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**PHASE II - TITLE I ENGINEERING ASSESSMENT
OF INACTIVE URANIUM MILL TAILINGS
RIVERTON SITE, RIVERTON, WYOMING**

DECEMBER 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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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, Riverton Site, Riverton, Wyoming"; 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 mill sites 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 data that may alter or have an impact on a final remedial action decision for any site are required, they 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 of 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 Grand Junction, CO offices and also the Union Carbide Corporation personnel of the Health Physics Division, Oak Ridge National Laboratory, who provided field radiological measurements and radio-metric analyses of samples. The preparation of this report could not have been accomplished without the cooperation and assistance of the following:

- (1) The Environmental Protection Agency; for consultation, data, and information from prior surveys and studies with notable assistance from the Office of Radiation Programs, Las Vegas, Nevada
- (2) State of Wyoming; Mr. Edd Johnson, Chief, Radiological Health Services
- (3) Wind River Indian Reservation; Mr. John Meyers, Sanitarian, Indian Health Service; Fort Washakie, Riverton, Wyoming
- (4) Solution Engineering, Inc.; Mr. Tom Fife; Alice, Texas
- (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 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 the Riverton, Wyoming site. The Phase II - Title I services include: the performance of core drillings; soil, water and other sample analyses; radiometric measurements to determine areas with radium-contaminated materials; the evaluation of resulting radiation exposures of individuals and nearby populations; the investigation of site geology, hydrology, and meteorology; and the evaluation and costing of alternative corrective actions.

Radon gas release from the 900,000 tons of tailings at the Riverton site constitutes the main environmental impact. The two alternative actions presented are fencing and maintenance of the site and off-site remedial action (Option I); and, in addition to the items in Option I, decontamination of the millsite and ore storage areas and additional stabilization cover to a minimum of 2 ft (Option II). The cost estimates for the options are \$460,000 and \$1,140,000, respectively.

Estimated costs for moving the tailings and all contaminated materials to unspecified sites 5 and 10 mi from the present location are \$6,000,000 and \$6,400,000, respectively.

Reprocessing the tailings for uranium is not 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°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 3.7×10^{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 7.4×10^8 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.
μ R/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

CHAPTER 1

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 Riverton 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

(1) See end of chapter for references.

- (d) Hydrology and contamination by water pathways
- (e) Potential health impact
- (f) Potential for extraction of additional uranium from the tailings

Investigation of these and other factors led to the detailed evaluation of two potential practical alternatives:

- (a) Minimum remedial action, which amounts to fencing, maintenance, and off-site remedial action
- (b) Increase stabilization cover to 2-ft thickness, maintenance, fencing, and off-site remedial action

Costs were estimated for moving the tailings and all contaminated materials 5 and 10 mi from the present site for long-term storage.

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 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

*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.

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. Field work on the Riverton site was performed from July 27 through July 29, 1976. Radon measurements were made from Oct 14 through Oct 18, 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 Riverton 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 maintenance 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 radio-isotopes 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 Riverton millsite and tailings pile are located 2 mi southwest of Riverton in Fremont County, Wyoming, and approximately 120 mi southeast of Teton National Park. It is in the Wind River Valley at an elevation of 4,950 ft above sea level on the Wind River Indian Reservation. The land around the site is mainly flat and gently sloping ranch land. The site and its relationship to the surrounding area are shown in the aerial photo in Figure 2-1, Chapter 2.

1.2.2 Ownership and History of Milling Operations and Processing

Although the site is on the Wind River Indian Reservation, the millsite has been deeded to others. Susquehanna-Western, Inc., originally known as Fremont Minerals, Inc., was the operational owner of the site beginning in 1958. Solution Engineering Company of Alice, Texas is the current owner of the site. From 1958 until it shut down in 1963, the plant processed approximately 900,000 tons of ore from surrounding areas. Both acid and carbonate circuits were used in the mill processing to provide flexibility in treating the many varieties of ore received. A sulfuric acid plant was a part of the original mill and is still in operation under lease by Western Nuclear Company.

1.2.3 Present Conditions of the Site

Figure 2-3, Chapter 2, is a descriptive map of a portion of the site as it now exists. Most of the mill equipment and some of the structures have been removed, including portions of the main mill building. The steel water tower remains and serves the sulfuric acid plant which is still in operation.

The 900,000 tons of tailings occupy a rectangular-shaped area of approximately 72 acres to an average depth of 7.5 ft. They have been stabilized against wind and water erosion by a 1.5 ft cover of pit-run sand and gravel. The surface of the pile slopes to the east, as does the natural slope of the ground. The site including the tailings are fenced with a barbed-wire fence. Figure 2-4, Chapter 2, is a typical cross-section through the pile.

1.2.4 Tailings and Soil Characteristics

The tailings consist of coarse and finely ground sand and slimes. The alluvial material under the tailings is composed of soil, gravel, and cobbles.

1.2.5 Geology, Hydrology, and Meteorology

The Riverton tailings pile is located on approximately 15 to 25 ft of soil and coarse-grained alluvium of the Wind River flood plain, underlain by approximately 2,000 ft of sedimentary Wind River Formation bedrock. The formation consists of an inter-bedded sequence of lenticular fine- to coarse-ground sandstones, siltstones, and shales with lesser amounts of bentonite, tuff, and limestone. These sedimentary beds are nearly horizontal below the site. A simplified well log at the site is shown in Figure 2-5, Chapter 2.

There are flowing surface waters within 0.5 mi in all directions from the pile. The Little Wind River flows northeastward 0.5 mi southeast of the pile. The Wind River flows to the east 1 mi north of the site. Numerous irrigation ditches flow near the site and empty into marshy areas east and southwest of the site. Because of the extensive flood plain, slightly elevated location of the pile, and protection from highway roadgrades, flood waters of the Wind River and Little Wind River cannot reach the tailings pile, although flood waters could rise within the base of the tailings. Overland flow on the pile is limited to the precipitation that actually falls on the site. A ditch and berm protect the pile from off-site runoff onto the site and trap overland runoff from the pile on site. Contamination of surface waters near the site is unlikely to occur from physical transport because the tailings are protected by a soil cover and the ditch and berm trap runoff. Contamination of surface waters near the site could occur by seepage from the pile from waters leaching through the pile and by unconfined ground waters rising within the tailings which later discharge into surface waters.

The confined ground waters in the Wind River Formation occur under very shallow as well as deeper artesian conditions. The shales act as confining layers to water in lenticular sandstone horizons, but the entire sequence behaves somewhat as a single aquifer. Intensive development of the area's ground water, including wells on the millsite, has affected water levels, flow gradients, and artesian pressures in the immediate vicinity of the city of Riverton. The ground water flow gradient is toward the Riverton well field, which is at a considerably greater depth than the potentially affected waters at the site. Recharge to the confined ground water system occurs by the flow of water across permeable bedrock. The tailings site is an area of potential recharge to the underlying aquifers of the Wind River Formation. Ground water from various horizons within this formation are used for domestic water supplies without treatment over much of the rural area. The city's well field consists of 15 wells 500 to 800 ft deep. This supply is barely adequate to supply peak daily pumping requirements during summer months.

The unconfined ground waters consist of waters within terrace deposits, within river alluvium, and waters within the shallow bedrock of the Wind River Formation. These sources are hydraulically interconnected and act as a single system. Due to natural topography and return irrigation flows, much of the area is waterlogged and evaporation results in salt deposits in the soils. The water table at the site is usually less than 6 ft below the original land surface and unconfined ground waters rise within the base of the tailings. Thus, there is a potential for contamination of the unconfined ground water, of the surface waters into which it discharges, and of the unconfined ground water system which is recharged in the area. Unconfined ground waters are not used for domestic water supplies in the Riverton area because of the insufficient quantity or poor chemical quality of the water, but the surface waters are used for irrigation and watering of stock.

The tailings are protected from winds and water erosion by soil and vegetative cover. High-intensity winds and storms are known in the area and limited water erosion of some of the finer cover material is evident on the steeper western boundary of the pile. Coarser material has not been affected.

The climate in the Riverton area is semiarid with an annual precipitation of 10 in./yr. Winds in the area tend to be in an east-west direction. Weather data were recorded at the Riverton airport.

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 the 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 pile. 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 pile.
- (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. No quantitative evaluation of this pathway was performed.
- (d) Ingestion of ground and surface waters contaminated with radioactive elements (primarily ^{226}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 6 locations in the vicinity of the Riverton tailings pile. The locations and values of the radon measurements, including background, are shown in Figure 3-3, Chapter 3. Two measurements of atmospheric radon indicated an average background concentration of 1.1 pCi/l for the Riverton area.

1.3.1.2 Direct Gamma Radiation

The range of natural background values in the Riverton area

was between 9 and 13 $\mu\text{R/hr}$, averaging 11 $\mu\text{R/hr}$ as measured with an energy-compensated Geiger Mueller detector.⁽²⁾ Above the surface of the tailings pile, gamma radiation rates were measured as high as 84 $\mu\text{R/hr}$. At the former ore stockpile area, gamma radiation reached a maximum of 280 $\mu\text{R/hr}$.

