MASTER

ENGINEERING ASSESSMENT OF
RADIOACTIVE SANDS AND RESIDUES

LOWMAN SITE,
LOWMAN, IDAHO

SEPTEMBER 1981

PREPARED FOR

UNITED STATES DEPARTMENT OF ENERGY
ALBUQUERQUE OPERATIONS OFFICE
URANIUM MILL TAILINGS
REMEDIAL ACTIONS PROJECT OFFICE
ALBUQUERQUE, NEW MEXICO

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BY

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This engineering assessment has been performed under DOE Contract No. DE-AC04-76GJ01658 between the U.S. Department of Energy and Ford, Bacon & Davis Utah Inc.

Copies of this report may be obtained from the Uranium Mill Tailings Remedial Action Project Office, U.S. Department of Energy, Albuquerque Operations Office, Albuquerque, New Mexico 87115.

FOREWORD

This report has been authorized by the U.S. Department of Energy (DOE), Albuquerque Operations Office, Uranium Mill Tailings Remedial Action Project Office, Albuquerque, New Mexico, under Contract No. DE-AC04-76GJ01658. The report is a revision of an earlier report dated December 1977, entitled "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Lowman Site, Lowman, Idaho," which was authorized by DOE, Grand Junction, Colorado, under Contract No. E(05-1)-1658.

This report has become necessary as a result of changes that have occurred since 1977 which pertain to the Lowman site and vicinity, as well as changes in remedial action criteria. The new data reflecting these changes are presented in this report. Evaluation of the current conditions is essential to assessing the impacts associated with the options suggested for remedial actions for the radioactive sands and residues.

Ford, Bacon & Davis Utah Inc. (FB&DU) has received excellent cooperation and assistance in obtaining new data to prepare this report. Special recognition is due Richard H. Campbell and Mark Matthews of DOE, Robert Funderburg of the Idaho State Radiation Control Office, as well as several local, county, and state agencies and private individuals.

ABSTRACT

Ford, Bacon & Davis Utah Inc. has reevaluated the Lowman site in order to revise the December 1977 engineering assessment of the problems resulting from the existence of radioactive sands and residues at Lowman, Idaho. This engineering assessment has included the preparation of topographic maps, the performance of core drillings and radiometric measurements sufficient to determine areas and volumes of radioactive sands and residues and radiation exposures of individuals and nearby populations, the investigations of site hydrology and meteorology, and the evaluation and costing of alternative corrective actions.

Radon gas released from the 191,000 tons of radioactive sands, residues, and contaminated soils at the Lowman site constitutes the most significant environmental impact, although windblown radioactive sands and external gamma radiation also are factors. The three alternative actions presented in this engineering assessment range from millsite and off-site decontamination with the addition of 3 m of stabilization cover material (Option I), to removal of the radioactive sands to remote disposal sites and decontamination of the former site (Options II and III). Cost estimates for the three options range from about \$2,500,000 for stabilization in-place, to about \$6,000,000 for disposal at a distance of about 15 mi.

Reprocessing the radioactive sands for uranium recovery is not practicable.

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CHAPTER 1

SUMMARY

CHAPTER 1

SUMMARY

1.1 INTRODUCTION

The U.S. Energy Research and Development Administration (ERDA) contracted in 1975 with Ford, Bacon & Davis Utah Inc. (FB&DU) of Salt Lake City, Utah, to provide architect-engineering services and final reports based on the assessment of the problems resulting from the existence of large quantities of radioactive uranium mill tailings at inactive mill sites in eight western states and in Pennsylvania. In 1980, the U.S. Department of Energy (DOE) contracted with FB&DU to produce revised reports of the sites designated in the Uranium Mill Tailings Remedial Action (UMTRA) program in order to reflect the current conditions, new criteria and options, and to estimate current remedial action costs.

A preliminary survey (Phase I) was carried out in 1974 by the U.S. Atomic Energy Commission (AEC) in cooperation with the U.S. Environmental Protection Agency (EPA) and the affected states. In a summary report,⁽¹⁾ ERDA identified 17 sites in Arizona, Colorado, Idaho, New Mexico, Utah, and Wyoming for which practical remedial measures were to be evaluated. Subsequently, ERDA added five additional sites (Riverton and Converse County, Wyoming; Lakeview, Oregon; Falls City and Ray Point, Texas). More recently, DOE has added a site in Canonsburg, Pennsylvania, one near Baggs, Wyoming, and two sites in North Dakota (Belfield and Bowman) and deleted Ray Point, for a total of 25 sites. DOE continues to investigate the status of the site near Baggs, Wyoming. Most of the mills at these sites produced by far the greatest part of their output of uranium under contracts with the 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.

Prior to 1975, the studies of radiation levels on and in the vicinities of these sites were limited in scope. The data available were insufficient to permit assessment of risk to people with any degree of confidence. In addition, information on practicable measures to reduce radiation exposures and estimates of their projected costs was limited. The purposes of these recent studies performed by FB&DU have been to update the information necessary to provide a basis for decision making for appropriate remedial actions for each of the 25 sites.

Evaluations of the following factors have been included in this engineering assessment in order to assess the significance

of the radiological conditions that exist today at the Lowman site:

- (a) Exhalation of radon gas from the radioactive sands and residues
- (b) On-site and off-site direct radiation
- (c) Land contamination from windblown sands and residues
- (d) Hydrology and contamination by water pathways
- (e) Potential health impact
- (f) Potential for extraction of additional minerals from the sands and residues

Investigation of these and other factors originally led to the evaluation of two potential practicable remedial action alternatives. Since that time, these alternatives have been judged unacceptable because of new criteria that have been proposed. In the work performed in the preparation of this report, the remedial action alternatives are revised as follows:

- (a) Option I - Stabilization of radioactive sands and residues on site with a 3-m cover
- (b) Option II - Disposal at an unspecified site located 15 mi from the present site
- (c) Option III - Disposal at an unspecified site located 30 mi from the present site

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

*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. The Phase I report on the Lowman site appears as Appendix I to Reference 4.

provided for the assessment of an appropriate remedial action to limit the exposure of individuals to radiation from uranium mill tailings.

Dr. William D. Rowe, testifying on behalf of the 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 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, adapted from Reference 1, summarizes the conditions in 1980. Based on the findings presented in the Phase I 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, Utah, 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. Work at Lowman was performed from September 20 through September 23, 1976, and the original Phase II - Title I engineering assessment was published in December 1977.(2)

On November 8, 1978, the Uranium Mill Tailings Radiation Control Act of 1978 (PL 95-604) became effective. This legislation provides for state participation with the Federal Government in the remedial action for inactive tailings piles. Pursuant to requirements of PL 95-604, the EPA has the responsibility to promulgate remedial action standards for the

cleanup of areas contaminated with residual radioactive material and for disposal of tailings. The U.S. Nuclear Regulatory Commission (NRC) has the responsibility for enforcing these standards.

In 1979, DOE established the UMTRA Program Office in Albuquerque, New Mexico. Work on the program has since been directed by personnel in that office. The supplementary field work by FB&DU in support of this report was performed during the week of June 2, 1980.

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 a continuation of the assessment made for Title I requirements and has been prepared by FB&DU. In connection with the field studies made in 1976, the Oak Ridge National Laboratory (ORNL) at Oak Ridge, Tennessee, under separate agreement with DOE, 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 Lowman site.

The specific scope requirements of the Title I assessment 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 cost.
- (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 at which mill tailings containing radium could be disposed; and once such sites are identified, perform evaluations 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 radioisotopes in the tailings
- (k) Review of existing information about 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 socio-economic 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 the Lowman site.

1.2 SITE DESCRIPTION

1.2.1 Location and Topography

The Lowman millsite is located in Boise County approximately 75 mi northeast of Boise, Idaho. The site is in a pine-covered mountain valley in the Boise National Forest. It rests on a west-facing terrace of the Sawtooth Mountain Range. The elevation of the site is generally 4,000 ft above sea level. Drainage from the site is into Clear Creek just above the junction of Clear Creek and the South Fork Payette River. The site and its relationship to the surrounding area are shown in the aerial photograph in Figure 2-1.

1.2.2 Ownership and History of Milling Operations and Processing

The original owner and only operator was the Porter Brothers Corporation of Boise, Idaho. The site now is owned by Velsicol Chemical Corporation, formerly known as the Michigan Chemical Corporation. Figure 2-3 shows the current ownership and legal description of the site.

The plant operated from 1955 until 1960. During that time approximately 200,000 tons of dredge product obtained from Bear Valley, 20 mi north of Lowman, were processed. The process used was a mechanical rather than a chemical process. Columbite-euxenite and monazite concentrates and other by-products such as magnetite, ilmenite, zircon, and garnet were extracted from the ore.

1.2.3 Present Condition of the Site

Some concrete foundations, a few small sheds, and some debris are all that remain of the mill structures. Just over 90,000 tons of sands remain on the site in several piles. The sands and residues are scattered throughout the 37-acre site in 10 locations covering about 5 acres. A descriptive map of the site is included as Figure 2-4.

All of the sands are radioactive in varying degrees. None of these materials have been stabilized. Some of the more radioactive sands have been eroded by water down a steep slope on the west side of the site and into an old settling pond adjacent to Clear Creek.

The site is about 80% covered with native grasses and trees, but there is no vegetation on the piles of sand. The barbed-wire fencing around the site is in a state of substantial disrepair. Since the field survey work, a posted gate with a lock has been installed to control vehicle access to the site.

1.2.4 Characteristics of Contaminated Materials and Soils

The radioactive sands are angular, dense, coarse-grained, and of several colors. The black sands are primarily magnetite; the red sands are garnet. The grey and white sands, also residues of the mechanical separation process, were deposited along the upper edge of the slope above Clear Creek. Table 2-1 is a listing of the amounts of these materials on the site.

The soil beneath the radioactive sands and residues is mountain loam, nearly black in color, with gravelly aggregates resulting from glacial deposits in some locations.

1.2.5 Geology, Hydrology, and Meteorology

The Lowman millsite is located on a glacial terrace, which has been incised by Clear Creek to the west of the site and is bordered by a ridge to the east. A lower river-laid terrace, on which a settling pond area was constructed, is adjacent to the higher millsite terrace. The glacial terrace material is composed of deep sandy and loamy soils, gravels, sands, boulders, and cobbles. The lower alluvial terrace is river-run material, primarily of granitic origin. Igneous granite bedrock (granodiorite) of the Idaho batholith underlies the site. This granite is fractured and weathered. Bedrock is exposed in the streambed and forms the escarpment to the east of the site. Figure 2-5 is a simplified stratigraphic column of the area.

The flowing surface waters near the site consist of Clear Creek, the South Fork Payette River, and the intermittent flow in ditches on the site. Clear Creek is a swiftly flowing stream that intersects the South Fork Payette River approximately 0.5 mi south of the site. It is possible that the lower terrace which borders the creek could be eroded by flood waters of Clear Creek, with resulting undercutting and erosion of the piles. However, there is no evidence that such flooding has occurred.

Contamination of the surface waters could occur by physical transport of the sands as a result of overland runoff and by

seepage through the piles into the waters. Placement of the piles parallel to the slopes, which tends to trap water behind the piles, has encouraged seepage into the surface waters. The degree of physical transport from the site has been aggravated by the steep banks of the sparsely vegetated piles, where some slopes have gullies up to 10 ft deep. Rill erosion is occurring on the cut behind and adjacent to the mill foundations. The ridge east of the piles limits the catchment area near the site; however, a substantial trench was constructed to convey process water from the eastern slope to the mill during operations. This ditch continues to channel runoff, and this concentration of flow aggravates erosion.

Shallow unconfined aquifers characterize the hydrology of the area. Clear Creek and the South Fork Payette River are gaining streams fed by flows from unconfined ground waters. The terrace materials tend to filter sediments from the waters and act as buffers to regulate overland and subsurface flow. The interface between the unconsolidated surficial materials and bedrock acts as the surface for lateral ground water flow. Seeps and springs are common in the area, particularly at the exposure of this interface. One such spring lies at the southern margin of the piles relatively near the source of domestic water for a mobile home. Eight wells within 2 mi of the site are on record at the Idaho State Department of Water Resources. Three wells in the area are Federal Government wells, but they have not been monitored. There is no problem associated with confined ground waters at the site because there are no confined ground waters associated with the igneous bedrock of the Idaho batholith.

