dose. The maximum annual value of 0.5 CWLM of radon daughter product exposure is approximately 1/10 of the 4 CWLM annual occupational exposure limit recommended by the FRC (6) for implementation on 1 January 1971, and less than 1/20 of the annual occupational exposure limit of 12 CWLM recommended for uranium miners in the present FRC regulations (4).

9. Remedial action may be suggested in the case of external gamma exposure rates of 0.05-0.10 mR/hr or radon daughter product activities of 0.01-0.05 WL since under conditions of continuous exposure these levels would result in maximum annual exposures of approximately 400-900 mrem and 0.5-2.5 CWLM. The upper limit of these ranges exceeds the strictly applied recommendations of the FRC and ICRP for exposures of an individual member of the public. However, this extension seems justified in situations in which unforeseen exposures have occured, since as stated by ICRP (5) "in general it will be appropriate to institute countermeasures only when their social cost and risk will be less than those resulting from the exposure." It is further stated by the ICRP (5) that very low levels of risk are implied in the dose limits for members of the public and that it is likely to be of minor consequence to their health if the dose limits are marginally or even substantially exceeded.

10. Remedial action is indicated at gamma exposures greater than 0.1 mR/hr or at radon daughter product activities greater than 0.05 WL. Under conditions of continuous exposure, these levels would result in minimum annual exposures of 900 mrem and 2.5 CWLM. All values above these would indicate the necessity for remedial action, since at these levels the maximum annual exposures recommended by the FPC and ICRP for an individual member of the public is exceeded.

11. With respect to the external gamma irradiation, from the estimates published by ICRP (7), it can be interpolated that the annual risk of leukemia under conditions of continuous exposure to 500 mrem per year is an increased incidence of about 10 cases per year per million persons exposed. The natural annual incidence of leukemia for all ages is given by ICRP (8) as 10-100 cases per million persons. With respect to radon daughter product exposures, it has been estimated by Archer and Lundin (9) that an exposure of 120 CWLM to a group of white adult males in the United States appears to approximately double the normal lung cancer incidence which for this population is about 2-3 cases per year per 10,000 persons. At an annual exposure of 2.5 CWLM, 48 years would be required to reach 120 CWLM.

12. It is considered that implementation of these recommendations for the various exposure ranges would make it highly unlikely that any serious health effects would result from exposure to radon daughter products or external gamma irradiation in this particular situation.

13. It is suggested that remedial action be taken only after an adequate number of measurements taken under a diversity of temporal and climatic conditions have clearly established that the average exposure is in excess of 0.1 mR/hr or 0.05 WL exist and in instituting corrective measures. However, it is considered that the additional health risks from continued exposure over this time period are of lesser consequence than the economic and social discomfitures of precipitous action.

Approved.

/s/ PAUL J. PETERSON,
for Jesse L. Steinfeld, M.D.,
Surgeon General, Public Health Service

July 27, 1970

REFERENCES

1. Personal communication, Mr. Robert D. Siek, Colorado State Department of Health.

2. U.S. Public Health Service Publication No. 494, Control of Radon and Daughters in Uranium Mines and Calculations on Biologic Effects, 1957.

3. Federal Radiation Council Report No. 8 Revised, Guidance for the Control of Radiation Hazards in Uranium Mining, 1967.

4. Federal Radiation Council Report No. 1. Background Material for the Development of Radiation Protection Standards, 1960.

5. Recommendations of the International Commission on Radiological Protection, ICRP Publication 9, 1966.

6. Federal Register, Vol. 34, No. 10, pp 576-577, 1969.

7. The Evaluation of Risks from Radiation, ICRP Publication 8, 1966.

8. Radiosensitivity and Spatial Distribution of Dose, ICRP Publication 14, 1969.

9. V.E. Archer and F. E. Lundin, Jr., Radiogenic Lung Cancer in Man: Exposure-Effect Relationship, Environmental Research 1, pp 370-383, 1967.

A.2 RADIOLOGICAL CRITERIA FOR DECONTAMINATION OF INACTIVE URANIUM MILL SITES*

1. General

Radiological criteria for an engineering assessment of possible remedial actions applicable to uranium mill tailings piles and for the decontamination of inactive uranium mill sites are provided herein. These criteria are applicable to the sites, to their surrounding areas which have been contaminated by radioactive materials from the sites, and to buildings in which the materials have been used.

Critical radiation exposure pathways from inactive uranium mill sites to members of the general population are:

(a) Radon escaping from the tailings pile carried by the wind into habitable structures where the holdup time is long enough, resulting in buildup of radon daughters to levels greater than the ambient air.