1.3.1.3 Windblown Contaminants

Background gamma radiation rates were reached within 0.2 mi to the south, east, and west of the pile and within 0.3 mi north of the pile. The results of the EPA gamma radiation survey around the tailings pile are shown in Figure 3-9, Chapter 3.

1.3.1.4 Ground and Surface Water Contamination

The Little Wind River flows within 0.5 mi south of the River-ton tailings pile and the Wind River flows within 1 mi north of the pile. Eight surface and ground water samples were taken from the vicinity of the tailings pile. The dissolved ^{226}Ra concentrations for the samples ranged from 0.12 to 0.68 pCi/l.⁽²⁾ Four samples were taken from a stream that flows by the southwest corner of the pile. No significant increase in the ^{226}Ra content of the stream was found as it flowed by the tailings. While radium from the tailings may be entering surrounding ground and surface waters, the level of contamination is considerably below the EPA Interim Drinking Water Regulations for radium, and is not a radium health hazard.

1.3.1.5 Soil Contamination

The leaching of radium into the subsoil beneath the tailings extends from 2 to 5 ft below the tailings-subsoil interface, averaging 3 ft, before reaching the average background level of radium concentration in local soil samples (1.1 pCi/g).

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:

<u>EGR</u>	<u>RDC^a</u>	<u>RecommendaTions</u>
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

^aBased on yearly average values from 6 air samples of at least 100-hr duration taken at a minimum of 4-wk intervals throughout the year

^bmR/hr = milliroentgen per hour, a measure of gamma radiation;
1 mR/hr = 1,000 μ R/hr

^cWL = 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 μ R/hr above background is used in such circumstances. Average background in the Riverton area was determined in this study to be 11 μ R/hr. As a guideline for the land beyond the site, if residual gamma levels are less than 10 μ R/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 waters should meet applicable state and federal standards.

1.3.3 Potential Health Impacts

Radon gas exhalation from the piles and the subsequent inhalation of radon daughters account for most of the total dose to the population from the Riverton site under present conditions. The gamma radiation exposure from the piles is essentially zero since

there are very few persons who live or work within 0.3 mi of the piles 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 piles. 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 Riverton 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. The end results of long-term exposure to low-level radiation is increased susceptibility to diseases such as lung cancer or leukemia, which also are attributable to many other causes. Thus, 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, and 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 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 a best estimate curve 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 3 mi from the Riverton site is 6.0×10^{-6} per person per year, or less than 3% of the average risk due to all causes for Wyoming residents (2.1×10^{-4}).⁽⁶⁾

The 25-yr health effects were calculated for three population projections using a present population of 9,359 assumed to be concentrated at 2.0 mi from the edge of the pile. The health effects from pile-induced Rn and background Rn were as follows:

25-yr Cumulative Effect Within 3 Mi From Edge of Pile

<u>Growth Rate</u>	<u>Pile-Induced RDC</u>	<u>Background RDC</u>
Static	1.4	13
Constant 4.0% growth rate	2.4	21
4% decreasing growth rate ^a	2.1	20

^aThe growth rate is constant for 10 yr, then decreases linearly to 0% at 25 yr.

Pile-induced radon daughter health effects were approximately 11% 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 samples from auger holes in the Riverton tailings pile showed barium and chromium in concentrations between 20 and 70 ppm. The highest selenium concentration was about 400

ppm and the arsenic concentration ranged as high as 170 ppm. Cadmium was present in concentrations less than 0.5 ppm in the tailings.

Eight surface and ground water samples were taken from the vicinity of the Riverton tailings pile and chemically analyzed. The locations of these samples are shown in Figure 3-10, and the analyses of these samples are presented in Table 3-5, Chapter 3. All of the water samples, both upstream and downstream from the tailings pile, contained selenium above the EPA Interim Drinking Water Standard. In addition, four samples contained cadmium in concentrations above the acceptable drinking water level. The low level of cadmium in the tailings and the fact that high cadmium content was found in waters upstream as well as downstream from the tailings indicate that the tailings were not a major source of cadmium contamination. Selenium contamination in the water was found both upstream and downstream from the tailings; however, the much higher level of selenium in the ground water immediately around the tailings suggests that this higher level of contamination is due to the tailings.

1.4 SOCIOECONOMIC AND LAND USE IMPACTS

The Riverton site is located in an unincorporated rural area surrounded by the Wind River Indian Reservation. There are a number of houses and trailer houses dispersed throughout the area near the many roads that lead to the city of Riverton or to principal highways. South of the site is a school and its associated community, St. Stephens, and on the millsite itself is an operating sulfuric acid plant. The neighboring land is mainly farms and ranches.

Most of the land in the vicinity is owned by the Shoshone Tribe or by individual Indians. Even when individuals desire to sell land in the reservation, the tribe has the right of first refusal. Land use and land values are in large part controlled by the tribe and council and their extensive ownership tends to increase pressure to develop inholdings of nonreservation land for homesites and for industrial growth.

The presence of the tailings has not affected land uses in the area or land values. Land is worth approximately \$1,000 to \$2,000/acre. Continued industrial and residential growth in the area will continue to put pressure on the site and its immediate environs to shift from farmland to residential or industrial land.

1.5 RECOVERY OF RESIDUAL VALUES

Estimates of the uranium content of the Riverton tailings by the AEC indicate an average U_3O_8 concentration of 0.015% for the tailings.

There are five factors that should be employed to evaluate whether reprocessing the Riverton 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 Riverton tailings is not a practical economic consideration at this time, and would not be practical until the market value of U_3O_8 reaches \$92/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.

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 Riverton, Wyoming area prior to 1972. A subsequent field survey identified 14 off-site locations where tailings use was suspected or confirmed. The cost of remedial action for these locations has been estimated to be \$65,000. Cleanup of the wind-blown tailings surrounding the pile has been estimated to cost a total of \$180,000. The total remedial action cost for off-site structures and for decontamination of off-pile open lands has been estimated to be \$245,000, exclusive of engineering costs and contingency. The locations 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.

1.8 LONG-TERM STORAGE SITE SELECTION

The Riverton site was not included in Phase I; hence, it was not included in the sites for which the moving option was to be considered. However, because of the relative magnitude of the potential health effects, removal options have been provided, and costs have been estimated for removal to distances of 5 and 10 mi.

1.9 REMEDIAL ACTIONS AND COST-BENEFIT ANALYSES

1.9.1 Remedial Action Options

Two remedial actions for the site include security fencing, a maintenance and monitoring program which would include the monitoring of nearby wells and surface waters, and off-site remedial action. Option I would provide fencing around the tailings and around the old mill and ore storage areas, but would take no action on the site in the way of cleanup or decontamination. Rubble and contaminated materials from off-site cleanup activities would be deposited on the surface of the tailings pile and stabilized with 1.5 ft of the same type of material as used in the original stabilization efforts. The cost of this option is \$460,000.

Option II accomplishes the same off-site work as Option I, but provides for demolishing and burying in the tailings all of the on-site contaminated structures, including contaminated portions of the old mill buildings. Also, adjacent areas contaminated by windblown tailings would be cleaned up, as would the old ore storage areas and soil beneath the mill building. All this material would be placed on the pile, over the debris. This area would then be covered with 2 ft of stabilization material and the balance of the pile with another 0.5 ft so that the entire pile would have a 2-ft stabilization cover. The estimated cost of this option is \$1,140,000, which also includes a perpetual care fund and security fencing (for the tailings only).

Although specific long-term storage sites have not been identified, the costs for relocating the tailings and contaminated material to sites at distances of 5 and 10 mi from the present location have been estimated as \$6,000,000 and \$6,400,000, respectively. These costs include preparation at the new site, remedial action, engineering, EIS, contingency, and perpetual care costs.

1.9.2 Cost-Benefit Analyses

As summarized in Table 1-2, the total costs for the remedial actions vary from \$460,000 to \$6,400,000. Each of these costs would yield a distinct health benefit. The number of potential cancer cases avoided per million dollars expended for each remedial action is given in Figure 9-1, Chapter 9. The curves indicate an increase in the benefit/cost ratio with time due to the increasing number of health effects avoided. The potential cancer

cases avoided for each remedial action and the cost per potential cancer case avoided are given in Table 9-2, Chapter 9. The removal alternatives have the largest health benefit/cost ratios because the health effects are eliminated by removing the radiation source.

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- 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>ARIZONA</u>										
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
<u>COLORADO</u>										
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
<u>IDAHO</u>										
Lowman	U	R	N	No	Yes	Yes	No	No	Yes	No
<u>NEW MEXICO</u>										
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
<u>OREGON</u>										
Lakeview	U	M-UO	N	Yes	No	Yes	Yes	No	No	No
<u>TEXAS</u>										
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.

^aThis table does not necessarily represent conditions at the present time.