Average annual precipitation at the site ranges between 20 and 25 in., much of which comes as snowpack. High-intensity rainstorms are infrequent, but such a storm at the site could result in serious erosion of the more susceptible areas of the piles. The strongest winds blow up and down the valley in a north-south direction, but the local land relief and the forest canopy tend to serve as windbreaks and protect the sands from wind erosion.

1.3 RADIOACTIVITY AND POLLUTANT IMPACTS ON THE ENVIRONMENT

About 85% of the total radioactivity originally in uranium ore remained in the sands after removal of the uranium. 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 sands. Although these radionuclides occur in nature, their concentrations in the sands are several orders of magnitude greater than their average concentrations in the earth's crust. Since these sands were processed by physical methods and were not chemically treated, the solubility of the ^{226}Ra has not been increased by processing and hence is not significantly more mobile.

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 sands and residues. Radon is a gas which diffuses from the piles. The principal exposure results from inhalation of ^{222}Rn daughters. This exposure affects the lungs. For this assessment, no criteria have been established for radon concentrations in air. However, the pathway for radon and radon daughters accounts for the major portion of the exposure to the population.
- (b) External whole-body gamma exposure directly from radionuclides in the piles.
- (c) Inhalation and ingestion of windblown sands. The primary health effect relates to the alpha emitters ^{230}Th and ^{226}Ra , each of which causes exposure to the bones and lungs.
- (d) Ingestion of ground and surface water contaminated with radioactive elements (primarily ^{226}Ra) and other toxic materials.
- (e) Contamination of food through uptake and concentration of radioactive elements by plants and animals is another pathway that can occur; however, this pathway was not considered in this study.

1.3.1.1 Radon Gas Diffusion and Transport

Measurements of radon flux from the sands made in 1976 using the charcoal canister technique⁽³⁾ ranged from 50 to 150 pCi/m²-s on the residue piles. Radon flux depends principally on radium content of the sands; however, it also varies considerably because of moisture, soil characteristics, and climatological conditions.

1.3.1.2 Direct Gamma Radiation

The range of natural background values in the Lowman area was between 10 and 12 $\mu\text{R/hr}$, averaging 11 $\mu\text{R/hr}$ as measured with an energy-compensated Geiger Mueller detector.⁽⁴⁾ Gamma rates were measured as high as 2,450 $\mu\text{R/hr}$ above the surface of the ore piles and 1,220 $\mu\text{R/hr}$ above the surface of the residue piles, as shown in Figure 3-9.

1.3.1.3 Windblown Contaminants

Background gamma radiation rates were reached within 0.2 mi to the north and 0.1 mi in the other directions from the site. The results of the EPA gamma radiation survey around the site are shown in Figure 3-11. The background line closely follows the area where the radioactive sands are located. An iso-exposure line indicating the portion of the land surrounding the site that is contaminated in excess of 5 pCi/g of radium above background concentration is shown in Figure 3-12.

A surface soil sample taken 0.1 mi north of the site contained 4 times background levels of ^{226}Ra (1.1 pCi/g). On-site soil samples had radium concentrations from background to 15 times average radium background concentration. However, one sample near Clear Creek and near the base of the grey sand pile contained 200 pCi/g of radium. This sample probably contained sand eroded from the pile by surface runoff.

1.3.1.4 Ground and Surface Water Contamination

Two surface water samples from Clear Creek upstream and downstream from the Lowman site were analyzed for ^{226}Ra . The upstream sample contained 0.16 pCi/l of radium; only a trace of radium was found in the downstream sample. The radium content of water from a spring south of the site was 0.12 pCi/l. These results indicate no contamination of surface water from radium leached from the sands.

1.3.1.5 Soil Contamination

The leaching of radium into the soil beneath the radioactive sands extends from 2 to 3 ft below the pile-soil interface before reaching twice the average background level of radium concentration in local soil samples (1.1 pCi/g). A few isolated locations were found where deeper contamination exists.

1.3.2 Remedial Action Criteria

Although the following discussion refers to uranium mill tailings, it also applies to the radioactive sands and residues on the Lowman site.

For the purpose of conducting the original engineering assessment, (2) provisional criteria provided by the EPA were used. The criteria were in two categories, and applied either to structures with tailings present or to land areas to be decontaminated. For structures, the indoor radiation level below which no remedial action was indicated was considered to be an external gamma radiation level of less than 0.05 mR/hr above background and a radon daughter concentration of less than 0.01 WL above background. Land could be released for unrestricted use if the external gamma radiation levels were less

than 10 $\mu\text{R/hr}$ above background. When cleanup was necessary, residual radium content of the soil after remedial action should not exceed twice background in the area.

Since enactment of the Uranium Mill Tailings Radiation Control Act of 1978 (PL 95-604), which was effective November 8, 1978, the EPA has published interim (45 FR 27366) and proposed (46 FR 27370) standards for structures and open lands. These standards establish the indoor radon daughter concentration, including background, below which no remedial action is indicated at 0.015 WL. The indoor gamma radiation limit is 0.02 mR/hr above background.

For open land, remedial action must provide reasonable assurance that the average concentration of ^{226}Ra attributable to residual radioactive material from any designated processing site in any 5-cm thickness of soils or other materials within 1 ft of the surface, or in any 15-cm thickness below 1 ft, shall not exceed 5 pCi/g.

Environmental standards have been proposed by the EPA (46 FR 2556) for the disposal of residual radioactive materials from inactive uranium processing sites. These standards require that disposal of residual radioactive materials be conducted in a way which provides a reasonable assurance that for at least 1,000 yr following disposal:

- (a) The average annual release of ^{222}Rn from the disposal site to the atmosphere by residual radioactive materials will not exceed 2 pCi/m²-s.
- (b) Substances released from residual radioactive materials after disposal will not cause:
 - (1) the concentrations of those substances in any underground source of drinking water to exceed the level specified below,* or
 - (2) an increase in the concentrations of those substances in any underground source of drinking water where the concentrations of those substances prior to remedial action exceed the levels specified below for causes other than residual radioactive materials.*

*These requirements apply to the dissolved portion of any substance listed above at any distance greater than 1.0 km from a disposal site that is part of an inactive processing site, or greater than 0.1 km if the disposal site is a depository site.

<u>Substance</u>	<u>mg/l</u>
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium	0.05
Lead	0.05
Mercury	0.002
Molybdenum	0.05
Nitrogen (in nitrate)	10.0
Selenium	0.01
Silver	0.05
	<u>pCi/l</u>
Combined ^{226}Ra and ^{228}Ra	5.0
Gross alpha particle activity (including ^{226}Ra but excluding radon and uranium).	15.0
Uranium	10.0

- (c) Substances released from the disposal site after disposal will not cause the concentration of any harmful dissolved substance in any surface waters to increase above the level that would otherwise prevail.

Since the passage of PL 95-604, the NRC has published final regulations for uranium mill tailings licensing in the Federal Register (45 FR 65521). They include the requirement that the stabilization method must include an earth cover of at least a 3-m thickness and sufficient to reduce the radon emanation rate from the contaminated materials to less than 2 pCi/m²-s above background. In addition, seepage of materials into ground water should be reduced by design to the maximum extent reasonably achievable.

While these standards may undergo further revisions, the interim and proposed standards as indicated above form the basis for determining required remedial actions and their associated costs.

1.3.3 Potential Health Impact

Radon gas exhalation from the radioactive sands and the subsequent inhalation of radon daughters account for most of the total dose to the population from the Lowman site under present conditions. The gamma radiation exposure from the piles is virtually zero since there are very few people who live or work within 0.2 mi of the radioactive sands, 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 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 residue piles. If the diffusion time can be made long enough, then, theoretically, virtually all of the radon and its daughter products will have decayed before escaping to the atmosphere. Calculations using the theoretical techniques of Kraner, Schroeder, and Evans⁽⁵⁾ earlier indicated that 13 ft of earth cover would be required to reduce the radon diffusion from the Lowman radioactive sands by 95%. Later experimental work⁽⁶⁾ has demonstrated that 2 to 3 ft of compacted clay may be sufficient to reduce radon flux to less than 2 pCi/m²-s, assuming the continued integrity of the clay cover.

The health significance to man of long-term exposure to low-level radiation is a subject that has been studied extensively. Since the end results of long-term exposure to low-level radiation may be diseases such as lung cancer or leukemia, which are also attributable to many other causes, the determination of specific cause in any given case becomes very difficult. Therefore, the usual approach to evaluation of the health impact of low-level radiation exposures is to make projections from observed effects of high exposures on the premise that the effects are linear. A considerable amount of information has been accumulated on the high incidence of lung cancer in uranium miners and others exposed to radon and its daughters in mine air. This provides a basis for calculating the probable health effects of low-level exposure to large populations. (The term "health effect" refers to an incidence of disease; for radon daughter exposure, a health effect is a case of lung cancer.) This is the basis of the health effects calculated 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-III report).⁽⁷⁾ This report presents risk estimators for lung cancer derived from epidemiological studies of both uranium miners and fluorspar miners. The average of the age-dependent absolute risk estimator for these two groups as applied to the population at large is 150 cancers per year

per 10^6 person-WLM of continuous exposure, assuming a lifetime plateau to age 75. The term WLM means working level months, 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 or with the parent radon. Because of the many factors that contribute to natural biological variability and of the many differences between exposure conditions in mines and residences, this estimator (150 cancer cases per year per 10^6 person-WLM of continuous exposure) is considered to have an uncertainty factor of about 3. Another means of expressing risk is the relative risk estimator, which yields risk as a percentage increase in health effects per 10^6 person-WLM of continuous exposure. However, this method has been shown to be invalid⁽⁸⁾ and is not considered in this assessment.

For the purpose of this engineering 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 predictions of radon concentrations in excess of the background value under present conditions, it was calculated that the average lung cancer risk attributable to radon released from the radioactive sands in the area within 3 mi of the Lowman site is 6.7×10^{-7} per person per year, or less than 1% of the average lung cancer risk due to all causes for Idaho residents (1.0×10^{-4}).⁽⁹⁾

The 25-yr health effects were calculated for three population projections using the present population of 90 people in the 0- to 3-mi area. The results for pile-induced radon and background radon for the area were as follows:

25-Year Cumulative Health Effects within 3 Miles of Edge of Radioactive Sands and Residues

<u>Projected Population Growth</u>	<u>Pile-Induced RDC</u>	<u>Background RDC</u>
0.8% constant growth rate	0.0017	0.12
5% declining growth rate*	0.0023	0.16
10% declining growth rate*	0.0037	0.26

Pile-induced radon daughter health effects are approximately 1.5% of the background radon daughter health effects for the 0- to 3-mi area. 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

Four water samples were taken from the vicinity of the Lowman site and analyzed for heavy metal content. Two samples were from Clear Creek upstream and downstream from the site, and two samples were from a well and a spring downgradient from the site. None of the samples indicated leaching of nonradioactive heavy metals from the site.

1.4 SOCIOECONOMIC AND LAND USE IMPACTS

The area near the site either is forest land or is used for recreation. Much of the land is administered by the U.S. Forest Service. There are no population concentrations near the site, although the community of Lowman has a general store, a service station, a lodge, and a motel. Some of the private tracts near the site have been subdivided into lots for summer homes. One such tract is located across the river from the site. Projected land uses are similar to present land uses, with increased development of lots for year-round uses, as well as for vacation purposes.

Single one-acre lots sell for approximately \$13,000 near the site area. The presence of the sands and residues has not affected land uses or values of nearby land, although the use of the site has been restricted by the sands and the aesthetic quality of the site has been diminished by the sparsely vegetated slopes and abandoned property on the site.

1.5 RECOVERY OF RESIDUAL VALUES

Only a few samples of radioactive sands were obtained during this study. Consequently, calculations based on these samples would not be statistically representative.

*Declines linearly from its initial value to zero in 25 yr and remains constant at zero thereafter.

There are, however, five factors that can be employed to evaluate whether reprocessing the Lowman radioactive sands and residues to extract uranium and other mineral values would be practicable:

- (a) The amount of sands and residues present
- (b) Concentrations of residual values
- (c) Projected recovery
- (d) Current market price of recovered values
- (e) Proximity to processing mills

The Lowman ore was processed using physical separation methods, and the concentrates shipped elsewhere for further processing.

Based on the aforementioned considerations, reprocessing of the Lowman radioactive sands for uranium is not practicable.