(b) Tailings material used for construction of habitable structures can result in a buildup of radon daughters and increased gamma levels.

(c) Gamma rays from tailings material cause whole body radiation exposure. This includes not only the "gamma shine" from the tailings pile that exposes people living nearby, but also the radiation exposure from tailings material that has been eroded off the pile onto surrounding land. The mill sites always show elevated gamma exposure levels because of contamination by ore, tailings solids, and process solutions.

(d) ^{226}Ra, Th, and other radionuclides from tailings piles can be leached into ground water and thereafter into public and irrigation water supplies.

(e) Windblown particulate material (Ra and Th) from the tailings pile can be inhaled causing a radiation dose to the lung.

Remedial actions may be required on inactive uranium mill tailings piles to reduce or prevent excess radiation exposure from radon progeny, gamma radiation, ^{226}Ra, and radioactive particulate material. If tailing material has been used as a building material, remedial actions may be required to reduce radon concentrations and/or gamma activity levels. Remedial actions performed on tailings piles

*Provided by U S Environmental Protection Agency, as attachment to letter dated Dec 1974.

and decontamination of mill sites and surrounding contaminated areas should result in residual exposures that are as low as practicable. There is no single permissible exposure level applicable to all such cases. An evaluation should be made on a case-by-case basis of the risk involved, balanced against (1) the cost of reducing the residual contamination, and (2) the economic effect on alternatives such as restricting the use of the land. The result of such an analysis can be used by all concerned to define the "as low as practicable" residual level of contamination that will be acceptable and determine whether restrictions will be required on the use of any contaminated land.

2. Tailings Pile or Pond

The operation of uranium mills results in the generation of waste material which is disposed of in tailings piles and ponds. Environmental contamination has occurred at those sites where measures were not taken to control the movement of the radioactive material. In order to restore the environmental quality and provide for protection of the public, such sites should be decontaminated and result in residual gamma radiation levels which are as low as practicable. For most situations this would require decontamination of the area by (1) removal of radioactive material to a location where the material would be isolated from the biosphere, or (2) providing sufficient cover such that the resultant gamma radiation levels are as low as practicable, preferably at background. However, under certain topographical conditions and economic considerations wherein complete removal is not practicable, the residual levels should not exceed 40 μR/hr above background. This value is arbitrarily chosen for the purpose of providing an engineering estimate on cleanup of contaminated areas. It is considered to be sufficiently low that the expected exposures occurring after any remedial action at this level would not constitute a public concern. However, this should not be considered as the final criterion.* The gamma radiation level is the net, corrected measurement at 3 ft above the ground.

For each site a determination should be made of the radium concentration in the soil. Cleanup should reduce the soil concentration to less than two times the radium background specific for the area.

If the radioactive material remains in place and stabilized, the area should be designated as a controlled area. Due to the difficulty of controlling radon diffusion and the existing state-of-the-art of stabilization, the land should be restricted as to human occupancy and be properly fenced to limit access.

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*When all phase II information is complete and the health impact of remedial actions identified an overall determination of as low as practicable protection levels can be assessed appropriately. Therefore, the above numbers are subject to change.

The ^{226}Ra activity contribution from the site in ground or surface water should meet applicable state or federal standards.

3. Open Land Areas

This area refers to all land beyond the fence of the sites where tailings are located. As with the tailings areas, decontamination of the uranium mill site and other areas contaminated by wind- or water-eroded tailings should result in residual gamma levels which are as low as practicable. Cleanup of the area would require returning of the windblown tailings material to the site and establishing a controlled area, or moving all the material to a location that will isolate the material from the biosphere.

If the residual gamma levels are less than 10μR/hr above background, the land may be released for unrestricted use. If residual levels are equal to or greater than 10μR/hr above background at a given site a determination should be made of the radium concentration in the soil. Cleanup should reduce the soil concentration to no more than two times the radium background specific for the area. Under certain topographical conditions wherein complete removal of tailings is not possible or practicable, the residual levels should be as low as practicable but should not exceed 40μR/hr above background and access should be controlled. This value is arbitrarily chosen for the purpose of providing an engineering estimate on cleanup of contaminated areas. The gamma radiation level is the net, corrected measurement at 3 ft above the ground.

4. Structures

It is possible that there will be several industrial and residential structures where tailings have been utilized for construction purposes. When it has been determined that tailings were used in the construction, the lower limits of the guidelines established by the Surgeon General for structures in Grand Junction, Colorado, will be used.