TABLE 1-2

SUMMARY OF REMEDIAL ACTION OPTIONS AND EFFECTS

Option Number	Cost ¹ (\$000)	Description of Remedial Action	Benefits	Adverse Effects
I	460	Fencing, maintenance, and remedial action at off-site locations	A,H	W,X,Y
II	1,140	Off- and on-site decontamination, stabilization increased to 2 ft, fencing, and maintenance	A,B,C,D, F,H	W,Z
Removal	6,000 to 6,400	Relocate tailings and contaminated materials to a long-term storage site 5 or 10 mi from the present site, and remedial action at off-site locations	A,B,E,G, H	W

Definition of Benefits

- A. Better security provided for tailings
- B. Better control of wind and water erosion
- C. Further reduction in radon exhalation to 30% of bare tailings flux
- D. Reduction of gamma radiation on tailings to background
- E. Radon source removed
- F. Site available for limited use except tailings area
- G. Entire site available for unrestricted use
- H. Off-site locations decontaminated

Definition of Adverse Effects

- W. Some security and maintenance required
- X. Site unavailable for any use
- Y. No reduction in health effects
- Z. Little reduction in health effects

Notes

¹Costs are in 1977-value dollars

CHAPTER 1 REFERENCES

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CHAPTER 2
SITE DESCRIPTION

CHAPTER 2

SITE DESCRIPTION

The purpose of this chapter is to describe the site at Riverton, Wyoming, and the characteristics of the tailings materials present on the site.

2.1 LOCATION

The Riverton millsite and tailings pile are approximately 2 mi southwest of Riverton, Fremont County, Wyoming. The site, shown in Figure 2-1, is in west central Wyoming, about 120 mi southeast of Teton National Park. More specifically, the site is in Sections 9 and 4, Township 1 South, Range 4 East, Wind River Meridian, at 42 deg 29 min 30 sec north latitude, and 108 deg 24 min 30 sec west longitude. The site is located on the Wind River Indian Reservation.

2.2 TOPOGRAPHY

The tailings site is located in the near-bottom or lowest and flattest part of the Wind River Valley at the point where the Wind River turns from its southeast direction to a nearly north direction. The Wind River Range with peaks up to 13,000 ft is on the southwest side of the valley and the Owl Creek Range with peaks over 12,000 ft is on the northeast. The site is about 0.5 mi north of the Little Wind River and 1 mi south of the Wind River. These rivers join about 4 mi east of the site. The elevation of the site is 4,950 ft above sea level. The area surrounding the site is irrigated ranch land. Figure 2-2 is a topographic map of the site.

2.3 OWNERSHIP

Although the site is on the Wind River Indian Reservation, the millsite has been deeded to others. The operational owner of the site was Susquehanna-Western, Inc. The site currently is owned by the Solution Engineering Company of Alice, Texas.

2.4 HISTORY OF MILLING OPERATIONS AND PROCESSING⁽¹⁾

This mill was built during 1958 and operated initially by Fremont Minerals, Inc. to treat a variety of ores from the surrounding area on a custom basis. Both acid and carbonate circuits were included in the mill processes to provide flexibility for the many types of ore received. The total mill capacity was initially 500 tons of ore per day. The milling company's name was subsequently changed to Susquehanna-Western, Inc. By 1960, the

⁽¹⁾ See end of chapter for references.

mill capacity was between 450 and 500 tons/day in the acid circuit and from 250 to 300 tons/day in the carbonate circuit. Operations continued until about mid-1963 when the mill was shut down. A sulfuric acid plant, rated at 100 tons/day using sulfur made from sour gas, was included in the mill facilities.

Amenability tests were conducted on samples of ore shipped to the mill to establish the choice between either the alkaline or the acid process. The acid process was generally favored for ore containing less than 6% lime. Crushing, sampling, and ore storage facilities were common to both processes.

The acid circuit included leaching in mechanically agitated tanks followed by recovery of the pregnant solution in a four-stage liquid-solid separation circuit. Both cyclones and thickeners were used in this circuit in a parallel arrangement which routed sands through the cyclones and slimes through the thickeners. Clarified solutions were then fed to a solvent extraction circuit using an amine-decanol-kerosene extractant subsequently stripped with carbonate solution. The latter was a portion of the clarified pregnant solution diverted from the carbonate-process operations, with the final pregnant strip solution then being recombined with the rest of the carbonate circuit pregnant solution before precipitation.

Air-agitated Pachuca tanks were used for leaching in the carbonate circuit, with the pregnant solutions then recovered from the leached residues in a three-stage filter circuit. The uranium was precipitated by caustic soda addition, the resultant barren solutions being recarbonated and recirculated.

2.5 PRESENT CONDITION OF THE SITE

Figure 2-3 is a descriptive map of a portion of the site as it now exists. The original mill equipment, some of the old mill structures and most of the old main mill building remain. The 125,000-gal metal water tower is intact. At the far west side of the mill area an active sulfuric acid plant is in operation and is leased by Western Nuclear Company. The site is fenced with a barbed-wire fence but cattle and horses still graze on the pile.

The approximately 900,000 tons of tailings occupy about 72 acres in a rectangular-shaped pile which slopes to the east. The slope difference along the top of the pile is about 18 ft. The pile is raised above the natural surface of the ground. The ground at the base of the pile has been graded to divert surface water around and away from the pile. The tailings have been stabilized with an earth cover, averaging 18 in. in thickness. The average thickness of the pile, including stabilization, is 7.5 ft. The cover is a well graded mixture of river-run aggregate with a maximum sized rock of about 6 in. Natural vegetation (weeds) has established itself in the material and provides about 20% cover. No irrigation has been utilized. The stabilization appears to have been very effective in preventing erosion by wind

or water. Figure 2-4 is a cross-section through the tailings pile.

2.6 TAILINGS AND SOIL CHARACTERISTICS

The tailings consist of coarse and finely ground sands and slimes. The alluvium beneath the pile is composed of soil, gravel, and cobbles.

2.7 GEOLOGY, HYDROLOGY, AND METEOROLOGY

2.7.1 Geology

The Riverton site is located on the flood plain of the Wind River. Terrace deposits do not underlie the site but are exposed at higher elevations nearby. Riverbed materials under the site consist of a few feet of soil and approximately 15 ft of coarse alluvial material which in turn is underlain by the Wind River Formation. The Wind River Formation of Eocene age underlies all of the Riverton area to a probable depth of at least 2,000 ft and a maximum depth of 5,000 ft. The formation consists of an interbedded sequence of lenticular fine-to-coarse grained sandstones, siltstones, and shales with lesser amounts of bentonite, tuff, and limestone. These sedimentary beds are nearly horizontal below the site. A simplified stratigraphic log of the strata immediately underlying the site is shown in Figure 2-5.

2.7.2 Surface Water Hydrology

There are flowing surface waters near the pile in all directions. The surface drainage around the site is shown in Figure 2-6. The Little Wind River flows northeastward 0.5 mi southeast of the site. The Wind River flows to the east 1 mi north of the site. A lined drainage canal runs south to the northeast corner of the site and then turns east and flows into a nearby marshy area east of the site; an irrigation ditch runs south toward the center of the northern boundary of the site and then turns east, and a ditch runs through the field adjacent to the western boundary of the pile and into a marshy area south of the site. Because of the extensive flood plain and the slightly elevated location of the pile, and protection from nearby highway road grades, flood waters of the Wind River or Little Wind River would not reach the tailings. There is no evidence of flood water erosion from surface waters at or near the site.

Overland flow on the pile is limited to the precipitation that actually falls on the pile. A graded ditched area and berm at the perimeter of the site act as a barrier to off-site overland flow from the site, and the soil cover protects the tailings from erosion. Contamination of surface waters near the site is unlikely to occur by seepage from the pile from precipitation percolating through the pile but contamination could occur from waters leaching the pile when unconfined ground waters rise and fall within the tailings and later discharge into nearby surface waters. Surface waters are not used for municipal and domestic water sup-

plies because the ground water is of far superior quality. However, surface waters near the site are used for irrigation and for stock watering.

2.7.3 Ground Water Hydrology

Ground water occurs under unconfined and confined conditions in the Riverton area. Confined ground waters within the Wind River Formation exist under very shallow as well as deeper artesian conditions. The shales of the formation act as confining layers to the upward and downward migration of water, and the sandstone lenses are the primary aquifers. Because the strata are lenticular, interfinger, and vary in thickness there is some migration from one horizon to another. Thus although individual layers yield water, the entire sequence behaves somewhat like a single aquifer. Intensive development of the area's ground water has affected the hydraulic pressure particularly near the city of Riverton where water levels in observation wells have dropped 60 to 70 ft in the last 50 yr. The lowered aquifer pressures within the well field at Riverton have altered the regional flow pattern to divert water from all sides toward the field. At the site, before intensive development of the area's wells, virtually all wells within the Wind River Formation would have been flowing artesian wells. Development of the wells at the mill affected flow directions in the vicinity and at least one well was reported to have gone dry. Figure 2-7 shows some of the registered wells near the site, but this list is incomplete because many of the wells are not registered.

Recharge to the confined ground water system occurs by infiltration into bedrock of waters from streams crossing outcrops, percolation through saturated overlying alluvium into outcrops, infiltration of direct precipitation onto outcrops, irrigation return flow and canal seepage into outcrops, and the transmission of water in some confined aquifers into other lenses. Thus, the tailings site is in an area of potential recharge to the underlying aquifers of the Wind River Formation.