1.6 MILL TAILINGS STABILIZATION

The methods and criteria for uranium mill tailings stabilization were briefly reviewed and found to apply to the radioactive sands at the Lowman site. The following summary of mill tailings stabilization is therefore applicable to the stabilization of radioactive sands.

Investigations of methods of stabilizing uranium mill tailings piles from wind and water erosion have indicated a variety of deficiencies among the methods. Chemical stabilization (treatment of the tailings surface) has been successful only for temporary applications and is thus viewed as inadequate for currently proposed disposal criteria. Volumetric chemical stabilization (solidifying the bulk of the tailings) techniques appear to be costly and of questionable permanence. Physical stabilization (emplacement of covers over the tailings) methods using soil, clay, or gravel have been demonstrated on a laboratory scale to be effective in stabilizing tailings. Artificial cover materials are attractive but have the disadvantage of being subject to degradation by natural and artificial forces. Vegetative stabilization (establishment of plant growth) methods are effective in limiting erosion. However, where annual precipitation is less than about 10 in., soil moisture content may be inadequate to ensure viability of the plant life.

Migration of contaminants into ground water systems must be limited under the NRC and EPA criteria. Control of water percolating through the tailings can be accomplished by

stabilizing chemically, by physically compacting the cover material, and by contouring the drainage area and tailings cover surface. Isolation of the tailings from underlying ground water systems can be accomplished by lining a proposed disposal site with natural or artificial impermeable membranes.

Several materials have been identified which sufficiently retard radon migration so that the radon flux is substantially reduced, on a laboratory scale. Unfortunately, no large-scale application has been undertaken which would demonstrate that these materials satisfy all of the technical criteria in the EPA-proposed standards and the NRC regulations for licensing of uranium mills. However, extensive investigations of these questions continue in the Technology Development program of the Uranium Mill Tailings Remedial Actions Project Office in Albuquerque, New Mexico.

In view of findings from stabilization research, it appears that physical stabilization of tailings with 3 m of well-engineered cover material may be sufficient to appropriately stabilize tailings at their disposal site to meet NRC regulations.

1.7 OFF-SITE REMEDIAL ACTION

A mobile scanning unit, operated by the AEC under inter-agency agreement with the EPA, performed a gamma radiation survey of the Lowman, Idaho, area prior to 1973. A subsequent field survey identified eight off-site areas where use of the radioactive sands was suspected or confirmed. The cost of remedial action for these locations has been estimated at \$250,000. The windblown contamination survey identified about 11 acres of off-site land contaminated in excess of 5 pCi/g above background levels. Cleanup of this land is estimated at \$200,000. Therefore, the total remedial action estimated cost for off-site structures is \$450,000, exclusive of engineering and contingency allowances.

1.8 DISPOSAL SITE SELECTION

In this report, two of the alternative remedial action options include moving the Lowman radioactive sands to a disposal site. Since the present site can probably meet the existing criteria for stabilization of the sands, no specific disposal sites have been identified. However, to provide an understanding of the magnitude of costs involved with off-site disposal of the sands, unspecified sites at distances 15 and 30 mi from the present site were evaluated. Since site-specific characteristics could influence the cost of these options quite substantially, care must be exercised in the use of these cost estimates. Option II corresponds with disposal at the 15-mi site and Option III with disposal at the 30-mi site. Since the responsibility for disposal site

selection lies with the Federal Government, with input from the State, the disposal sites evaluated in this report must be considered only as tentative.

In each of these options, surface material would be removed, as appropriate, from the disposal area and stockpiled. A retaining dike and diversion ditches would be constructed if necessary. The radioactive sands would be emplaced, contoured, and covered with 3 m of soil. The surface would be covered with 0.3 m of riprap or vegetation would be established for erosion control, and the entire site would be fenced.

1.9 REMEDIAL ACTIONS AND COST-BENEFIT ANALYSES

1.9.1 Remedial Action Options

The remedial action options examined include stabilization of the residue piles in their present locations, and removal of all radioactive materials to an area where these materials could be isolated from the public. The options for which cost estimates were made include stabilization on the present site with 3 m of cover material and the removal of the radioactive sands to one of two unspecified locations. The options are summarized in Table 1-2.

The basis for comparison, from which the cost effectiveness of remedial alternatives can be judged, is the present condition of the site with no remedial action.

Option I represents remedial action activities to stabilize the piles more completely in their present locations with the addition of 3 m of cover. Erosion of the sands and residues would be controlled more completely and radon exhalation would be reduced to not more than 2 pCi/m²-s above background. The site would have limited future use.

1.9.2 Cost-Benefit Analyses

As summarized in Table 9-1, the total costs for the three remedial action options vary from about \$2,500,000 to about \$6,000,000. Each of these options would have associated health and monetary benefits. The options are identified by number in Paragraph 1.1.

The number of cancer cases avoided per million dollars expended for each option is given in Figure 9-3. The curves in this figure indicate an increase in benefit-cost ratio with time due to the greater reduction in population exposure over longer periods of time as a result of remedial action. The potential cancer cases avoided for each option and the cost per potential cancer case avoided are given in Table 9-2.

TABLE 1-1

SUMMARY OF CONDITIONS NOTED AT TIME OF 1980 SITE VISITS

	Condition of Tailings ^a	Condition of Structures On Site ^b	Mill Housing ^c	Adequate Fencing, Posting, Security	Property Close to River or Stream	Houses or Industry within 0.5 Mi	Evidence of Wind or Water Erosion	Possible Water Contam- ination	Tailings Removed for Private Use	Other Hazards On Site
<u>ARIZONA</u>										
Monument Valley	U	R	N	No	No	Yes	Yes	No	Yes	No
Tuba City	U	PR-UO	E-P	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	Yes	Yes	Yes	No
Gunnison	S	B-O	N	No	Yes	Yes	No	Yes	No	No
Maybell	S	R	N	Yes	No	No	Yes	No	No	No
Naturita	RMS	PR-O	N	Yes	Yes	Yes	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	Yes	Yes	Yes	Yes	Yes	No	No
Slick Rock (UCC)	S	R	E-P	Yes	Yes	Yes	No	Yes	No	No
<u>IDAHO</u>										
Lowman	U	R	N	No	Yes	Yes	Yes	Yes	Yes	No
<u>NEW MEXICO</u>										
Ambrosia Lake	U	PR-O	N	No	No	No	Yes	No	No	No
Shiprock	S	PR-O	N	Yes	Yes	Yes	No	Yes	Yes	No
<u>NORTH DAKOTA</u>										
Belfield	R	PR-O	N	No	No	Yes	No	No	No	No
Bowman	R	R	N	No	No	No	No	No	No	No
<u>OREGON</u>										
Lakeview	S	B-O	N	Yes	No	Yes	Yes	No	No	No

TABLE 1-1 (Cont)

	Condition of Tailings ^a	Condition of Structures On Site ^b	Mill Housing ^c	Adequate Fencing, Posting, Security	Property Close to River or Stream	Houses or Industry within 0.5 Mi	Evidence of Wind or Water Erosion	Possible Water Contam- ination	Tailings Removed for Private Use	Other Hazards On Site
<u>PENNSYLVANIA</u>										
Canonsburg	P	B-O	N	Yes	Yes	Yes	No	Yes	Yes	Yes
<u>TEXAS</u>										
Falls City	P	B-O	N	Yes	No	No	Yes	No	No	No
<u>UTAH</u>										
Green River	S	B-Y	N	Yes	Yes	Yes	Yes	Yes	No	No
Mexican Hat	U	PR-UO	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	Yes	No	No	No	No	No	No
Riverton	S	PR-O	N	No	No	Yes	No	No	No	No

^aS - Stabilized but requires improvement

P - Partially stabilized

U - Unstabilized

RMS - Reprocessed, moved and stabilized - contamination remaining

R - Removed - contamination remaining

^bM - 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

^cN - None

E - Existing

O - Occupied

P - Partially occupied

TABLE 1-2

SUMMARY OF REMEDIAL ACTION OPTIONS AND EFFECTS

<u>Option Number</u>	<u>Site Specific Cost (\$000)</u>	<u>Description of Remedial Action</u>	<u>Benefits</u>	<u>Adverse Effects</u>
I	2,500	The radioactive sands would be stabilized in place with 3 m of local earth cover. Natural vegetation would be established or a riprap cover provided. On- and off-site contaminated materials would be cleaned up as necessary.	A-E, H-J	Z
II	6,000	The radioactive sands, contaminated soil, and rubble would be moved by truck to an unspecified site located about 15 mi from the radioactive sands site. The radioactive sands site would be decontaminated and released for unlimited use.	A, C-G, I-K	--
III	5,700	Same as Option II, except radioactive sands moved to an unspecified site located about 30 mi from the radioactive sands site.	A, C-G, I-K	--

Notes

1. All options include on- and off-site remedial action.
2. For Options II and III, costs include removal of 3 ft of contaminated earth beneath the radioactive sands.

TABLE 1-2 (Cont)

Definition of Benefits

- A. Off-site structures decontaminated
- B. Access to the radioactive sands site controlled by fencing and posting
- C. Off-site windblown radioactive sands cleaned up
- D. Wind and water erosion controlled
- E. Gamma radiation reduced
- F. The source of gamma radiation and radon gas removed from the area
- G. No building restrictions on or near site
- H. The prime use of the final disposal location unchanged
- I. Disposal site maintenance required only on a limited basis; minimal possibility of contaminating air or water supplies
- J. A reduction in rate of radon exhalation to at least 2 pCi/m²-s
- K. Maintenance and fencing at the radioactive sands site eliminated

Definition of Adverse Effects

- Z. Limited use of the radioactive sands site

CHAPTER 1 REFERENCES

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CHAPTER 2
SITE DESCRIPTION

CHAPTER 2

SITE DESCRIPTION

The purpose of this chapter is to describe the Lowman site, its surroundings, and the characteristics of the radioactive sands and residues present on the site.

2.1 LOCATION

The millsite and sands area is located approximately 0.5 mi northeast of Lowman, Idaho, in Boise County. Lowman is approximately 75 mi northeast of Boise, Idaho. More specifically, the site is in Section 27, Township 9 North, Range 7 East, Boise Principal Meridian, at 44 deg 05 min 09 sec north latitude and 115 deg 36 min 30 sec west longitude. An aerial photograph of the site and surrounding areas is shown in Figure 2-1.

2.2 TOPOGRAPHY

The topography of the site is characterized by steep, pine-covered mountains of the Boise National Forest. The location is in the western slope drainage basin of the Sawtooth Mountain Range, whose peaks rise to over 10,000 ft 60 road miles to the east. Mountain peaks in the immediate vicinity of the site rise to elevations of over 6,000 ft. The topography of the approximately 37-acre site is shown in Figure 2-2.

2.3 OWNERSHIP

The site is presently owned by Velsicol Chemical Corporation, formerly known as the Michigan Chemical Corporation of Chicago, Illinois. A land ownership and site description map prepared for DOE⁽¹⁾ is shown in Figure 2-3.

2.4 HISTORY OF MILLING OPERATIONS AND PROCESSING⁽²⁾

The mill operated from 1955 to 1960 for the recovery of a columbite-euxenite concentrate and a monazite concentrate, plus other potentially valuable by-products, such as magnetite, ilmenite, zircon, and garnet. The mill feed was a jig concentrate of sands obtained from the dredging of placer gravels obtained from Bear Valley, 20 mi north of Lowman. The jig concentrate was trucked to the mill for further beneficiation.

The final concentrates were treated on a toll basis for the Porter Brothers Corporation by the Mallinckrodt Chemical Works at Hematite, Missouri. Recovered at the Mallinckrodt plant were columbium and tantalum pentoxides, uranium oxide, rare earths, titanium, and thorium-iron residues. Porter Brothers Corporation held a contract with the AEC for the sale of the uranium oxide. It also held a contract with the

General Services Administration covering the sale of the columbium-tantalum pentoxides.⁽³⁾ Some by-product magnetite and ilmenite were shipped to the AEC in Las Vegas, Nevada, for stemming material at the Nevada Test Site, and some of the garnet sands were used for sand blasting.

The milling process consisted of wet and dry circuits. In the wet portion, the black sand was sized and magnetite removed by an electromagnetic separator. Two classifiers deslimed the feed, removing 2.7 specific gravity solids at minus-65 mesh from the sands.