A.3 GRAND JUNCTION REMEDIAL ACTION CRITERIA (10CFR712)

PART 712—GRAND JUNCTION REMEDIAL ACTION CRITERIA

AUTHORITY: Sec. 203, 86 Stat. 226.

§ 712.1 Purpose.

(a) The regulations in this part establish the criteria for determination by ERDA of the need for, priority of and selection of appropriate remedial action to limit the exposure of individuals in the area of Grand Junction, Colo., to radiation emanating from uranium mill tailing which have been used as a construction-related material.

(b) The regulations in this part are issued pursuant to Pub. L. 92–314 (86 Stat. 222) of June 16, 1972.

§ 712.2 Scope.

The regulations in this part apply to all structures in the area of Grand Junction, Colo., under or adjacent to which uranium mill tailings have been used as a construction-related material between January 1, 1951, and June 16, 1972, inclusive.

§ 712.3 Definitions.

As used in this part:

(a) "Administrator" means the Administrator of Energy Research and Development or his duly authorized representative.

(b) "Area of Grand Junction, Colo.," means Mesa County, Colo.

(c) "Background" means radiation arising from cosmic rays and radioactive material other than uranium mill tailings.

(d) "ERDA" means the U.S. Energy Research and Development Administration or any duly authorized representative thereof.

(e) "Construction-related material" means any material used in the construction of a structure.

(f) "External gamma radiation level" means the average gamma radiation exposure rate for the habitable area of a structure as measured near floor level.

(g) "Indoor radon daughter concentration level" means that concentration of radon daughters determined by: (1) Averaging the results of 6 air samples each of at least 100 hours duration, and taken at a minimum of 4-week intervals throughout the year in a habitable area of a structure, or (2) utilizing some other procedure approved by the Commission.

(h) "Milliroentgen (mR) means a unit equal to one-thousandth (1/1000) of a roentgen which roentgen is defined as an exposure dose of X or gamma radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign.

(i) "Radiation" means the electromagnetic energy (gamma) and the particulate radiation (alpha and beta) which emanate from the radioactive de- 56778
cay of radium and its daughter products.

(j) "Radon daughters" means the consecutive decay products of radon-222. Generally, these include Radium A (polonium-218), Radium B (lead-281), Radium C (bismuth-214), and Radium C' (polonium-214).

(k) "Remedial action" means any action taken with a reasonable expectation of reducing the radiation exposure resulting from uranium mill tailings which have been used as construction-related material in and around structures in the area of Grand Junction, Colo.

(l) "Surgeon General's guidelines" means radiation guidelines related to uranium mill tailings prepared and released by the Office of the U.S. Surgeon General, Department of Health, Education and Welfare on July 27, 1970.

(m) "Uranium mill tailings" means tailings from a uranium milling operation involved in the Federal uranium procurement program.

(n) "Working Level" (WL) means any combination of short-lived radon daughter products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

§ 712.4 Interpretations.

Except as specifically authorized by the Administrator in writing, no interpretation of the meaning of the regulations in this part by an officer or employee of ERDA other than a written interpretation by the General Counsel will be recognized to be binding upon ERDA.

(b) Where ERDA approved data on indoor radon daughter concentration levels are not available:

(1) For dwellings and schoolrooms:

(i) An external gamma radiation level of 0.05 mR/hr. or greater above background.

(ii) An indoor radon daughter concentration level of 0.01 WL or greater above background (presumed).

(A) It may be presumed that if the external gamma radiation level is equal to or exceeds 0.02 mR/hr. above background, the indoor radon daughter concentration level equals or exceeds 0.01 WL above background.

(B) It should be presumed that if the external gamma radiation level is less than 0.001 mR/hr. above background, the indoor radon daughter concentration level is less than 0.01 WL above background, and no possible need for remedial action exists.

(C) If the external gamma radiation level is equal to or greater than 0.001 mR/hr. above background but is less than 0.02 mR/hr. above background, measurements will be required to ascertain the indoor radon daughter concentration level.

(2) For other structures: (i) An external gamma radiation level of 0.15 mR/hr. above background averaged on a room-by-room basis.

(ii) No presumptions shall be made on the external gamma radiation level/indoor radon daughter concentration level relationship. Decisions will be made in individual cases based upon the results of actual measurements.

§ 712.8 Determination of possible need for remedial action where criteria have not been met.

The possible need for remedial action may be determined where the criteria in § 712.7 have not been met if various other factors are present. Such factors include, but are not necessarily limited to, size of the affected area, distribution of radiation levels in the affected area, amount of tailings, age of individuals occupying affected area, occupancy time, and use of the affected area.