Ground water from the Wind River Formation is used for domestic supplies without treatment in much of the rural area. In the urbanized area virtually all ground water development is in the city well field of 15 wells 500 to 800 ft deep. A major problem facing the city is the present difficulty in meeting peak daily pumping requirements in July and August and alternate water sources are being developed. General confined ground water flow directions at the site would trend northeast toward the city's well field.

The unconfined ground waters in the Riverton area consist of waters within the terrace deposits, within the river alluvium, and waters within shallow bedrock of the Wind River Formation. These sources are hydraulically interconnected and act as a single system. Due to the natural topography and the return irrigation flows, much of the area is waterlogged. Evaporation of the shal-

low ground water results in salt deposits in the soils. Such deposits can be seen in the fields near the site. The water table is shallow and at the site is usually less than 6 ft below the original land surface. The unconfined ground waters rise within the base of the pile. Thus, there is a potential of contamination to the unconfined ground water system, to the surface waters into which it discharges, and to the confined ground water system recharged in the area. The ground water gradient is approximately parallel to that of the land surface which trends northeast toward the junction of the two rivers. Unconfined ground waters are not used for municipal or domestic water supplies in the Riverton area because of insufficient quantity or poor chemical quality.

2.7.4 Meteorology

The climate at Riverton is semiarid to arid and is characterized by great deviations from normal precipitation. During the past 29 yr the annual precipitation measured at Riverton has ranged from 6.05 to 18.43 in. and has averaged 9.62 in. Most of this precipitation falls during April through June. High-intensity rainfall such as thunderstorms can be expected and have caused limited erosion of the soil material on the tailings. Snowmelt is not of major concern because it generally does not result in rapid runoff and consequent erosion.

Weather data for Riverton have been gathered at the airport northwest of town. Although the airport is on higher ground close to the mountains, the weather data should apply at the site. A wind rose is presented in Figure 2-8. The wind records indicate a predominance of winds in the east-west directions.

FIGURE 2-1. AERIAL PHOTOGRAPH OF SITE

MILLSITE

WATER TOWER

NOTE
MAP DEVELOPED FROM FB&DU
SURVEY DATA LOGGED
JULY 27, 1976

LEGEND
□ EDGE OF TAILINGS

0 500 FT
CONTOUR INTERVAL 2 FT

FIGURE 2-2. TOPOGRAPHIC MAP

FIGURE 2-3. DESCRIPTIVE MAP

FIGURE 2-4. CROSS-SECTION AT STATION 15+00

FIGURE 2-5. SIMPLIFIED LOG OF WELL AT THE SITE

130-16

FIGURE 2-6. SURFACE DRAINAGE

130 16

Location in Town-
ship 1 South
Range 4 East

	Name	Static Water Level*	Total Depth	Flow in gpm**
SE SE Section 4	Mayland #1	SWL 150 ft	265 ft	A 3
SW SW Section 4	Western Nuclear #2	SWL 26	60 ft	P 100
SE SW Section 4	Fremont Minerals #1	MWBZ 385	450 ft	A 100 P 550
NE NE Section 9	Westlake #1	MWBZ 250	267 ft	A 8
NW NW Section 9	Fremont Minerals #1	MWBZ 44 SW 6	63 ft	P 100
NW NW Section 2	KWRL well	MWBZ 185-205 SWL+11	205 ft	A 12
NW NW Section 2	Riverton Auction	SWL 30	45 ft	P 20
NW SW Section 2	Elwood #1	SWL 9	63 ft	
NE SW Section 4	Lucas #1	SWL 10	25 ft	P 6
NW SE Section 4	Raymond #2	MWBZ 300 SWL 15	320 ft	P 15
NE SW Section 4	Bunnies #1	SWL 20	400 ft	P 10
NE NW Section 3	Island #1	SWL 70	160 ft	P 15
NE NW Section 2	Moss #1	SWL 25 ft	160 ft	P 10
SE SE Section 2	Wicker #1	SWL 30	160 ft	P 10
SE SE Section 2	Guthrie #1	SWL 15	50 ft(?)	P 25
NE NW Section 4	Willis #1	completed 12/28/76	200 ft(?)	
NE NW Section 2	Pearl #2		160 ft	
SE SE Section 4	Weber #1		350 ft	
NE NW Section 2	Lumms #1	MWBZ 130-180 SWL 40	180 ft	P 15
NE NW Section 2	Wacks #1	SWL 40	165 ft	P 12
NE NW Section 2	Lye #1		170 ft(?)	
NE NW Section 2	Mahafley #1	MWBZ 145-168 SWL 63	170 ft	P 20
NE NW Section 2	Pebbles #1		160 ft(?)	
NE NW Section 2	Petty #1	SWL 42	170 ft	P 25
NW NW Section 2	Gaines #1		75 ft	

* SWL = Static water level

MWBZ = Main water-bearing zone

** A = Artesian flow

P = Pumped well

FIGURE 2-7. REGISTERED WELLS NEAR RIVERTON, WYOMING

FIGURE 2-8. RIVERTON, WYOMING SURFACE WIND ROSE
(CUMULATIVE DATE FROM 1967 TO 1972)

130-16

CHAPTER 2 REFERENCES

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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 Riverton uranium tailings pile and the resulting potential exposure to the population residing and working in the vicinity of Riverton, Wyoming. In addition, this chapter describes briefly the potential radioactive and chemical pollutants and their pathways in the environment. The radiological 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 Riverton, 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 11 off-site soil samples for each member of the uranium decay chain, assuming equilibrium, was 1.1 pCi/g.⁽¹⁾ The sample locations taken within a 150-mi radius of Riverton 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 1.4×10^{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 1.2 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 3.

Background values of radon concentrations were measured at two locations using continuous radon monitors supplied by ERDA.⁽²⁾ An average outdoor value of 1.1 pCi/l was obtained from the samples for the Riverton area.

Background gamma ray levels, as measured 3 ft above the ground, also were determined at several locations to 0.4 mi from the site by using a calibrated and energy-compensated Geiger Mueller detector. A value of 11 $\mu\text{R/hr}$ was established as the average background level, but the values ranged from 9 to 13 $\mu\text{R/hr}$.⁽¹⁾ Cosmic rays are part of the measured background radiation levels. The contribution from cosmic rays is generally dependent upon the altitude and is approximately 6 $\mu\text{R/hr}$ in the Riverton area,⁽³⁾ or approximately 55% 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:

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

⁽¹⁾ See end of chapter for references.

- (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. No quantitative evaluation of this pathway was performed.
- (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

Field measurements of the radon exhalation flux from the tailings using the charcoal canister technique⁽⁴⁾ are listed in Table 3-3. The current values range from 51 to 81 pCi/m²-s on the tailings pile. Radon flux depends principally on radium content of tailings. In general, reported values of radon flux vary considerably from time to time at a single sampling location due in part to differing moisture, soil, and climatological factors, to major changes in pile configuration, and to the difficulty of performing such measurements.

Radon gas above background, considered to be from the pile, was detected at distances up to 2 mi from the site. The locations and corresponding average radon concentrations measured during this program with the continuous radon monitors are shown in Figure 3-3. The background radon concentration ranged from 0.8 to 1.3 pCi/l, with an average of 1.1 pCi/l.

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 on the tailings pile. Figure 3-5 illustrates the measurements 0.5 mi northeast of the tailings pile. A diurnal variation of ^{222}Rn concentration is evident in both figures. 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 the radon flux and the total radon release from the pile with diffusion theory using radium soil concentrations, and pile configurations deduced from the drilling and survey data. Then the radon transport off-pile is calculated by Gaussian diffusion⁽⁵⁾ plus wind drift conditions. Meteorology for Riverton, Wyoming during a 4-yr period (1967-1972) was used. The measured values are somewhat higher than the model results; however, the effects of localized anomalies are not considered.

From the data and model curves a best estimate curve of radon concentration-versus-distance was formulated for Riverton. This best estimate curve also is shown in Figure 3-6. The best estimate curve was used to calculate potential health effects resulting from radon diffusing from the Riverton 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 were taken with calibrated, energy-compensated Geiger Mueller detectors.⁽¹⁾ The highest gamma radiation rate (84 $\mu\text{R/hr}$) was measured toward the center of the eastern half of the tailings pile. Gamma measurements on the pile ranged between 2 and 7 times background. In the former mill and ore storage areas, gamma radiation rates were measured from 2 times background to 280 $\mu\text{R/hr}$ east of the former mill building.

Gamma rate measurements away from the tailings pile, taken at 100-yd intervals, reached background levels at less than 0.2 mi to the west, south, and east of the pile. Towards the north, the gamma radiation rate reached 1.5 times the background rate at 0.27 mi. These gamma radiation rate measurements away from the pile are also shown in Figure 3-7. The reduction of gamma

radiation as a function of distance from the pile is shown in Figure 3-8.

3.4.3 Windblown Contaminants

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

Figure 3-9 shows iso-exposure lines due to the residual windblown tailings as determined by EPA.⁽⁶⁾ If scattered tailings and ore are removed from inside the 10 μ R/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 μ R/hr.