Ilmenite, garnet, and a small amount of magnetite were removed by induced-roll separators in the dry circuit. A columbite-euxenite bulk product was removed from monazite in a high-tension separator. The columbite-euxenite and monazite concentrates then were separately and alternately treated in a single gravity concentration circuit consisting of an air-tabling and a wet-tabling operation.

2.5 PRESENT CONDITION OF THE SITE

Figure 2-4 is a descriptive map of a portion of the site as it now exists. The original mill buildings were removed from the site, but the concrete foundations of the old mill building remain. The scale house, concrete walls of the ore storage bunkers, wooden water tank, some sheds, and a scrap pile remain on the site. Gravel and dirt roads interlace the site.

There are about 10 separate locations on the site where radioactive sands or residues from the milling operations were deposited. One pile of original ore (dredge concentrate) remains just northeast of the old mill location. Most of the piles are on the natural bench of the site, but some grey and white sands are on the steep edge which slopes down (west) into Clear Creek. These sands (especially the grey) have been eroded by water from the site to some extent. A settling pond in the low part of the site has been the main collector of sands that have eroded off the steep-banked site. A metal-lined drainage ditch that was installed to divert upslope drainage away from the sands continues to accomplish its intended function, even though the metal lining has lost its integrity. The sand areas, millsite, and ore storage areas occupy about 18 acres of the 37-acre site. The combined area of all the sands and ore is approximately 5 acres.

The site is about 80% covered with native grasses and trees, but there is no vegetation on the sand piles. No stabilization cover of any type has been placed on the sands or residues. In addition to the steepness of the slopes, the lack of stabilization cover has contributed to surface water runoff resulting in minor erosion and spread of the radioactive sands.

There are remnants of barbed-wire fencing around the north and east perimeters of the site. A lockable gate bars the entrance to the site from the south, off Idaho State Highway 21. The gate is effective in keeping cars and trucks off the site but is ineffective in stopping motorcycles and people on foot from entering. Even though a radiation warning sign is posted at the gate, there is evidence of trespassing by cyclists and hikers.

2.6 CHARACTERISTICS OF CONTAMINATED MATERIALS AND SOIL

The types, volumes, and weights of contaminated materials at the Lowman site are summarized in Table 2-1. As shown, an estimated total of 191,000 tons of contaminated materials is present on site.

No fine grinding or chemical processing of the ores was performed at the site. The sand residues are angular, dense, and coarse-grained, and are therefore fairly resistant to wind erosion. The heavy black sands also are resistant to water erosion.

The soil beneath the sands is sandy loam, brown to black in color and not very thick, as typical of most mountainside soil. Glacial deposits of aggregates are also found in the site area.

2.7 GEOLOGY, HYDROLOGY, AND METEOROLOGY

2.7.1 Geology

The Lowman millsite is located on a terrace of glacial outwash material that has been incised by the swiftly flowing Clear Creek to the west of the site, and is bordered by a relatively steep-sloped ridge to the east.⁽⁴⁾ A smaller river-laid terrace is adjacent to the west side of the millsite at a lower elevation. This terrace was used as the site of a settling pond during mill operations. Granite (granodiorite) bedrock of the Idaho batholith is exposed in the streambed and along ridge escarpments. The upper terrace material that underlies the site and separates it from bedrock is composed of deep sandy and loamy soils, gravels, sands, boulders, and cobbles. The lower alluvial terrace is made up of riverwash material, primarily of granitic origin.

The bedrock at Lowman is of igneous rather than sedimentary origin. The interface between bedrock and overlying unconsolidated materials is highly variable and influences the ground water flow systems of the area. The rocks are variably fractured and weathered. A simplified stratigraphic column of the bedrock and overlying materials is shown in Figure 2-5.

2.7.2 Surface Water Hydrology

While no opportunity was provided for FB&DU to conduct field evaluations of site hydrology, existing information was examined to characterize general hydrologic conditions in the vicinity of the site. The results of this survey are contained in this and Paragraph 2.7.3. Apparently no further hydrologic characterization of the Lowman site is contemplated at this time.

The flowing surface waters near the site consist of Clear Creek, the South Fork Payette River, and ditches on the site. The Clear Creek drainage area is shown in Figure 2-6. Clear Creek merges with the South Fork Payette River at Lowman, which is approximately 0.5 mi south of the site. Clear Creek flows on an essentially bedrock surface and is actively downcutting its channel. It has sufficient channel capacity to carry minor floods, and there is no evidence of erosion of even the lowest terrace, although it is possible that a large flood might top this terrace. Areas of the pile nearest the bank could be subject to erosion by undercutting of the bank, but the only sandy residues that have washed downstream are those that have been eroded from the steep slopes by surface runoff.

Water quality and flooding data for Clear Creek are largely unavailable. There does not appear to be a history of significant flooding of Clear Creek except from the backup of flood waters of the South Fork Payette River. Sampling of surface waters does not indicate any contamination from the radioactive sands and residues although contamination of surface waters near the piles could occur by physical transport of the sands in overland runoff and by seepage from the piles. The physical transport of sand from the piles has been aggravated by the steep banks of the sparsely vegetated piles, the slopes of which have been gullied up to 10 ft in depth by storm runoff. Rill erosion is occurring on the back-cut behind and adjacent to the mill foundations. The ridge to the east of the piles limits the catchment area near the site; however, a substantial trench was constructed during milling operations to convey process water from the eastern slope around the ridge to the mill. The ditch continues to channel runoff and intercepts shallow subsurface lateral flow. This concentration of flow could cause erosion problems on the glacial terrace. The placement of radioactive residues parallel to the slope of the piles traps water on the surface and has served to discourage runoff and to increase filtration into the sands.

2.7.3 Ground Water Hydrology

Shallow, unconfined aquifers characterize the hydrology of the area. Clear Creek and the South Fork Payette River are gaining streams recharged by flows of unconfined ground waters. The mountain slope land with its veneer of soil overlying fractured bedrock releases waters at a moderate to rapid rate

and dries out quite rapidly after snowmelt. The terrace lands, such as those that underlie the site, act as filters of sediment and tend to regulate overland and subsurface flow as waters percolate through the deposits before reaching the creeks and rivers. Subsurface flow at the millsite consists of percolation into the unconfined ground water system with shallow lateral flow along the interface between the unconsolidated materials and the underlying bedrock. Generalized ground water flow directions in the area are shown in Figure 2-7. Eight wells within 2 mi of the site are on record at the Idaho Department of Water Resources.(5)

Only one seep is present on the site itself, but there are several seeps and springs nearby along the interface of the terrace with the underlying bedrock surface. One of these springs is situated along the southern margin of the glacial terrace near the source of domestic water of a nearby trailer home. Some of these springs are recharged by storage from underlying bedrock. Others, such as along the southern margin of the pile, are recharged by infiltration through the terrace deposits.

There is no problem associated with contamination of the confined ground waters of the site because there are no confined ground waters associated with the igneous bedrock of the Idaho batholith.

2.7.4 Meteorology

Very little quantitative information exists regarding the frequency, duration, and intensities of winds at Lowman. The strongest winds are those that blow up or down the valley. Local relief and orientation of streams, valleys, and mountains affect wind direction while irregular terrain and the forest canopy tend to serve as windbreaks. Data taken from the Lowman Ranger Station for the period of 1964 to 1974 are summarized in Table 2-2. These data were used in health effects calculations.

Average annual precipitation at the site ranges between 20 and 25 in. Snowpacks are moderate and snowmelt can occur on and off in late winter months. Runoff is usually spread over a 3- to 4-mo period ending in late May. Heavy rainstorms occur approximately once every 10 yr. Such high-intensity rainfall at the site would result in serious erosion of the more susceptible areas of the piles.

FIGURE 2-1. AERIAL PHOTOGRAPH OF SITE

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FIGURE 2-2. TOPOGRAPHIC MAP

FIGURE 2-3. LAND OWNERSHIP AND SITE DESIGNATION MAP

LOWMAN, IDAHO SITE

BEGINNING AT A POINT WHICH IS S 0°01'W, 326.7 FT FROM THE N.E. 1/4 CORNER OF SECTION 27, T9N, R7E, SAID POINT BEING THE NO. 1 POINT ON THE HOMESTEAD ENTRY SURVEY NO. 490 (H.E.S.), AND RUNNING THENCE S 0°01'W, 993.3 FT TO H.E.S. 490 CORNER NO. 2, THENCE WEST 330 FT TO H.E.S. 490 CORNER NO. 3, THENCE SOUTH 755.04 FT TO H.E.S. 490 CORNER NO. 4 THENCE WEST 112 FT TO THE NORTH R/W LINE OF IDAHO STATE HIGHWAY NO. 21, THENCE NORTHWESTERLY ALONG SAID R/W LINE TO THE EAST MEANDER LINE OF CLEAR CREEK, THENCE NORTHERLY ALONG SAID MEANDER 1708 FT (MORE OR LESS) TO H.E.S. 490 CORNER NO. 6, THENCE EAST 1045.44 FT TO THE POINT OF BEGINNING.

CONTAINS 36 ACRES (MORE OR LESS)

NOTE:

ADAPTED FROM REFERENCE 1

NO SCALE

FIGURE 2-4. DESCRIPTIVE MAP

ERA	SYSTEM	SERIES	FORMATION	CHARACTER
CENOZOIC		HOLOCENE AND LATE PLEISTOCENE	ALLUVIAL DEPOSITS	GRANITIC PEBBLES AND SAND AQUIFER
		PLEISTOCENE	GLACIAL TERRACE— OUTWASH	POORLY SORTED, BOULDERS, COBBLES, GRAVEL AND SAND AQUIFER
MESOZOIC	CRETACEOUS LATE JURASSIC		IDAHO BATHOLITH	GRANITIC BATHOLITH, PRIMARILY GRANODIORITE & QUARTZ MONZONITE ONLY UPPERMOST FRACTURED AND WEATHERED ZONE IS AN AQUIFER

FIGURE 2-5. SIMPLIFIED STRATIGRAPHIC COLUMN

FIGURE 2-6. SURFACE DRAINAGE

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FIGURE 2-7. GENERAL DIRECTION OF GROUND WATER FLOW

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TABLE 2-1
CONTAMINATED MATERIALS AT THE LOWMAN SITE

<u>Material</u>	<u>Volume (yd³)</u>	<u>Weight (tons)</u>	<u>% U₃O₈</u>
White Sand	--	50,000	0.01
Black Sand	--	23,000	0.02
Grey Sand	--	10,000	0.18
Original Source Ore	--	5,000	0.22
Contaminated Soil in Mill and Ore Storage Area	9,700 ^a	13,000 ^e	--
Contaminated Subsoil Beneath Sands	48,400 ^b	65,000 ^e	--
On-Site Windblown	9,700 ^c	13,000 ^e	--
Off-Site Windblown	8,900 ^d	12,000 ^e	--
Total		191,000	

^aBased on 3 acres contaminated to an average depth of 2 ft.

^bBased on 10 acres contaminated to an average depth of 3 ft below interface.

^cBased on 12 acres contaminated to an average depth of 6 in.

^dBased on 11 acres contaminated to an average depth of 6 in.

^eWeight based on a density of 100 lb/ft³.

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TABLE 2-2

METEOROLOGY FOR LOWMAN, IDAHO
(Data Recorded at Lowman Ranger Station from 1964 to 1974)

<u>Direction</u>	<u>Frequency (%)</u>	<u>Direction</u>	<u>Frequency (%)</u>
N	2.9	S	0
NNE	5.5	SSW	0
NE	34	SW	0
ENE	42	WSW	0
E	0	W	0
ESE	0	WNW	0
SE	0	NW	0
SSE	0	NNW	0

Calm exists 15.6% of the time.

Annual average windspeed--6.5 mi/hr

Pasquill Stability Class--D for 50% of the time and
E for 50% of the time

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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 Lowman sand and residue piles and the resulting potential exposure to the population residing and working in the vicinity of Lowman, Idaho. In addition, this chapter briefly describes the potential radioactive and chemical pollutants and their pathways in the environment. The notations and abbreviations used are given in Table 3-1.

A radiological survey of the Lowman site was conducted by Oak Ridge National Laboratory (ORNL)⁽¹⁾ concurrently with work performed by FB&DU in 1976. The principal results of that work are included in this engineering assessment.

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 a tailings pond. The sands and slimes that remain constitute the tailings piles. Generally, 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 will 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. (Refer to Glossary at the end of the report.)