§ 712.5 Communications.

Except where otherwise specified in this part, all communications concerning the regulations in this part should be addressed to the Director, Division of Safety, Standards, and Compliance, U.S. Energy Research and Development Administration, Washington, D.C. 20545.

§ 712.6 General radiation exposure level criteria for remedial action.

The basis for undertaking remedial action shall be the applicable guidelines published by the Surgeon General of the United States. These guidelines recommend the following graded action levels for remedial action in terms of external gamma radiation level (EGR) and indoor radon daughter concentration level (RDC) above background found within dwellings constructed on or with uranium mill tailings:

EGR	RDC	Recommendation
Greater than 0.1 mR/hr.	Greater than 0.05 WL.	Remedial action indicated.
From 0.05 to 0.1 mR/hr.	From 0.01 to 0.05 WL.	Remedial action may be suggested.
Less than 0.05 mR/hr.	Less than 0.01 WL.	No remedial action indicated.

§ 712.7 Criteria for determination of possible need for remedial action.

Once it is determined that a possible need for remedial action exists, the record owner of a structure shall be notified of that structure's eligibility for an engineering assessment to confirm the need for remedial action and to ascertain the most appropriate remedial measure, if any. A determination of possible need will be made if as a result of the presence of uranium mill tailings under or adjacent to the structure, one of the following criteria is met:

(a) Where ERDA approved data on indoor radon daughter concentration levels are available:

(1) For dwellings and schoolrooms: An indoor radon daughter concentration level of 0.01 WL or greater above background.

(2) For other structures: An indoor radon daughter concentration level of 0.03 WL or greater above background.

§ 712.9 Factors to be considered in determination of order of priority for remedial action.

In determining the order of priority for execution of remedial action, consideration shall be given, but not necessarily limited to, the following factors:

(a) Classification of structure. Dwellings and schools shall be considered first.

(b) Availability of data. Those structures for which data on indoor radon daughter concentration levels and/or external gamma radiation levels are available when the program starts and which meet the criteria in § 712.7 will be considered first.

(c) Order of application. Insofar as feasible remedial action will be taken in the order in which the application is received.

(d) Magnitude of radiation level. In general, those structures with the highest radiation levels will be given primary consideration.

(e) Geographical location of structures. A group of structures located in the same immediate geographical vicinity may be given priority consideration particularly where they involve similar remedial efforts.

(f) Availability of structures. An attempt will be made to schedule remedial action during those periods when remedial action can be taken with minimum interference.

(g) Climatic conditions. Climatic conditions or other seasonal considerations may affect the scheduling or certain remedial measures.

§ 712.10 Selection of appropriate remedial action.

(a) Tailings will be removed from those structures where the appropriately averaged external gamma radiation level is equal to or greater than 0.05 mR/hr. above background in the case of dwellings and schools and 0.15 mH/hr. above background in the case of other structures.

(b) Where the criterion in paragraph (a) of this section is not met, other remedial action techniques, including but not limited to sealants, ventilation, and shielding may be considered in addition to that of tailings removal. ERDA shall select the remedial action technique or combination of techniques, which it determines to be the most appropriate under the circumstances.

APPENDIX B

RULES AND REGULATIONS PERTAINING TO RADIATION CONTROL; THE STATE OF COLORADO

B.1 Part VIII - Regulation Requiring Stabilization of Uranium and Thorium Mill Tailings Piles

APPENDIX B

RULES AND REGULATIONS PERTAINING TO RADIATION CONTROL

B.1 PART VIII - REGULATION REQUIRING STABILIZATION OF URANIUM AND THORIUM MILL TAILING PILES (Radiation Regulation No. 2)

RH 8.1 All uranium and thorium mill tailing piles and ponds from inactive mills shall be stabilized in the following manner:

8.1.1 Ponds shall be drained and covered with materials that prevent blowing of dust. Water drained from the ponds shall be disposed of in a manner approved by the Water Pollution Control Commission.

8.1.2 Taking into consideration the types of materials at each site, piles shall be leveled and graded so that there is, insofar as possible, a gradual slope to ensure that there shall be no low places on the pile where water might collect. Side slopes shall be stabilized by riprap, dikes, reduction of grades, vegetation, or any other method or combination of methods that will ensure stabilization.

8.1.3 If pile edges are adjacent to a river, creek, gulch or other watercourse that might reasonably be expected to erode the edges during periods of high water, the exposed slopes shall be stabilized and the edges shall be diked and riprapped sufficiently to prevent erosion of the pile.