Surface soil samples were taken in the area surrounding the tailings.⁽¹⁾ The sample locations and ^{226}Ra concentrations are shown in Figure 3-10. Radium concentration in soil samples decreased to about 3 times background 200 yd east and 200 yd west of the pile, although an anomalously high concentration was found in a sample 600 yd to the west. To the south, radium concentration was almost 4 times background at 400 yd. At a point 600 yd north of the pile, radium concentration was 6 times background. In general, these high levels are attributable to windblown tailings.

No air particulate measurements were performed at the Riverton site.

3.4.4 Ground and Surface Water Contamination

Eight surface and ground water samples were taken from the vicinity of the Riverton tailings pile and analyzed for ^{226}Ra as shown in Figure 3-10.⁽¹⁾ Four samples were taken from a stream that flows by the southwest corner of the pile from the northwest. Two samples taken upstream from the pile contained 0.206 and 0.141 pCi/l of ^{226}Ra while the two samples taken downstream from the pile contained 0.155 and 0.239 pCi/l of ^{226}Ra , showing no significant increase in the ^{226}Ra content. However, samples taken from a ditch that flows along the north edge of the tailings pile indicated an increase in ^{226}Ra content from 0.144 to 0.404 pCi/l in water nearer the pile. Two samples of ground water obtained from wells northwest and southwest of the pile contained ^{226}Ra at 0.675 and 0.115 pCi/l, respectively. The northwest well, 300 ft deep, was on the former millsite and supplied water for the mill.

Previously, water samples were collected from 12 private wells and at the St. Stephens school in the vicinity of the site.⁽⁶⁾ These wells averaged 250 ft in depth with a maximum depth of 300 ft. A background well water sample was also collected. All samples contained less than 1 pCi/l of ^{226}Ra .

The ground upon which the tailings pile is located is alluvium and the water table may rise into the tailings. At the time these measurements were made the water table was below the tailings-soil interface; however, there is a potential for unconfined ground water to leach the tailings.

While radium from the tailings may be entering surrounding ground and surface water, the level of contamination is considerably below the EPA Interim Drinking Water Regulations for radium contamination and is not a radium health hazard.

3.4.5 Soil Contamination

The amount of ^{226}Ra activity in the tailings and the extent of leaching of radium from the tailings into the soil were determined by drilling auger holes in and around the tailings pile and into the soil beneath it. The radioactivity profile was measured in these holes with a Geiger tube probe in a lead shield that collimates the radiation. Soil samples also were taken from selected holes for radiometric analyses. The locations of the holes are shown in Figure 2-3, Chapter 2.

Typical ^{226}Ra activity profiles in the Riverton tailings and subsoil are shown in Figures 3-11 and 3-12. Figure 3-11 illustrates the ^{226}Ra profile at hole RW-3 located on the southeast quarter of the tailings pile. The profile was determined with the gamma probe and by analyses of samples taken from a nearby pit (test pit 1). Two test pits were dug with a backhoe to obtain samples for analyses in the eastern half of the tailings pile. The analyses of samples from test pit 1 and hole RW-3 indicated that radioactive contamination decreased to three times the average ^{226}Ra background concentration about 2.5 ft below the original surface. (1)

Figure 3-12 is the profile of radium activity at auger hole RW-4, at the northeast end of the pile. At that location, the ^{226}Ra analysis indicated background radium concentration about 1.5 ft below the tailings-subsoil interface. Soil contamination above twice average ^{226}Ra background concentration ranged from 1 to 4 ft beneath the tailings subsoil interface. Radium concentration in the tailings ranged up to 1,100 pCi/g in the auger holes as shown in Figures 3-11 and 3-12.

3.4.6 Off-Site Tailings Use

A mobile gamma survey located sites where the gamma radiation rate was above the background level. A follow-up survey was performed at these locations to determine the source of the radiation. The results of these surveys are discussed in Chapter 7.

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.

3.5 REMEDIAL ACTION CRITERIA

Radiological criteria established for this engineering assessment for possible remedial action applicable to uranium mill tailings are divided into two general categories: criteria applicable to structures with tailings underneath them or within 10 ft,⁽⁷⁾ and criteria pertaining to the mill tailings site and open land.⁽⁸⁾ Copies of the complete documents establishing these criteria are presented in Appendix A. Also given in Appendix A are the Grand Junction remedial action criteria for structures (10CFR712).

The criteria which apply to the structures are the guidelines published by the Surgeon General of the United States.⁽⁷⁾ These guidelines recommend the following graded levels for remedial action in terms of the EGR levels and indoor RDC levels above background found within the dwellings constructed on or near uranium mill tailings:

<u>EGR, mR/hr</u>	<u>RDC*, WL</u>	<u>Recommendation</u>
Greater than 0.1	Greater than 0.05	Remedial action indicated
From 0.05 to 0.1	From 0.01 to 0.05	Remedial action may be suggested
Less than 0.05	Less than 0.01	No remedial action indicated

*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 pile:

- (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 2 mi from the tailings pile.
- (b) External Gamma Radiation - gamma radiation above background is measurable to distances up to 0.3 mi from the pile, 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 0.3 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 is 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 Riverton 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, contamination from the tailings pile. However, the conditions at the site indicate a potential for contamination. Furthermore, on the basis of the EPA water sampling program, (6) none of their samples exceeded the

guidance established by EPA under the Safe Drinking Water Act.

- (e) Subsoil Contamination - leaching of radioactive materials into the ground beneath the pile and at the mill-site is on the order of 1 to 4 ft.
- (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 it constitutes the most significant pathway. (9-11) Furthermore, it is assumed that the uncertainty in the estimates of the potential health effects from these pathways 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 pCi/l of ^{222}Rn = 0.005 WL

It is assumed that the component of indoor radon concentra-

tion 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:

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

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 best-estimate curve of radon concentration-versus-distance (Figure 3-6) was used to determine the health effects due to radon from the Riverton 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 average annual radiation-induced lung cancer risk as a function of distance from the edge of the pile is given in Figure 3-13 for prolonged continuous exposure. The curves shown in the figure are the sum of the estimated annual radiation-induced risk from Riverton tailings plus the average lung cancer risk per year from all causes for residents of the State of Wyoming.⁽¹⁸⁾ It is noted that the risk for developing lung cancer is nearly double the natural occurrence risk toward the edge of the pile.

No health effects were attributed to gamma radiation from the pile, because gamma population exposures are negligible within 0.30 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 3.0 mi from the tailings pile perimeter are given in Table 3-4. The 1975 population of Riverton and the surrounding area is given in Chapter 4.

The health effect values are obtained by converting the appropriate radon concentrations in the Riverton 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 10% of background values.

If the relative risk estimator is used, the health effects estimates are correspondingly larger than the ones given in Table 3-4. The uncertainty in the health effects estimation is about a factor of 4. Also shown in Table 3-4 are cumulative values based on a static population and on two other growth rate projections. The health effects in Table 3-4 are considered in conjunction with remedial action costs in Chapter 9.

3.7 NONRADIOACTIVE POLLUTANTS

The tailings pile contains other potentially toxic materials. Chemical analyses of samples from auger holes in the Riverton tailings pile showed barium and chromium in concentrations between 20 and 70 ppm. The highest selenium concentration measured was about 400 ppm; and the arsenic ranged as high as 170 ppm. Vanadium was present in a range of concentrations from 30 to 240 ppm. Cadmium was present in less than 0.5 ppm in the tailings.

Eight water samples were taken from the vicinity of the Riverton tailings pile and chemically analyzed. The locations of these samples are shown in Figure 3-10. Four of these samples were obtained from a stream flowing past the southern corner of the tailings pile. Two samples were obtained from an irrigation ditch north of the pile, and the final two samples from wells in the vicinity of the tailings pile. The analyses of these samples are presented in Table 3-5.

All of the water samples taken from the vicinity of the Riverton tailings pile, both up and downstream from the pile, contained selenium above the EPA Interim Drinking Water Standard. The highest selenium content, which was 25 times the standard, was found in water taken from a well southeast of the pile. Four surface water samples also contained cadmium above the Interim Drinking Water Standard. The low level of cadmium in the tailings and the fact that high cadmium content was found in waters upstream as well as downstream from the tailings indicate that the tailings were not a major source of cadmium contamination. Similarly, selenium above acceptable drinking water levels was found in waters up and downstream from the tailings; however, the much higher level of selenium in the ground water immediately around the tailings would lead one to suspect this higher level of contamination is due to the tailings.