3.3 NATURAL BACKGROUND RADIATION

Several sources of radiation occur naturally in the environment. Natural soils contain trace amounts of uranium, thorium, and radium that give rise to radon gas and to alpha, beta, and gamma radiation. The average background value in nine off-site soil samples for each member of the uranium decay chain, assuming equilibrium, was 1.1 pCi/g.⁽¹⁾ The sample locations within a 90-mi radius of Lowman and the corresponding ²²⁶Ra concentrations are shown in Figure 3-2. Another natural source of radiation in the environment arises from the decay of ²³²Th, the predominant thorium isotope. The half-life of ²³²Th 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 factors of 2 and 5, respectively.

Additional soil samples for the determination of the background concentration of ²²⁶Ra were collected at three locations at an average distance of 0.5 mi from the radioactive sands area and were found to average 1.1 pCi/g, in agreement with results described above. The sample locations are shown in Figure 3-3 along with the corresponding concentrations of ²²⁶Ra.

Background values of radon concentrations were measured at four locations (shown in Figure 3-4) using continuous radon monitors supplied by ERDA.⁽²⁾ An average outdoor value of 1.2 pCi/l was obtained from the 24-hr samples for the vicinity of Lowman. The range of the measurements extends from 1.1 to 1.3 pCi/l.

Background external gamma radiation (EGR) levels, as measured at 3 ft above the ground, also were determined at several locations greater than 0.2 mi from the site by using a calibrated and energy-compensated Geiger Mueller detector. A value of 11 μ R/hr was established as the average background level, but the values ranged from 10 to 12 μ 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 5 μ R/hr in the Lowman area,⁽³⁾ or approximately 45% of the average measured 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.
- (b) External whole-body gamma exposure directly from the radionuclides in the tailings pile (primarily from ^{214}Bi) and in surface contamination from tailings spread in the general vicinity of the pile.
- (c) Inhalation of windblown tailings; the primary hazard relates to the alpha emitters ^{230}Th and ^{226}Ra , each of which causes exposure to the bones and the lungs.
- (d) Ingestion by man of ground or surface water contaminated from either radioactivity (primarily from ^{226}Ra) leached from the tailings pile or from solids physically transported into surface water.
- (e) Erosion and removal of tailings material from the pile by flood waters or heavy rainfall; this can create additional contaminated locations with the same problems as the original tailings pile.
- (f) Physical removal from the tailings pile also provides a mechanism for contamination of other locations.
- (g) Contamination of food through uptake and concentration of radioactive elements by plants and animals is another pathway that can occur; however, this pathway was not considered in this assessment.

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

3.4.1 Radon Gas Diffusion and Transport

Measurements of the radon flux from the sand and residue piles using the charcoal canister technique⁽⁴⁾ were made in 1977. The locations and resulting fluxes are shown in Figure 3-5; the values range from 50 to 150 pCi/m²-s on the piles. The weather was dry during the measurement period but the soil was moist from rain a few days previously. Radon flux depends principally on radium content of the piles. 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.

From the model calculations, radon gas above background from the piles is predicted to a distance of 0.4 mi from the site. Measurement locations and corresponding 24-hr average radon concentrations including background are illustrated in Figure 3-4.

Variations of radon concentration at two locations during the measurement period and the concomitant weather conditions are shown in Figures 3-6 and 3-7. The sample location for Figure 3-6 is on the site of the old mill building. Figure 3-7 illustrates the measurements at the motel 0.5 mi southwest of the site. A diurnal variation of ²²²Rn concentration may be seen in both figures, indicating the presence of a source of ²²²Rn greater than background near the measurement locations. Thus, the higher-than-normal background values are not merely the result of a high instrument background count. These 24-hr measurements were obtained during atmospheric conditions normal for that time of year (September). Data were not recorded during wind or rainstorms.

Radon concentration measurements taken during this program showed a slight diurnal variation, with nighttime levels being higher than daytime levels. 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 piles.

The radon concentration measurements and model predictions are plotted in Figure 3-8 as a function of distance from the edge of the site. Model calculations were performed with annual meteorology data and conservatively estimated meteorology to provide an additional estimate of the radon concentration in the vicinity of the piles. The FB&DU model first determines radon flux and the total radon releases from the piles 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⁾ using annual average wind conditions. The meteorology used for the model predictions was taken at the Lowman Ranger Station during the period 1964 through 1974.

Due to the low radon concentration measured on the site, the model results were used to estimate conservatively the potential health effects resulting from radon diffusing from the Lowman site.

3.4.2 Direct Gamma Radiation

The EGR levels, including background, measured on the site are shown in Figure 3-9. These measurements were taken 3 ft above ground with calibrated energy-compensated Geiger Mueller detectors.⁽¹⁾ The highest gamma radiation rate (2,450 $\mu\text{R/hr}$) was measured on the ore pile north of the mill area. The next highest radiation rate (1,220 $\mu\text{R/hr}$) was found on the grey sand pile along the top edge of the slope above Clear Creek. Gamma radiation rates were generally well above background rates throughout the area where residue piles are located.

EGR measurements away from the piles, taken at 100-yd intervals, reached background levels within 0.2 mi north of the site and within 0.1 mi in the other directions. These measurements are also shown in Figure 3-9. The reduction of gamma radiation as a function of distance from the sands area is shown in Figure 3-10.

3.4.3 Windblown Contaminants

Another pathway is the result of windblown radioactive sands. Prevailing winds are from the north and south through Clear Creek Valley.

Figure 3-11 shows iso-exposure lines due to the residual windblown sands as determined by the EPA.⁽⁶⁾ If scattered sands and ore are removed from inside the 10 $\mu\text{R/hr}$ line (toward the piles) or if the pile is covered to provide essentially complete gamma shielding, the remaining sands outside the line (away from the piles) would produce a new gamma exposure rate, 3 ft above ground, approximately equal to 10 $\mu\text{R/hr}$. The 10 $\mu\text{R/hr}$ iso-exposure line extends slightly to the north of the millsite to include the ore stockpile. There is little windblown radioactive material, since the background line closely follows the boundary of the area where the piles are located.

Measurements were made to establish a boundary around the site contaminated by windblown materials in excess of 5 pCi/g of ^{226}Ra . A lead-shielded scintillometer, NaI(Tl), was used. One end of the scintillometer was unshielded and directed toward the ground, where it was held about 1 in. above the soil surface. An unshielded reading was obtained. A 0.5-in.-thick lead shield was then placed between the detector and the soil surface and a second reading was taken. The difference between the unshielded and shielded readings, called the "delta", is an indication of the ^{226}Ra concentration in the soil at that location. A delta of about 400 counts/min with the instrument

used has been estimated to indicate a soil concentration of about 5 pCi/g of ^{226}Ra .

Traverses with the scintillometer were conducted across open lands adjacent to the radioactive sands area and were continued until a soil contamination of 5 pCi/g of ^{226}Ra was indicated. Figure 3-12 shows the traverses and the location of the 5 pCi/g of ^{226}Ra level on each traverse. These points are connected by a line to indicate the estimated area surrounding the site contaminated in excess of 5 pCi/g of ^{226}Ra . The greatest extent of radioactive spread was found to the north (up the canyon from the site), where the 5-pCi/g level was reached at a distance of 500 ft from the site. To the south and east the 5-pCi/g level was reached within 200 ft of the site, and the 5-pCi/g boundary extends about 250 ft beyond Clear Creek on the west side of the site. This estimated boundary correlates very closely to that identified by the EPA(6) as "background".

Surface soil samples were taken in the area surrounding the piles.⁽¹⁾ The sample locations and ^{226}Ra concentrations are shown in Figure 3-13.

Surface soil samples taken on site contained ^{226}Ra in concentrations ranging from background levels to 15 times background. An exception was one sample taken between the lower settling pond and Clear Creek that contained 200 pCi/g of ^{226}Ra . This sample evidently included sand that had washed down the slope from the grey sand pile.

The total contaminated area that is assumed to be the result of windblown sands covers approximately 23 acres. However, only 11 acres of the windblown contaminated land are situated outside the site boundaries.

3.4.4 Ground and Surface Water Contamination

Three surface water samples were taken in the vicinity of the Lowman site and analyzed for ^{226}Ra , as shown in Figure 3-13.⁽¹⁾ Two samples were taken from Clear Creek, one sample upstream and one downstream from the site. The upstream sample contained 0.16 pCi/l. The sample downstream contained only a trace of ^{226}Ra . The third sample taken from a spring southwest of the site contained 0.12 pCi/l of ^{226}Ra . From the water sample analyses, there is no indication of ^{226}Ra leaching from the Lowman sands into the surrounding ground and surface waters. This finding is consistent with the refractory nature of the Lowman ore and residue sands.

3.4.5 Soil Contamination

The extent of leaching of radium from the sands and residues into the soil was determined by drilling hand auger holes in and around the piles and into the soil beneath them.

The radioactivity profile was measured in these holes with a Geiger tube probe in a lead shield that collimates the radiation.

The gamma measurements indicated that twice background concentrations of radium were generally reached at depths of 2 to 3 ft below the interface. In a few cases, contamination was 2 to 3 times background radium concentration 3 ft below the pile-soil interface.

3.4.6 Off-Site Use of Radioactive Sands

A mobile gamma survey located sites in Lowman 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.

In cooperation with the EPA, the Idaho Radiation Control Section measured radon working levels from December 1973 to June 1974 in a commercial establishment in Lowman where radioactive sands had been used. Working levels ranged from 0.011 to 0.030 with an average of 0.02 for the measurement period. The occupancy factor will be considered in determining the need for remedial action.

3.5 REMEDIAL ACTION CRITERIA

Although the following discussion refers to uranium mill tailings, it also applies to the radioactive sands and residues on the Lowman site.

The Grand Junction criteria for remedial action were adopted as a basis for the engineering assessments that preceded the enactment of PL 95-604, the Uranium Mill Tailings Radiation Control Act of 1978. The criteria adopted applied to: (a) the cleanup of structures⁽⁷⁾ where tailings are present, and (b) the cleanup of open land.

Prior to passage of PL 95-604, the criteria applied to structures were the guidelines established by the U.S. Surgeon General by letter of July 27, 1970, to the Director of the Colorado Department of Health for use in dwellings constructed with or on tailings. The guidelines were expressed in terms of external gamma radiation and radon daughter concentrations.

By letter of December 1974, the EPA provided radiological criteria for decontamination of inactive uranium millsites and associated contaminated land areas. These criteria were expressed in terms of the "as low as practicable" philosophy and required that after remedial action has been completed, the residual gamma radiation levels should not exceed 40 μ R/hr above background in unusual circumstances and must be near background levels in most cases. Furthermore, these criteria required

that cleanup of radium contamination should reduce the soil concentration of radium to less than twice background. The stabilized tailings area should be designated as a controlled area, restricted from human occupancy and fenced to limit access. However, open land areas where residual gamma levels were less than 10 μ R/hr above background were allowed to be released for unrestricted use.

Title II, Section 206 of PL 95-604 required the EPA to promulgate standards for the protection of the public and the environment from radiological and nonradiological hazards associated with residual radioactivity (as defined in the Act) at inactive uranium mill tailings and depository sites. The EPA subsequently published both interim cleanup standards (45 FR 27366) and proposed disposal standards (46 FR 2556).

3.5.1 EPA Interim and Proposed Standards

The interim cleanup standards and the proposed disposal standards require that remedial actions be conducted to provide reasonable assurance that:

- (a) For a period of at least 1,000 yr following disposal:
 - (1) Radon released from the disposal site to the atmosphere would not exceed 2 pCi/m²-s;
 - (2) Substances released from the disposal site to underground sources of drinking water would not contaminate the water in excess of limits described in the tabulation below; and,
 - (3) Substances released from the disposal site to surface waters would not contribute to contamination otherwise existing in the water.

<u>Substance</u>	<u>mg/l</u>
Arsenic.	0.05
Barium	1.0
Cadmium.	0.01
Chromium	0.05
Lead	0.05
Mercury.	0.002
Molybdenum	0.05
Nitrogen (in nitrate).	10.0
Selenium	0.01
Silver	0.05

<u>Substance</u>	<u>pCi/l</u>
Combined ^{226}Ra and ^{228}Ra	5.0
Gross alpha particle activity (including ^{226}Ra but excluding radon and uranium)	15.0
Uranium	10.0

- (b) The average concentration of ^{226}Ra attributable to residual radioactive material from any designated processing site in any 5-cm thickness of soils or other materials on open land within 1 ft of the surface, or in any 15-cm thickness below 1 ft, shall not exceed 5 pCi/g.
- (c) The levels of radioactivity in any occupied or occupiable building shall not exceed either of the values specified in the listing below, because of residual radioactive materials from any designated processing site.