8.1.4 Drainage ditches shall be provided around the pile edges sufficent to prevent surface runoff water from neighboring land from reaching and eroding the pile.

8.1.5 The pile shall be stabilized against wind and water erosion. The method of stabilization may consist of vegetation or a cover of soil, soil containing rock or stone, rock or stone, cement or concrete products, petroleum products, or any other soil stabilization material presently recognized or which may be recognized in the future, or any combination of the foregoing as may be required for proper protection from wind, or water erosion.

8.1.6 Access to the stabilized pile area shall be controlled by the operator or owner and properly posted.

8.1.7 The pile shall be maintained in such a manner that excessive erosion of, or environmental hazard from radioactive materials does not occur.

8.1.8 The owner of the tailing pile site shall give the Colorado Department of Health written notice ten (10) days in advance of any contemplated transfer of right, title or interest in the site by deed, lease, or other conveyance. The written notice shall contain the name and address of the proposed purchaser or transferee. Prior written approval of the Department shall be obtained before the surface area of the land shall be put to use and it shall have been determined that the radiation dosage to the public resulting from the proposed use does not exceed 0.5 rem per year.

8.1.9 With the exception of use at a mill or for reprocessing at the site or another location, prior written approval of the Colorado Department of Health must be obtained before any tailings material is removed from any active or inactive mill.

8.1.10 Detailed plans for stabilizing tailings piles shall be submitted to the Colorado Department of Health for review and approval prior to undertaking stabilization of the pile.

8.1.11 The State Board of Health may waive individual requirements in regard to stabilization or utilization of tailings material if it can be shown that they are unnecessary or impracticable in specific cases.

8.1.12 The effective date of this regulation shall be 45 days after the date of adoption.

Adopted: December 12, 1966

APPENDIX B

RULES AND REGULATIONS PERTAINING TO RADIATION CONTROL

B.1 **PART VIII - REGULATION REQUIRING STABILIZATION OF URANIUM AND THORIUM MILL TAILING PILES (Radiation Regulation No. 2)**

RH 8.1 All uranium and thorium mill tailing piles and ponds from inactive mills shall be stabilized in the following manner:

8.1.1 Ponds shall be drained and covered with materials that prevent blowing of dust. Water drained from the ponds shall be disposed of in a manner approved by the Water Pollution Control Commission.

8.1.2 Taking into consideration the types of materials at each site, piles shall be leveled and graded so that there is, insofar as possible, a gradual slope to ensure that there shall be no low places on the pile where water might collect. Side slopes shall be stabilized by riprap, dikes, reduction of grades, vegetation, or any other method or combination of methods that will ensure stabilization.

8.1.3 If pile edges are adjacent to a river, creek, gulch or other watercourse that might reasonably be expected to erode the edges during periods of high water, the exposed slopes shall be stabilized and the edges shall be diked and riprapped sufficiently to prevent erosion of the pile.

8.1.4 Drainage ditches shall be provided around the pile edges sufficent to prevent surface runoff water from neighboring land from reaching and eroding the pile.

8.1.5 The pile shall be stabilized against wind and water erosion. The method of stabilization may consist of vegetation or a cover of soil, soil containing rock or stone, rock or stone, cement or concrete products, petroleum products, or any other soil stabilization material presently recognized or which may be recognized in the future, or any combination of the foregoing as may be required for proper protection from wind, or water erosion.

8.1.6 Access to the stabilized pile area shall be controlled by the operator or owner and properly posted.

8.1.7 The pile shall be maintained in such a manner that excessive erosion of, or environmental hazard from radioactive materials does not occur.

8.1.8 The owner of the tailing pile site shall give the Colorado Department of Health written notice ten (10) days in advance of any contemplated transfer of right, title or interest in the site by deed, lease, or other conveyance. The written notice shall contain the name and address of the proposed purchaser or transferee. Prior written approval of the Department shall be obtained before the surface area of the land shall be put to use and it shall have been determined that the radiation dosage to the public resulting from the proposed use does not exceed 0.5 rem per year.

8.1.9 **With the exception of use at a mill or for reprocessing at the site or another location, prior written approval of the Colorado Department of Health must be obtained before any tailings material is removed from any active or inactive mill.**

8.1.10 **Detailed plans for stabilizing tailings piles shall be submitted to the Colorado Department of Health for review and approval prior to undertaking stabilization of the pile.**

8.1.11 The State Board of Health may waive individual requirements in regard to stabilization or utilization of tailings material if it can be shown that they are unnecessary or impracticable in specific cases.

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