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

FIGURE 3-2. LOCATION FOR ^{226}Ra BACKGROUND SAMPLES

SITE NO.	24 HR INDOOR (pCi/l)	24 HOUR OUTDOOR (pCi/l)	AV. WIND DIRECTION	AV. WIND SPEED	LOCATION
1	—	6.2	NNW	6	ON PILE
2	—	3.3	NW	2	0.25 MI NE OF PILE
3	—	2.5	NW	2	0.5 MI NE OF PILE
4	—	5.0	NNW	12	2.0 MI S OF PILE
5	—	1.3 *	N	8	3.0 MI SW OF PILE
6	1.0	0.8 *	NW	3	4 MI N OF PILE

* LOCATION USED FOR BACKGROUND

NOTE:
MEASUREMENT LOCATION NO. 5 WAS OUT OF SERVICE BETWEEN 1400 AND 2300 HOURS AND NO. 6 BETWEEN 0900 AND 1600 HOURS

FIGURE 3-3. RADON CONCENTRATION IN VICINITY OF PILE

FIGURE 3-4. ^{222}Rn AND ATMOSPHERIC TRANSIENTS ON PILE ON OCTOBER 14, 1976

130-16

LEGEND

- FB&DU WEATHER DATA
- WIND DIRECTION (UP=NORTH, DOWN=SOUTH)

FIGURE 3-5. ^{222}Rn AND ATMOSPHERIC TRANSIENTS 0.5 MI NE OF PILE ON OCTOBER 15, 1976

130-16

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

130-16

- NOTES:
- 1. NUMBERS SHOWN ARE GROSS GAMMA LEVELS IN $\mu\text{R/hr}$
 - 2. DATA FROM REFERENCE 1

FIGURE 3-7. GAMMA LEVELS IN THE SITE VICINITY

FIGURE 3-8. REDUCTION OF EXTERNAL GAMMA RADIATION LEVELS WITH DISTANCE FROM THE TAILINGS PILE

130-16

NOTE:
REFERENCE DRAWING: RADIOLOGICAL
SURVEY AT THE INACTIVE URANIUM
MILLSITE; NEAR RIVERTON, WYOMING;
ORP/LV-77-2, USEPA, LAS VEGAS FACILITY;
JUNE 1977.

0 500 1000 1500 2000 FT

FIGURE 3-9. EPA GAMMA SURVEY SURROUNDING MILLSITE

FIGURE 3-10. SURFACE AND SUBSURFACE RADIUM CONCENTRATIONS

FIGURE 3-11. RADIOMETRIC PROFILE AT DRILL HOLE RW-3

130-16

FIGURE 3-12. RADIOMETRIC PROFILE AT DRILL HOLE RW-4 130-16

FIGURE 3-13 LUNG CANCER RISK FROM CONTINUOUS EXPOSURE TO RADON DIFFUSION

130-16

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 = 1.3×10^5 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 2.58×10^{-4} coul/kg air. This is equal to the energy deposition of 88 ergs/g of dry air or 93 ergs/g of tissue.
μ R/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 = 1.6×10^{-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 WYOMING

Isotope (Decay Chain)	Average Value (pCi/g)	Range (pCi/g)
^{226}Ra (^{238}U)	1.07 ± 0.32	0.65 - 1.7
^{232}Th (^{232}Th)	1.23 ± 0.52	0.59 - 1.78

TABLE 3-3

RADON EXHALATION FLUX FROM THE RIVERTON TAILINGS

<u>Sample</u>	<u>Location</u>	<u>Radon Flux (pCi/m²-sec)</u>
1 (SW-33)	Southwest corner of pile	51
2 (SE-29)	Southeast corner of pile	57
3 (NE-24)	Northeast corner of pile	72
4 (NW-14)	Northwest corner of pile	81

TABLE 3-4

ESTIMATED HEALTH IMPACT FROM RIVERTON TAILINGS
FOR AN AREA 0-3 MILES FROM TAILINGS EDGE

<u>Time Period</u>	<u>Population (Persons)</u>	<u>Total Pile-Induced RDC Health Effects/yr</u>	<u>Background RDC Health Effects/yr</u>
1975	10,000	0.06	0.5
2000 (4% constant growth rate	26,600	0.18	1.3
2000 (4% growth rate ^a)	19,500	0.12	1.0

25-Yr Cumulative Health Effect

<u>Population Growth</u>	<u>Pile-Induced RDC</u>	<u>Background RDC</u>
Static population	1.4	13.0
4% constant growth rate	2.4	21.0
4% growth rate ^a	2.1	20.0

^aThe growth rate is constant for 10 yr then decreases linearly to 0% at 25 yr.

TABLE 3-5

CHEMICAL ANALYSES OF RIVERTON WATER SAMPLES (mg/l)

<u>Sample^a</u>	<u>As</u>	<u>Ba</u>	<u>Cd</u>	<u>Cr</u>	<u>V</u>	<u>Fe</u>	<u>Pb</u>	<u>Se</u>
A - Stream NW of pile, up-stream from pile	0.013	0.19	<0.001	<0.001	0.030	0.990	<0.001	0.021
B - Stream NW of pile, up-stream from pile	0.010	0.14	0.017	<0.001	0.060	0.740	<0.001	0.024
C - Stream SW corner of pile	<0.001	0.34	<0.001	<0.001	<0.001	0.680	<0.001	0.026
D - Stream SW of pile, down-stream from pile at road bridge	0.022	0.50	0.028	<0.001	<0.001	4.900	<0.001	0.027
E - Irrigation ditch N of pile, standing water	<0.001	0.24	0.032	0.028	0.011	5.700	0.004	0.017
F - Irrigation ditch NE of pile, standing water	<0.001	0.20	0.037	0.021	0.040	4.800	<0.001	0.015
G - Well at Indian home SE of tailings pile	0.039	0.35	<0.001	<0.001	<0.001	1.620	<0.001	0.254
H - Well at millsite furnishes water for site	0.023	0.20	<0.001	<0.001	0.410	0.066	<0.001	0.089
EPA Interim Drinking Water Standards ^b	0.05	1.0	0.01	0.05	--	0.3 ^c	0.05	0.01

^aSee Figure 3-10 for locations^bFederal Register, Dec 24, 1975^cRecommended Limit from Manual for Evaluating Public Drinking Water Supplies, U.S. Public Health Service, 1969

CHAPTER 3 REFERENCES

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CHAPTER 4
SOCIOECONOMIC AND LAND USE IMPACTS

CHAPTER 4

SOCIOECONOMIC AND LAND USE IMPACTS

The uranium tailings site at Riverton, Wyoming is located approximately 2 mi southwest of the city in the southeastern section of the Wind River Indian Reservation. The county seat of Fremont County is in Lander, 24 mi southwest of Riverton. The tribal headquarters are in Fort Washakie, 24 mi west of Riverton. The political jurisdictions of Fremont County are shown in Figure 4-1.

4.1 SOCIOECONOMIC BACKGROUND

Land in the Riverton area was ceded by the Indians of the Shoshone Reservation to the United States Government in 1905, and the area was opened for settlement in 1906. The town became a ranching and farming community. More recently its economy has diversified from a rural base to an economic base that includes mining, education, services, crafts, government, manufacturing and agriculture.

The future demographic and economic conditions of Riverton can be projected by extrapolating statistical data obtained for the four census records of 1940 through 1970.⁽¹⁾ Riverton has experienced consistently high rates of population growth over the past 40 yr, exceeding the growth rates of the county and state at each census period. Its population has virtually quadrupled in 40 yr. During this time the percent of the male population has increased somewhat (to 49.6%) but still remains slightly less than for the county or state as a whole. The median age of city residents has declined consistently to 25.4 in 1970.

Ethnically, the population of Riverton is mostly Caucasian with a sizeable Indian and Spanish American component that has comprised between 12 and 16% of the total population of the last 40 yr. The high percentage of Indian residents is due to Riverton's location bounded by the Wind River Reservation which is the home of many Shoshone and Arapahoe Indians. Educational attainment and median income are relatively high and have approximately equaled or surpassed those of the state. Most workers now are employed as professionals, craftsmen, service providers, clerks, operators, or farmers. Farmers and farm laborers show a consistent decline in both real numbers and percent of the population. Mining has had a major impact upon the county's economy since the 1940's and manufacturing, government, education, and services have increased in importance. The work force is relatively evenly divided between these sectors of the economy.

⁽¹⁾ See end of chapter for references.

4.2 POPULATION ESTIMATES

The 1970 census figures show a population of 7,995 city residents and 28,352 county residents. The 1975 city population was estimated at 9,359 with an additional 640 people living in the area. A figure of 10,000 people therefore is used as the population base in the health effects assessment.⁽²⁾ (See Chapter 3.) The general population distribution of the county is shown in Figure 4-2.

Several factors must be considered in determining population projections and future growth patterns for Riverton. First, water available to support growth is limited. Second, there is a possibility for additional industrialization. However, distance from major markets, the relative isolation of the region, and competition from Rock Springs make large-scale industrialization unlikely. Third, any growth over a sustained period is dependent on policies that allow growth on the reservation and development of its resources. Fourth, growth has been sustained over a period of four decades and the potential for natural resources development and for development of Riverton as the center for providing goods and services to the area's mining, ranching, and Indian-related construction programs remains high.

Considering these factors, four annual rates of growth are projected for Riverton. The highest assumes a 9.0% annual growth rate. Such growth would occur with extensive mining and industrial development. The second rate is 4.0%, the rate of growth currently used by Riverton officials. The third rate employed is 3.11%, which is an alternative rate used by Riverton officials. The fourth rate is 1.7%, which assures a continuation of the 1960's growth rate. Population growth projections for constant growth rates are presented in Figure 4-3.