Average annual indoor radon decay
product concentration--including
background (WL) 0.015

Indoor gamma radiation--above
background (mR/hr). 0.02

3.5.2 NRC Regulations on Uranium Mill Tailings

In the NRC's final regulations for uranium mill licensing requirements, amendments to 10 CFR Parts 40 and 150 incorporate licensing requirements for uranium and thorium mills including tailings and wastes into the Commission's regulations.

The amendments of Part 40, Section 40.2a, include the statement:

Prior to the completion of the remedial action, the Commission will not require a license pursuant to this Part for possession of byproduct material as defined in this Part that is located at a site where milling operations are no longer active, if the site is designated a processing site covered by the remedial action program of Title I of the Uranium Mill Tailings Radiation Control Act of 1978. The Commission will exert its regulatory role in remedial actions, primarily through concurrence and consultation in the execution of the remedial action pursuant to Title I of the Uranium Mill Tailings Radiation Control Act of 1978.

In view of the foregoing and since under provisions of PL 95-604 a site on which tailings have been stabilized must be maintained under a license issued by the NRC, all uranium mill tailings disposal sites under PL 95-604 may eventually be subject to the criteria set out in Appendix A to Part 40. The criteria pertaining to tailings and waste disposal and stabilization that may apply in whole, or in part, to remedial action activities under PL 95-604 are summarized as follows:

Criterion 1 - The disposal site selection process should be an optimization to the maximum extent reasonably achievable for long-term isolation of the tailings from man, considering such factors as remoteness, hydrologic and other natural characteristics, and the potential for minimizing erosion.

Criterion 2 - To avoid proliferation of small waste disposal sites and thereby reduce perpetual surveillance obligations, with certain qualifications, byproduct material from in situ extraction operations and wastes from small remote above-ground extraction operations shall be disposed of at existing large mill tailings disposal sites.

Criterion 3 - The prime option for disposal of tailings is placement below grade. Where this is not practicable, it must be demonstrated that an above-grade disposal program will provide reasonably equivalent isolation of tailings from natural erosional forces.

Criterion 4 - If tailings are located above ground, stringent siting and design criteria should be adhered to. Factors to be considered include the following:

- (a) Minimization of upstream catchment area
- (b) Topographic features for wind protection
- (c) Relatively flat embankment slopes
- (d) Self-sustaining vegetative or riprap cover
- (e) Earthquake impact avoidance
- (f) Promotion of soil deposition

Criterion 5 - Steps shall be taken to reduce seepage of toxic materials into ground water to the maximum extent reasonably achievable.

Criterion 6 - Sufficient earth cover, but not less than 3 m, shall be placed over tailings or wastes at the end of milling operations to result in a calculated reduction in surface exhalation of radon from the tailings or wastes to less than 2 pCi/m²-s above natural background levels. Direct gamma exposure from the tailings or wastes should be reduced to background levels.

Criterion 11 - Provisions are set out for eventual transfer of ownership of the tailings to the State or to the United States.

Criterion 12 - The final disposition of tailings or wastes at milling sites should be such that ongoing active maintenance is not necessary to preserve isolation. Annual inspections should be conducted by owners.

EPA proposed and interim environmental standards for uranium mill tailings stabilization are generally consistent with the NRC proposed criteria as given above. However, they add the important further condition that the stabilization should be designed to provide reasonable assurance of remaining effective for at least 1,000 yr.

3.6 POTENTIAL HEALTH IMPACT

An assessment has been made of the potential health impact of the sands and residues. The 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.(1,8) In order to estimate the health effects attributable to radon released from the piles, the model values were used; the model values indicated elevated radon levels to 0.4 mi from the site.
- (b) External Gamma Radiation - Gamma radiation above background is measurable to distances up to 0.2 mi from the piles to the north and 0.1 mi in the other directions. There are no residents in the area. People on site will receive some gamma exposure until the piles are covered with sufficient material to reduce the gamma radiation. Exposure to the local population within 1 mi of the piles has been evaluated and yields a negligible health impact compared with exposure from radon daughters.

- (c) Airborne Activity - The lack of significant quantities of windblown sands 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.(9,10) Stabilization of the Lowman sands against wind erosion will eliminate any gradual accumulation of sands off the site.
- (d) Water Contamination - The ^{226}Ra activity in nearby surface water does not indicate contamination from the sand piles, but a potential exists for erosion of sands into Clear Creek by surface runoff from rainstorms.
- (e) Subsoil Contamination - Leaching of radioactive materials into the ground beneath the piles and at the millsite is on the order of 2 to 3 ft with isolated areas of deeper contamination.
- (f) Physical Removal - Radioactive sands that have been placed near a structure or used in its construction are sources of elevated gamma levels and radon daughter concentrations in the structure. Radiation exposure to individuals living or working in these structures can be significant. (For details refer to Chapter 7.)

Only the potential health effects from the inhalation of radon daughters (pathway a) are estimated quantitatively in this assessment because this pathway produces the most significant exposure.(8-10) Furthermore, the uncertainty in the estimates of the potential health effects from this pathway far exceeds the magnitude of the health effects from the other pathways.

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

3.6.1 Assumptions and Uncertainties in Estimating Health Effects

Since radiation exposure from ^{222}Rn progeny 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 are often expressed in terms of rems; however, estimates of the WLM-to-rem conversion factor for internal lung exposure to alpha particles from ^{222}Rn progeny are observed to vary by over an order of magnitude.⁽¹¹⁾ 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 BEIR-III⁽¹²⁾ risk estimator for lung cancer is based only on the absolute model since the relative risk model is not considered valid.⁽¹³⁾

The BEIR-III risk estimators for radon daughters are age-dependent, with the age specified as the age at the diagnosis of cancer. The minimal latent period following exposure is also age-dependent. The following values can be determined:

<u>Age (yr)</u>	<u>Minimal Latent Period From Age at Exposure (yr)</u>	<u>Excess Risk at Age of Diagnosis (cancers per yr per 10^6 person WLM)</u>
0-14	25	0
15-34	15	0
35-49	10	9
50-65	10	18
66-75	10	42

These risk values are expressed in terms of WLM using the BEIR-III recommended conversion factor of 6 rem per WLM. These risk estimators are based on combined estimates for uranium miners and fluorspar miners; no data exist that indicate whether these values may be used for groups irradiated in childhood. Nevertheless, in the treatment below they are conservatively assumed to apply to the population at large.

The BEIR-III report does not discuss plateau periods. However, some data presented in the report indicate cancers are still being detected as much as 50 yr after the period of

exposure. Therefore, it is reasonable to assume that a lifetime plateau to age 75 may be applicable.

The age-dependent excess risks presented in the BEIR-III report must be adjusted, when applied to the population at large, to account for the fact that the breathing rate of miners on the job is about 1.9 times greater than that of the general population.⁽¹⁴⁾ Since exposure is considered proportional to the breathing rate, the exposure (and hence the excess risk) of the general population would be smaller by this same factor.

The cumulative risk estimator is obtained from the BEIR-III data adjusted for breathing rate by determining specific cancer risks for each year following an exposure. These risks are summed for the years between age at exposure and age 75. The contribution to the cumulative risk estimator from each age group is weighted by the respective fractions of the U.S. population found in those age groups.⁽¹⁵⁾ For the lifetime plateau to age 75, no cancers were assumed to occur in the years subsequent to age 75. The following cumulative risk estimator for the population at large is obtained using a lifetime plateau to age 75 and weighting by the age distribution of the U.S. population:

$$150 \text{ cancers per yr/10}^6 \text{ person} - (\text{WLM continuous}) \quad (3-1)$$

Because of the many factors that contribute to natural biological variability and of the many differences in exposures among miners and among the population at large, this risk estimator is considered to have an uncertainty factor of about 3.

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

$$1 \text{ pCi/l of } ^{222}\text{Rn} = 0.005 \text{ WL} \quad (3-2)$$

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

The exposure rate in terms of WLM/yr can be obtained from a continuous 0.005-WL concentration as follows:

$$(0.005 \text{ WL})(8766 \frac{\text{hr}}{\text{yr}}) \left[\frac{1 \text{ WLM}}{(1 \text{ WL})(170 \text{ hr})} \right] = 0.25 \frac{\text{WLM}}{\text{yr}} \quad (3-3)$$

The risk estimator used for continual exposure to gamma radiation is expressed as:(16)

$$72 \cdot \dot{D} + 0.8 \cdot \dot{D}^2 \text{ cancers per yr/} 10^6 \text{ person rems/yr-continuous} \quad (3-4)$$

where $\dot{D}$ is the dose rate in rem/yr. In this assessment it is assumed that a gamma exposure of 1 R in air is equivalent to a dose of 1 rem in tissue.

3.6.2 Health Effects

The health effects attributable to radon released from the site in its present condition were calculated using a flux of 145 pCi/m²-s for the radioactive sands. This value was calculated using diffusion theory and the physical properties of the sands. Even though the calculated value for radon flux appears larger than the measured values, it is considered a more defensible estimate of the radon release rate since measurements of radon flux to date have been made only at a single point in time and give no suggestion of the magnitude of annual variations. In the absence of this information, the conservative estimate was chosen as the basis for health effect calculations.

The transport of radon from the sands was modeled using a Gaussian plume model, meteorology characteristics of the area, and population distribution surrounding the sands area as a function of the radius and direction from the center of the radioactive sand piles. The piles were modeled as a single vertical cylinder with an area and volume equal to the actual area and volume of the piles.

Total predicted outdoor ²²²Rn concentration is shown as a function of distance from the edge of the sands area in a west-southwest direction in Figure 3-8. The predicted ²²²Rn concentration at 0.15 mi from the edge of the sands area is about 30% higher than background level. The predicted radon concentration appears to be in general agreement with measured values shown in Figure 3-8.

Figure 3-14 shows the lung cancer risk per year from continuous exposure to radon as a function of distance west-southwest of the sands area. The curve shows that the risk for developing lung cancer from radon emanating from the sands is about 10% higher than the natural occurrence from all causes at a distance of 0.15 mi from the edge of the sands area but declines to the natural occurrence within 0.4 mi.

The population distribution within 3 mi of the edge of the sands area was developed using an actual count of nearby homes and population information provided by Lowman postal officials. This distribution includes all residents close enough to the sands area to be noticeably exposed to radon exhalation from the sands, as described in Chapter 4.

The three population projections used to estimate the cumulative health impacts attributable to the radioactive sands were the 0.8% constant growth rate and the 5% and 10% declining growth rates discussed in Paragraph 4.2. All three growth projections assume that the population is distributed in the proportions reflected in Table 4-1.

Table 3-3 presents the estimated health impacts from the radioactive sands for 0 to 3 mi from the edge of the sands area, based on the estimated 1980 population distribution presented in Table 4-1. The cumulative health effects for the three growth scenarios considered for Lowman are also included. In Table 3-3, the health effects caused by the radon from the sand piles are shown to be less than 2% of those caused by background radon for the vicinity within 3 mi of the edge of the sands area.

3.7 NONRADIOACTIVE POLLUTANTS

Four water samples were taken from the vicinity of the Lowman site and chemically analyzed. The locations of these samples are shown in Figure 3-13. Two of these samples were from Clear Creek upstream and downstream from the pile. The other two samples were taken from a well and a spring downgradient from the tailings piles. The chemical analyses for these samples are listed in Table 3-4. None of these water samples indicated leaching of nonradioactive pollutants from the piles.