Assumptions of a steady rate of growth may be 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".

It appears that either the 4.0% declining or the 4.0% constant rates of population growth are most reasonable. These rates would result in 1.95 to 2.67 city residents in the year 2000 for every resident in Riverton in 1975, and between 1.95 and 7.11 residents in the year 2025 for every resident there in 1975.

4.3 LAND USE

The Riverton site is located in a rural area 2 mi southwest of the city in an unincorporated area surrounded by the Wind River Indian Reservation. Land use is typical of a rural fringe area relatively near a community center. There are a number of homes

and trailer houses dispersed throughout the area along roads connecting the area to principal highways and to the city of Riverton. Just south of the site is a religious school and an adjacent community, but most of the land is divided into farms and ranches as shown in Figure 4-4. The site itself is used as a sulfuric acid plant. Much of the nearby land is owned by the Shoshone Tribe or by individual Indians. Even when individuals desire to sell land on the reservation, the tribe has the right of first refusal. Thus, the tribe controls land use on the reservation. Present policy is to try to discourage individual development and encourage clustered development on the reservation. However, the extent of non-Indian holdings of land and of the privately owned land near Riverton encourages growth of homes, mobile homes, and pockets of industrial growth.

4.4 IMPACT OF THE TAILINGS ON LAND VALUES

The presence of the tailings has not changed land uses in the area. Although the land is fenced, it is still being used as pasture land. The millsite is used as a sulfuric acid plant. The industrial and residential growth in the area will continue to exert pressures on the site and its environs to shift from farmland to residential or industrial uses. The current value of the land near the site is difficult to determine because of the tribal ownership of much of the land. However, recent transactions in the valley indicate that land in the area is worth approximately \$1,000 to \$2,000/acre.⁽²⁾ The presence of the tailings has not affected land values.

FIGURE 4-1. MAP OF POLITICAL JURISDICTIONS

130-16

FIGURE 4-2. MAP OF POPULATION CENTERS

130-16

FIGURE 4-3. POPULATION PROJECTIONS

FIGURE 4-4. VICINITY LAND USE

130-16

CHAPTER 4 REFERENCES

1. J. L. England; "Baseline Data and Land Use Impact of the Riverton, Wyoming Uranium Tailings Site"; Center for Health and Environmental Studies, Brigham Young University; Provo, Utah; Jul 1977.
2. Office of the Mayor; Riverton, Wyoming; personal communication based on utility hookups; 1976.

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 Riverton tailings pile represent a future uranium resource?
- (b) Should the pile be reprocessed?
- (c) Is there any likelihood that once stabilized the pile would be disturbed again?

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 operations 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 dis-

(1) See end of chapter for references.

posalsite that can be readily stabilized and maintained, or must be adjacent to the tailings disposal site. A heap leach site of about 21 acres of relatively flat ground would be required if the 900,000 tons of Riverton tailings were to be leached and stabilized in place. The reprocessing site also would 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 50 and 100 mi from Riverton. All of these mills have capacities of 1,000 tons/day or more.

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) a conventional uranium mill would provide a higher recovery than 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 RIVERTON 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 Riverton tailings pile consists of 900,000 tons of tailings containing 0.015% 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 Riverton pile contains 270,000 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.

Ranges 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 RIVERTON MINERAL RECOVERY POTENTIAL

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

	<u>U_3O_8 Recover-</u>	<u>Operating</u>	<u>Construction</u>	<u>Total</u>	<u>Cost/lb</u>
	<u>able (lb)</u>	<u>Costs*(\$M)</u>	<u>Costs*(\$M)</u>	<u>Cost(\$M)</u>	<u>(\$)</u>
Heap Leach	59,000	3.2*	2.7*	5.9	100
Conven- tional	103,000	6.3*	4.7*	11.0	107
Haulage to Exist- ing Mill	103,000	5.0**	4.5***	9.5	92

* For a 500-ton/day facility

** For a 1,000-ton/day facility

***Transportation cost for 50 mi at \$0.10/ton-mi

From the economic evaluation of the reprocessing of the Riverton tailings it can be seen that none of the three proposed options are presently economically feasible. The lowest cost for reprocessing appears to be \$92/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 24 yr. However, the price of uranium is quite volatile and the costs calculated in this assessment possibly could be surpassed by the market price of uranium.

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

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)

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)

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)

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)

TABLE 5-1

ASSAY RESULTS OF RIVERTON TAILINGS AND BACKGROUND SAMPLES

Percentage by Weight

<u>Element</u>	<u>Atomic Absorption</u>	<u>Spectrographic</u>	<u>Chemical</u>	<u>AEC* Estimate</u>
Aluminum	--	>1.0	--	--
Arsenic	0.0161	--	--	--
Barium	0.0064	--	--	--
Boron	--	<0.01	--	--
Cadmium	0.000032	--	--	--
Calcium	--	>1.0	--	--
Chromium	0.0023	<0.01	--	--
Cobalt	0.00091	--	--	--
Copper	0.00211	<0.01	--	--
Cyanide	<0.000001	--	--	--
Gallium	--	--	--	--
Iron	2.18	>1.0	--	--
Lead	0.000324	<0.01	--	--
Magnesium	--	>1.0	--	--
Manganese	--	1.0 - 0.01	--	--
Mercury	<0.00000002	--	--	--
Molybdenum	--	<0.01	--	--
Nickel	--	<0.01	--	--
Potassium	--	>1.0	--	--
Selenium	0.0391	--	--	--
Silica	--	>1.0	--	--
Silver	0.000245	--	--	--
Sodium	--	>1.0	--	--
Titanium	--	1.0 - 0.01	--	--
Uranium (U ₃ O ₈)	--	--	0.007	0.015
Vanadium (V ₂ O ₅)	0.0031	<0.01	0.024	--
Zinc	0.00385	--	--	--

*Calculated tails assay based on plant operation⁽¹⁾

CHAPTER 5 REFERENCES

1. ERDA-GJO, private communications.
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 Riverton 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.

⁽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 Riverton, precipitation averages about 10 in. annually.

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 Riverton tailings is likely to constitute a problem. The techniques which could be employed to control leaching from 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 μ R/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 6-1. REDUCTION OF RADON EXHALATION FLUX WITH DEPTH OF COVER

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

130-16

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; University 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 of 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 off site where tailings are located and, based upon the Surgeon General's guidelines and on criteria established for this assessment, to estimate the cost 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 inter-agency agreement with the EPA, performed a gamma radiation survey of the Riverton, Wyoming area prior to 1972. Of the 2,573 locations scanned, 87 anomalies were reported. A joint team from the EPA Office of Radiation Programs, Las Vegas, Nevada (EPA-ORP-LV) and from the Wyoming Department of Health and Social Services performed individual gamma surveys of locations where anomalies were reported 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 outside gamma readings inside the structures exceeded 20 μ R/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 14 off-site locations with possible tailings use. At five of these locations, listed as tailings used or otherwise deposited within 10 ft of habitable structures, the tailings were windblown from the pile. Of the remaining nine locations, two were vacant lots, two were uranium base camps, and five were possible tailings use locations.

Of the remaining anomalies, 15 were caused by the presence of radioactive material in instruments or in ore, 33 resulted from natural radioactive materials, and 23 could not be verified as anomalies above background.

⁽¹⁾ See end of chapter for references.

An additional contaminated off-site structure was identified during the present investigation. The lumberyard in Riverton, a former AEC ore-buying depot, was found to have localized contamination to a depth of about 1 ft. The cost of cleanup of this contamination has been included in the cost of remedial action for off-site structures and is estimated to be \$1,000.

The cost for remedial action at off-site structures has been estimated at \$65,000, 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 locations 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 3-9, 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 gamma radiation of no more than 10 μ R/hr. All areas would be decontaminated by moving an average of 6 in. of soil, gravel roads, etc. to the pile. After decontamination, the affected areas would be restored with additional clean material and removed vegetation would be reestablished. All structures would be decontaminated by either wet or dry vacuum procedures.

The estimated cost for the cleanup of off-pile open land areas contaminated with windblown tailings is \$180,000, 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 Wyoming at Riverton, Wyoming"; 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

The Riverton site was not included in Phase I; hence, it was not included in the sites for which the moving option was to be considered. However, because of the relative magnitude of the potential health effects, removal options have been provided and costs have been estimated for removal to distances of 5 and 10 mi.

CHAPTER 9

REMEDIAL ACTIONS AND COST-BENEFIT ANALYSES

CHAPTER 9

REMEDIAL ACTIONS AND COST-BENEFIT ANALYSES

Various remedial actions for the tailings pile were investigated. The alternatives presented are those considered to be the most realistic and practical when evaluated in regard to present technology, equipment, existing site conditions, and proximity of the pile to existing and potential human occupancy. Remedial measures for the site can be separated into two options:

- (a) No action on the tailings, but provision for maintenance, better security, and off-site remedial actions.
- (b) In addition to (a), the site would be decontaminated and an additional 0.5 ft of stabilization cover placed on the tailings.

Costs were estimated also for relocating tailings and contaminated material to an unspecified long-term storage location.