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

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

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FIGURE 3-3. BACKGROUND SOIL SAMPLE LOCATIONS

6 □ 3.75 MI E OF SITE

5 □ 2.0 MI E OF SITE

DATE	SITE NO.	24 HR OUTDOOR (pCi/l)	24 HR INDOOR (pCi/l)	LOCATION
9/21/76	1	1.8	—	FORMER MILLSITE AREA
9/20/76	2	1.1*	—	AT GATE TO SITE, 0.1 MI S
9/21/76	3	1.1*	—	0.25 MI SW OF SITE
9/20/76	4	1.2	1.1	MOTEL, 0.5 MI SW OF SITE
9/22/76	5	1.3*	—	2.0 MI E OF SITE
9/22/76	6	1.1*	1.2	SERVICE STATION 3.75 MI E OF SITE

* LOCATIONS USED FOR BACKGROUND

FIGURE 3-4. RADON CONCENTRATION IN VICINITY OF SITE

FIGURE 3-5. RADON CANISTER LOCATIONS AND FLUX VALUES

LEGEND
 FB&DU WEATHER DATA

FIGURE 3-6. ^{222}Rn AND ATMOSPHERIC TRANSIENTS IN MILL BUILDING AREA SEPTEMBER 21, 1976

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FIGURE 3-7. ^{222}Rn AND ATMOSPHERIC TRANSIENTS AT MOTEL IN LOWMAN ON SEPTEMBER 20, 1976

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FIGURE 3-8. REDUCTION OF OUTDOOR ^{222}Rn CONCENTRATION WITH DISTANCE FROM THE SANDS AREA

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FIGURE 3-9. GAMMA LEVELS AT SITE 3 FT ABOVE GROUND

FIGURE 3-10. REDUCTION OF EXTERNAL GAMMA RADIATION LEVELS WITH DISTANCE FROM THE SANDS AREA

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FIGURE 3-11. EPA GAMMA SURVEY SURROUNDING MILLSITE

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FIGURE 3-12. WINDBLOWN CONTAMINATION SURVEY

FIGURE 3-13. SURFACE AND SUBSURFACE RADIUM CONCENTRATIONS

FIGURE 3-14. LUNG CANCER RISK FROM CONTINUOUS EXPOSURE TO RADON

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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.
working level (WL)	measure of potential alpha energy per liter of air from any combination of short-lived radon daughters ($1 \text{ WL} = 1.3 \times 10^5 \text{ MeV}$ of alpha energy).
working level month (WLM)	exposure to air containing a RDC of 1 WL for a duration of 170 hr.

TABLE 3-1 (Cont)

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.
$\mu\text{R/hr}$	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.

Note: Also see definitions of terms in Glossary.

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TABLE 3-2

BACKGROUND RADIATION SOURCES IN SOIL FROM SOUTHWEST IDAHO

<u>Isotope (Decay Chain)</u>	<u>Average Value (pCi/g)</u>	<u>Range (pCi/g)</u>
^{226}Ra (^{238}U)	1.12 ± 0.29	0.64 - 1.37
^{232}Th (^{232}Th)	1.18 ± 0.46	0.42 - 1.91
^{40}K	18.6 ± 2.5	15.4 - 22.1
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TABLE 3-3

ESTIMATED HEALTH IMPACT FROM LOWMAN RADIOACTIVE SANDS
FOR AN AREA 0 TO 3 MILES FROM EDGE OF SANDS AREA

<u>Time Period</u>	<u>Population (Persons)</u>	<u>Total Pile-Induced RDC Health Effects/Yr</u>	<u>Background RDC Health Effects/Yr</u>
1980	90	0.000060	0.0041
2005 (0.8% constant growth rate)	110	0.000073	0.0049
2005 (5% declining growth rate)*	171	0.00012	0.0077
2005 (10% declining growth rate)*	317	0.00020	0.014

25-Yr Cumulative RDC Health Effects

<u>Growth Projection</u>	<u>Pile-Induced</u>	<u>Background</u>
0.8% constant growth rate	0.0017	0.12
5% declining growth rate*	0.0023	0.16
10% declining growth rate*	0.0037	0.26

*Declines linearly from its initial value to zero in 25 yr and remains constant at zero thereafter.

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TABLE 3-4

CHEMICAL ANALYSES OF LOWMAN WATER SAMPLES (mg/l)

Sample ^a	As	Ba	Cd	Cr	V	Fe	Pb	Se
A - Clear Creek upstream from pile	0.008	0.07	<0.001	0.013	0.060	0.142	0.010	<0.001
B - Clear Creek downstream from pile	0.004	0.15	<0.001	<0.001	0.060	0.078	<0.001	<0.001
C - Spring south of pile	0.007	0.11	<0.001	0.007	0.020	0.326	<0.001	<0.001
D - Well south of pile	0.024	0.03	<0.001	0.011	0.120	0.417	<0.001	<0.001
EPA Interim Primary Drinking Water Regulations ^b	0.05	1.0	0.01	0.05	--	0.3 ^c	0.05	0.01

^aSee Figure 3-13 for locations.

^bFederal Register, Dec 24, 1975

^cRecommended limit from Manual for Evaluating Public Drinking Water Supplies, U.S. Public Health Service, 1969

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CHAPTER 4
SOCIOECONOMIC AND LAND USE IMPACTS

CHAPTER 4

SOCIOECONOMIC AND LAND USE IMPACTS

The Lowman site is located in Boise County, Idaho, about 75 road miles northeast of Boise, the capital of Idaho. The site is 0.5 mi east of the town of Lowman. State Highway 21 is immediately south of the site. Idaho City, the county seat, is 34 mi southwest of Lowman by way of State Highway 21. The Boise County boundaries are shown in Figure 4-1.

4.1 SOCIOECONOMIC BACKGROUND

Agriculture and forestry have traditionally provided Boise County with most of its industrial output. Employment related to recreational activities will play an increasingly important role in the area. Lots for seasonal homes and cabins are in demand. Timber will continue to be harvested, but a major expansion of the timber industry is unlikely because of inadequate transportation in the area.

The future of the mining sector of the economy appears to be bright. A large open-pit molybdenum mine is planned for a location approximately 10 mi southeast of Lowman, toward Garden Valley. It is projected that 600 people will be employed in the resulting mining operations. However, most of the employees will probably live in the Garden Valley or Banks area rather than the Lowman area because of better facilities and easier access to the mine. Several smaller mining operations, including a gold mine, are presently in the proving stage in the Lowman area.

Idaho Power Company has announced a plan called the South Fork Project that would involve the construction of four electric-generating dams on the South Fork Payette River. The four powerhouses would produce a total of 84,000 kW of electricity. This project has been postponed, but work continues toward its approval.

The telephone company has purchased land to build a substation in the area and plans to begin construction in 1981. Telephone service to the community will make the area more attractive as a residential and recreational area.

U.S. Forest Service personnel presently work in the Lowman area only from May to October, but by 1985 year-round operations are expected. This upgraded service is expected to bring 15 additional families to the valley as permanent residents.

4.2 POPULATION ESTIMATES

The populations of both Boise County and Lowman have increased over the past few years. The 1980 census figures

indicate that the population of Boise County increased 21% during the last decade, from 1,763 inhabitants in 1970 to 2,133 in 1980.⁽¹⁾ The 1980 census figures indicate that the population of the Lowman Census District is 73 people.⁽¹⁾ However, Lowman postal officials⁽²⁾ estimate the full-time residents of Lowman to total approximately 90, and this figure was used as the base population of the area for population projections, distributions, and health effect calculations. The estimated 1980 population distribution at Lowman is shown in Table 4-1 as a function of distance and direction from the radioactive sands site.

The projects described in the previous section suggest that the population of the area will continue to increase. However, other factors must also be considered in determining population projections and future growth patterns for the Lowman area. The population is small and very dependent upon fluctuations in the tourist, recreation, mining, and lumber industries in the area. With these factors and the new projects in mind, the three population projections shown in Figure 4-2 were selected as possible growth rates for Lowman.

The least optimistic projection for the area is based on the recent growth history of the United States.⁽³⁾ It estimates that the population will increase 0.8%/yr to a population of about 110 people by the year 2005. This growth scenario is presented as a lower bound on the future growth of the area.

The growth projection considered most reasonable for the area is the 5% declining annual growth rate. If this pattern is experienced, the annual growth rate of the area will decrease linearly from its initial rate of 5%/yr to zero growth after 25 yr. The population would thus reach a figure of about 170 people by the year 2005 and remain constant thereafter.

The most optimistic projection, a 10% declining annual growth rate, is presented as a likely upper bound on the future growth rate of the area. The annual growth rate will decline linearly from its initial rate of 10%/yr to zero growth after 25 yr. If this growth scenario were experienced, the population would double in 8.5 yr, reach a figure of about 320 people by the year 2005, and remain constant thereafter.

4.3 LAND USE⁽³⁾

A limited amount of land in the area is still being mined. Most of the land near the site either is forest land or is used for recreational homesites. Throughout the region there are numerous lots for sale, ranging in size from 0.2 to 1 acre. One subdivision with lots of this size is located across Clear Creek from the millsite. Land use in the Lowman area is depicted in Figure 4-3.

Projected land uses for the area near Lowman are similar to present land uses, with increased development of the lots as sites for both year-round and vacation homes.⁽⁴⁾

4.4 IMPACT OF THE RADIOACTIVE SANDS ON LAND VALUES

Single lots of private land ranging in size from 0.2 to 0.6 acre with a 100-ft frontage on the South Fork Payette River have assessed values of approximately \$10,000. Similar lots in the area without river frontage range from \$4,000 to \$8,000 each.

The presence of the radioactive sands and residues restricts the use of the site itself but has no discernible impact on land uses and values in the surrounding area. The assessed value of the 37-acre site, \$13,720, is much lower than that of the surrounding land because the presence of the radioactive sands and residues has greatly reduced the site's aesthetic qualities and utility for any form of development.

FIGURE 4-2. POPULATION PROJECTIONS

360-17 2/81

FIGURE 4-3. VICINITY LAND USE

360-17 12/77

TABLE 4-1

ESTIMATED 1980 POPULATION DISTRIBUTION AT LOWMAN

<u>Direction</u>	<u>Radial Distance from Edge of Radioactive Sands Site (mi)</u>								<u>Total</u>
	<u>0.15</u>	<u>0.25</u>	<u>0.50</u>	<u>0.75</u>	<u>1.0</u>	<u>1.5</u>	<u>2.5</u>	<u>3.0</u>	
W	0	0	1	16	3	0	0	0	20
WSW	0	0	9	10	0	0	0	0	19
SW	1	0	9	9	0	0	0	0	19
SSW	0	3	6	0	0	0	0	0	9
SE	0	0	0	6	0	3	0	0	9
ESE	0	0	0	0	0	0	7	7	14
Total	1	3	25	41	3	3	7	7	90

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CHAPTER 5
RECOVERY OF RESIDUAL VALUES

CHAPTER 5

RECOVERY OF RESIDUAL VALUES

The mineralized residues on the Lowman site are markedly different from the mill tailings at other sites in that they have not undergone chemical processing.⁽¹⁾ The feed to this plant was concentrate of heavy sands produced by a dredge in a placer mining operation about 20 mi to the north on Bear Creek. These sands were treated by physical concentration methods to produce one product with a high content of rare earth minerals, mainly columbite-euxenite, and a second product with enhanced monazite content. The monazite is a mineral containing both uranium and thorium, as well as phosphates and silicates. The euxenite is a multiple oxide mineral of cerium, columbium, tantalum, etc., which also contains small concentrations of uranium and thorium.

Characteristically, these products are considered refractory, or essentially non-amenable to the conventional processes used in uranium ore processing. Therefore, they were shipped to a specially designed plant at Hematite, Missouri, operated by Mallinckrodt Chemical Company. This plant produced both a uranium concentrate for sale to the AEC and a rare earth concentrate. The remaining residues on the Lowman site, which are in separated piles, were sampled and analyzed in connection with the Phase I site evaluation.

The results of the analyses were as follows:

<u>Material</u>	<u>% U₃O₈</u>	<u>% ThO₂</u>	<u>²²⁶Ra pCi/g</u>	<u>Approx. Tons</u>	<u>U₃O₈ (lb)</u>
Ore	0.22	0.06	616	5,000	22,000
Grey Sands	0.18	0.17	504	10,000	36,000
White Sands	0.01	0.02	28	50,000	10,000
Black Sands	0.02	0.01	56	23,000	9,000
Red Garnet	0.02	0.01	56	—	—
Total				88,000	77,000

Only the first two piles (ore and grey sands) shown in the tabulation have sufficient uranium to be of potential commercial interest. However, since the quantities involved are

much too small to justify construction of a processing plant (only 15,000 tons) and since the material is not amenable to the process used in any of the operating mills, reprocessing for additional metal recovery appears to be impractical. While the northern Rocky Mountain region appears to have a reasonable potential for further uranium resource development, significant finds of deposits with the types of minerals represented by the Lowman residues do not seem likely. Thus, any capital expenditure in the interest of processing the Lowman residues is difficult to justify.