Several of the remedial measures are common to both options and were considered in estimating the total cost of each option. For example, in both options fencing would be required. Therefore, 6-ft-high chainlink fence with three strands of barbed wire along the top is included. Also, radiation warning signs would be displayed prominently on fences and gates, and in other appropriate areas. Off-site remedial action as described in Chapter 7 would be included.

Long-term maintenance also would be required for both options. Maintenance generally would include monitoring, periodic inspection 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 a perpetual care fund which at 7% annual interest would provide the funds necessary for projected inspection and maintenance functions. The perpetual care fund is a mechanism to indicate the long-range control and financing needed to maintain the integrity of the inactive pile.

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

9.1 SECURITY, MAINTENANCE, AND OFF-SITE REMEDIAL ACTION (OPTION I)

The stabilization program performed by the former owners, Susquehannah Western, Inc., has been beneficial in preventing additional release of radiation materials to the environment.

The principal objective of this option is to provide better security and continued maintenance for the tailings, but to make no stabilization improvements.

The remedial action at off-site structures and lots is included and is described in Chapter 7. The contaminated debris obtained from such cleanup would be deposited on the surface of the pile near the center of its long axis about two thirds of the distance from the western edge. Here, it would be stabilized with a minimum of 1.5 ft of the same kind of material as was used on the original stabilization.

9.1.1 Security and Maintenance

Based on the radiometric levels present at the site and on Phase II criteria, the tailings pile, the mill and the ore storage areas 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 completely around the areas. Radiation warning signs would be posted on the security fencing and gates. No irrigation would be required, but physical maintenance would be required periodically to correct erosion problems on the pile and in the drainage system.

9.1.2 Resulting Impacts

Under Option I any release of radioactive materials from the tailings pile would continue, but public access would be made more difficult by improved fencing. The tailings site would have no additional commercial, industrial, or residential use.

9.1.3 Costs

As shown in Table 9-1, \$460,000 is the lowest cost option for the site. The major cost components are as follows:

(a) Engineering (12% of item b)	\$ 27,000
(b) Remedial action	221,000
(c) Environmental assessment and EIS preparation	32,000
(d) Contingency (15% of items a, b, and c)	40,000
(e) Perpetual care fund	<u>140,000</u>
Total Cost	\$460,000

The perpetual care fund at 7% interest would provide approximately \$9,800/yr for monitoring and maintenance of the fencing and the tailings.

9.2 ON- AND OFF-SITE DECONTAMINATION, STABILIZATION IMPROVEMENTS (OPTION II)

In addition to the actions taken in Option I, the locations adjacent to the pile where tailings have been blown by winds would

be decontaminated as described in Chapter 7. Also, the old mill and other contaminated structures, equipment, and foundations on the site would be demolished and buried within the tailings. Contaminated soil beneath the old mill building and in the ore storage areas would be removed and placed on the pile on top of the contaminated rubble resulting from on- and off-site cleanup activities. The amount of such soil to be removed would be that required to reduce radium concentration in the soil to twice background. The resulting holes would be backfilled. The water tower would not have to be removed, but it would be decontaminated by steam cleaning and wet washing. None of the structures used in the sulfuric acid operation would be involved with decontamination efforts.

The contaminated materials on the pile then would be stabilized with 2 ft of earth cover of the same type as was used originally. In addition, another 0.5 ft of the same type of earth cover material would be added to the entire pile, making a total of 2 ft of earth cover on the tailings.

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, except that only the tailings pile would be fenced. Physical maintenance would be that necessary to assure the integrity of stabilization, fencing, and drainage system. No continuing irrigation program is specified.

9.2.2 Resulting Impacts

Stabilization improvement 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 gamma radiation to near background levels, and also would reduce the exhalation of radon from the pile by 30% compared with the exhalation from bare tailings. The site would have greater use than under Option I in that all the area outside of the tailings fence could have limited usage.

9.2.3 Costs

As shown in Table 9-1, the cost of this option is \$1,140,000. The major cost components are as follows:

(a) Engineering (11% of item b)	\$ 86,000
(b) Remedial action	780,000
(c) Environmental assessment and EIS preparation	38,000
(d) Contingency (15% of items a, b, and c)	136,000

(e) Perpetual care fund

100,000

Total Cost

\$1,140,000

The perpetual care fund at 7% interest would provide approximately \$7,000/yr for monitoring and maintenance. The expected maintenance would be less than for Option I by \$2,800/yr primarily because of the lesser amount of fencing involved.

9.3 REMOVAL OF TAILINGS AND CONTAMINATED MATERIALS FROM THE SITE

Although specific long-term storage sites have not been identified, the costs for relocating the tailings and contaminated material to sites at distances 5 and 10 mi from the present location have been estimated as \$6,000,000 and \$6,400,000, respectively. These costs include the remedial action, engineering, EIS, contingency, and perpetual care costs.

9.4 ANALYSES OF COSTS AND BENEFITS

The purpose of this section is to compare the cost of the alternatives with the corresponding anticipated benefits. As summarized in Table 9-1, the total estimated costs for the remedial options are \$460,000 for Option I and \$1,140,000 for Option II. Removal would cost from \$6,000,000 to \$6,400,000.

9.4.1 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 Riverton 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 the 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 essentially a 100% reduction in exposure to the population of concern.

There is a small health benefit predictable from decontamination; however, it has not been included in these analyses. Therefore, Option I has a negligible health benefit. Option II has a higher health benefit due to a corresponding reduction in radon exhalation. The results of the determination of potential cancer cases avoided (health benefits) for Options I and II and for removal of the tailings are given as a function of time in Table 9-2. The health benefit/cost ratio is shown in Figure 9-1 and indicates an increase in the ratio with time due to the increasing number of health effects avoided. The removal alternatives have the largest health benefit/cost ratios because the health effects are eliminated by removing the radiation source.

9.4.2 Land Value Benefits

Most of the land surrounding the site is under the jurisdiction of the Wind River Indian Reservation authorities.

The presence of the tailings pile affects land usage and values only slightly. The actions taken in any of the options would have little effect on the values of the site or on its surrounding areas. The value of Option II is associated with the decontamination of the site, and isolating the tailings would make the balance of the site available for other restricted purposes, but it would have a negligible effect on the value of the total site. Removal of tailings and contaminated material at the present site would allow unlimited use of the entire site.

FIGURE 9-1. POTENTIAL CANCER CASES AVOIDED PER MILLION DOLLARS EXPENDED

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TABLE 9-1

COST ESTIMATE SUMMARY

<u>Option No.</u>	<u>Description</u>	<u>Estimated Cost*</u>
I	Fencing, maintenance, and remedial action at off-site locations	460
II	Off- and on-site decontamination, stabilization increased to 2 ft, fencing, and maintenance	1,140
Removal	Relocate tailings and contaminated materials to a long-term storage site 5 or 10 mi from the present site, and remedial action at off-site locations	6,000-6,400

*Costs are in thousands of dollars, based on 1977 value

TABLE 9-2

POTENTIAL CANCER CASES AVOIDED AND COST
PER POTENTIAL CANCER CASE AVOIDED
FOR RIVERTON SITE

A. NUMBER OF POTENTIAL CANCER CASES AVOIDED			
<u>Options:</u>	<u>I</u>	<u>II</u>	<u>Removal (5 mi-10 mi)</u>
Option Costs (in million \$)	0.46	1.14	6.0-6.4
Years After Remedial Action			
25	0	0.1	2.1
50	0	0.3	4.8
75	0	0.5	7.5
100	0	0.7	10.2
Potential Cancer Cases After 100 yr	10.2	9.5	0
B. COST PER POTENTIAL CANCER CASE AVOIDED (Million \$)			
<u>Options:</u>	<u>I</u>	<u>II</u>	<u>Removal (5 mi-10 mi)</u>
Option Costs (in million \$)	0.46	1.14	6.0-6.4
Years After Remedial Action			
25	--	11.4	2.9-3.1
50	--	3.8	1.3-1.3
75	--	2.3	0.8-0.9
100	--	1.6	0.6-0.6

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 occurred, 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 FRC 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 discomforts 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 μ R/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.

*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 $10\mu\text{R/hr}$ above background, the land may be released for unrestricted use. If residual levels are equal to or greater than $10\mu\text{R/hr}$ 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 $40\mu\text{R/hr}$ 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.

**ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
RULES AND REGULATIONS**

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**PART 712—GRAND JUNCTION
REMEDIAL ACTION CRITERIA**

Sec.	
712.1	Purpose.
712.2	Scope.
712.3	Definitions.
712.4	Interpretations.
712.5	Communications.
712.6	General radiation exposure level criteria for remedial action.
712.7	Criteria for determination of possible need for remedial action.
712.8	Determination of possible need for remedial action where criteria have not been met.
712.9	Factors to be considered in determination of order of priority for remedial action.
712.10	Selection of appropriate remedial action.

AUTHORITY: Sec. 203, 86 Stat. 228.

§ 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 tailings 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 5 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 decay 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-214), 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 1.3×10^6 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.

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(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.

§ 712.3 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 mR/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.