The procedures used to extract valuable minerals from monazite type ores have been described in the literature.⁽²⁾ The two principal methods involved either digestion with hot, concentrated sodium hydroxide, or with hot, strong sulfuric acid. The reagent requirements are very large, and the processes are obviously much more costly than those used on the more common types of uranium ores.

The spot market price for uranium has dropped markedly in the last 2 yr to about \$25/lb of U_3O_8 early in 1981. Current projections of supply and demand indicate that there is no basis for a turn-around in uranium prices for about 5 yr. The supply and market for uranium, as estimated by the DOE Assistant Secretary for Resource Applications, are given in Table 5-1.⁽³⁾

In summary, the radioactive sands and residues at the Lowman site represent no practical uranium resource.

TABLE 5-1

U.S. URANIUM SUPPLY AND MARKET SUMMARY

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	<u>Sales Commitments</u>		<u>Est. U₃O₈ To Be Available For Sale</u>	<u>Procure- ment of Foreign Uranium</u>	<u>Reported Unfilled Requirement</u>	<u>Total Domestic Production Potential (1+2+3)</u>	<u>Total Domestic Supply (1+3+4)</u>	<u>Apparent Buyer Requirements (1+4+5)</u>
<u>Year</u>	<u>To Domestic Buyers</u>	<u>To Foreign Buyers</u>						
1980	21,500	2,000	2,600	1,800	400	26,100	25,900	23,700
1981	20,000	1,000	3,100	2,700	800	24,100	25,800	23,500
1982	19,400	1,000	4,300	2,800	1,300	24,700	26,500	23,500
1983	17,400	900	7,100	2,500	1,800	25,400	27,000	21,700
1984	16,000	500	7,800	2,500	4,000	24,300	26,300	22,500
1985	13,900	500	8,800	2,400	4,300	23,200	25,100	20,600
1986	11,200	300		1,000	9,900			22,100
1987	11,400	300		1,000	11,700			24,100
1988	10,500	300		1,000	12,000			23,500
1989	9,500	100		1,000	15,100			25,600
1990	7,300	100		1,000	14,400			22,700

Source: DOE/RA-0053

Survey of United States Uranium Marketing Activity, July 1980 (p. 17)

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CHAPTER 6
MILL TAILINGS STABILIZATION

CHAPTER 6

MILL TAILINGS STABILIZATION

The methods and criteria for stabilizing uranium mill tailings were briefly reviewed to assess their relevance to the radioactive sands and residues at the Lowman site. The conclusion was that the methods and criteria developed to date for uranium mill tailings can be assumed also to apply to the radioactive sands and residues at the Lowman site. Therefore, the following discussion on the stabilization of uranium mill tailings also is applicable to the stabilization of radioactive sands.

In all alternative remedial actions considered in this study, the stabilization of mill tailings is required. Stabilization, as used here, means implementation of efforts to prevent the introduction of potentially harmful materials into the biosphere from the tailings. Government agencies and private industry have conducted and are conducting research to develop economical and environmentally suitable methods of stabilizing uranium mill tailings. The methods, technology, and data on stabilization that are presently available were reviewed and are described in this chapter. This information includes results from previous investigations, as well as findings of current and continuing research.

The objective of stabilizing the uranium mill tailings is to eliminate the pathways to the environment for the radioactive and other toxic particles which are described in Chapter 3. Alternatively, conditioning tailings might significantly reduce the rate at which potentially hazardous substances are released to the environment. 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

Implicit in these objectives is the additional goal of ensuring long-term stability and isolation of the tailings without the need for continued active maintenance. These objectives are consistent with those of the proposed EPA standards for inactive uranium mill tailings disposal.⁽¹⁾

6.1 PREVENTION OF WIND AND WATER EROSION

Wind and water erosion could be prevented by treating the tailings surface (surface stabilization), solidifying the bulk of the tailings (volumetric stabilization), by emplacing covers over the tailings (physical stabilization), or by establishing plant growth over the tailings (vegetative stabilization). Each of these is discussed in the following paragraphs.

6.1.1 Surface Stabilization

Surface stabilization involves applying chemicals to the surface of the tailings to form a water- and wind-resistant crust. Surface 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. Surface stabilizers, however, are susceptible to physical breakup and gradual degradation and may not meet the long-term requirements for permanent stabilization of uranium mill tailings.

Other complications also can arise in achieving satisfactory surface stabilization. For example, the surfaces of tailings piles seldom are homogeneous, and variables such as particle size, acidity, and moisture content affect the bonding characteristics and stability of the surface stabilizers.^(2,3) Studies are currently being conducted to assess the possibilities of conditioning uranium mill tailings to minimize their impact if they were to migrate to the biosphere.⁽⁴⁾ It is possible that some conditioning techniques may change the characteristics of the tailings such that degradation of surface stabilizers by the tailings would be minimized.

Among the substances used to form crusts on mill tailings surfaces and thus reduce their susceptibility to wind erosion are: resinous adhesives; lignosulfonates; elastomeric polymers; milk of lime; mixtures of wax, tar, and pitch; potassium and sodium silicates; and neoprene emulsions.

Tests were conducted by the Bureau of Mines⁽²⁾ 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 lignosulfonate 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^(5,6) to achieve surface stabilization and to reduce wind erosion. The material decomposed and exposed the tailings within 2 to 3 yr after application.

"Cut-back" asphalt and asphalt-in-water emulsions also have been tested for use in protecting soils against wind and water erosion.⁽⁷⁾ Both were shown to be effective for short periods of time when applied as a fine spray on sandy soils. On clay soils, the film disintegrated within a few weeks of application, apparently because of expansion and contraction of the clays during cycles of wetting and drying. The film was porous, allowed infiltration of water, and did not interfere with germination of wheat, grass, or legume seeds. The film is damaged by insects and rodents, and respraying may be necessary. Three to five years after application of the asphalt treatment, the amount of dry erodible surface area in the tested soils had increased, suggesting that asphalt treatments may not be desirable under all conditions.

More recent experiments performed for DOE are attempting to establish that surface stabilizers are useful in the long term.^(3,8,9,10,11) Although some asphaltic emulsions applied on tailings surfaces have degraded in less than 1 yr, covering the surface stabilizer with soil after application can extend its useful life. Nevertheless, additional data must be obtained to demonstrate long-term effectiveness of surface stabilizers.

Asphalt emulsions might be useful if mixed with a sufficient thickness of tailings or overburden material (admixing) to form a volumetric seal, as opposed to a thin coating on the tailings surface.⁽¹²⁾ Admixing depths would have to be sufficient to minimize the potential for breakup of the volumetric seal. Recent studies have suggested that asphalt emulsion seals for uranium mill tailings may be stable for long-term applications.⁽¹¹⁾ Results of tests to determine the effects of temperature cycling (freeze-thaw), aqueous leaching, oxidation, exposure to brine solutions, and microbial attack indicate satisfactory stability of asphalt emulsions.

6.1.2 Volumetric Stabilization

Volumetric stabilization, which has been used in other mineral industry operations, involves the mixing of chemicals in sufficient quantities with tailings to produce a solidified, leach-resistant mass, much like mixing cement with sand and gravel to form concrete. The chemicals could be added in two ways: to a tailings slurry in a pipeline, or to the tailings in-situ. The in-situ method of stabilization is relatively new and research is being conducted to determine desirable materials to be added to tailings and the best techniques of application.^(10,11)

One of the features claimed for this stabilization method is that all pollutant chemicals are locked in the solidified mass so they cannot be leached from the solid. Recent studies have indicated that volumetric stabilization may suffer from eventual degradation, and requires careful matching of environmental conditions, tailings, and solidifying chemicals in order to be effective.⁽⁹⁾

A cover material, such as soil, might be required to protect the solidified mass from wind and water erosion, depending on the substances added to the tailings. Shallow rooted vegetation can be established after soil cover has been placed over the solidified mass. However, the long-term effect of plant root penetration into the stabilized tailings is unknown but probably would be a function of the specific chemical makeup of the solidified mass. Continued research to identify the conditions under which vegetation could thrive without affecting the integrity of volumetric stabilizers is required.

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, polymeric film, etc.).

Covers of gravel or crushed rock have been shown to be effective in preventing wind erosion and allow infiltration of water without permitting substantial erosion.⁽¹³⁾ Riprap, a cover of substantial rocks, armors the surface against erosion and may enhance growth of vegetation.^(14,15) Clays or clayey soils would be self-healing if the tailings settled, would hold moisture, and could be a key component of a stabilizing cover.

Artificial covers, such as a layer of asphalt or a synthetic membrane, could be placed over the tailings to reduce wind and water erosion. However, synthetic membrane materials containing plasticizers, e.g., polyvinyl chloride (PVC), are not suitable for exposed surface application because they are susceptible to damage by ultraviolet radiation. However, a thin synthetic sheet, although protected by soil from direct exposure, would have questionable mechanical strength and might not be able to maintain integrity in the long term.

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. Broad range surface runoff control channels and grading are also imperative to assure that the tailings site is protected from erosion by rainstorms and floods. Such treatments can greatly reduce long-term maintenance requirements and costs.

Both root growth and animal burrowing may provide pathways from the stabilized tailings to the environment and are therefore of concern. Research is currently under way to evaluate various chemical biobarriers for uranium mill tailings.⁽¹¹⁾ Herbicides in the form of polymeric sheets and pellets are being tested to determine their long-term ability to prohibit root growth into the tailings through the stabilizing cover material. Apparently, polymeric sheets containing herbicide are more costly than pellets, and pellets are substantially more convenient to use.

Burrowing habits of rodents and potential methods to limit burrowing are being investigated. It is believed that mechanical barriers will be more effective and less costly than chemical barriers in excluding burrowing animals from disposed tailings.

6.1.4 Vegetative Stabilization

Vegetative stabilization involves the establishment of plant growth on the tailings or on a growing medium placed over the tailings on the premise that the root system will tend to hold the soil in place.

Criteria for plant selection provide that the plants will:⁽¹¹⁾

- (a) Be tolerant of local environmental conditions.
- (b) Have properties that will aid in erosion control.
- (c) Have propagules that are readily available.
- (d) Be relatively easy to establish.
- (e) Be perennials, or annuals with good reproductive capabilities.
- (f) Have minimal rooting depth requirements.
- (g) Be of low food value and/or palatability.
- (h) Have low value as habitat for wildlife.

Many species of plants require little or no maintenance after growth becomes established, an essential aspect of vegetative stabilization. Vegetation may be able to survive provided that:

- (a) Evapotranspiration is not excessive.
- (b) Landscapes are properly shaped.
- (c) Nontoxic soil media capable of holding moisture are provided.
- (d) Irrigation and fertilization appropriate to the area are applied to initiate growth.

Growth of vegetation at sites receiving less than 10 in. of annual precipitation and with high evapotranspiration rates requires initial irrigation and fertilization. At Lowman, precipitation averages 20 to 25 in. annually.

A principal disadvantage of vegetative stabilization is the possibility of uptake of radioactive elements by the plants. However, if the plants are properly selected, and if there is a sufficient depth of soil cover over the tailings, this uptake will be minimal. Barriers to root penetration are currently being evaluated.

6.2 PREVENTION OF LEACHING

Leaching into underground aquifers is one of the pathways that chemicals and radioactive materials might follow to the environment. The techniques that could be employed to control leaching from tailings piles include the following:

- (a) Employ surface, volumetric, or physical stabilization to minimize infiltration of water, which would prevent leaching of hazardous elements into underground aquifers.
- (b) Physically compact the tailings to reduce the percolation of water through the materials.
- (c) Contour the drainage area and tailings surface to minimize the potential for water to penetrate into the tailings.
- (d) For a new site, line the disposal area with a low-permeability membrane.
- (e) Condition tailings to reduce leachability or contaminant content.

Current research of various liner systems has identified eight liner materials for continued laboratory study:

- (a) Natural soil amended with sodium-saturated montmorillonite (Volclay*)
- (b) Typical local clay with an asphalt emulsion radon-suppression cover
- (c) Typical local clay with a multibarrier radon-suppression cover
- (d) Rubberized asphalt membrane
- (e) Hydraulic asphalt concrete
- (f) Chlorosulfonated polyethylene (Hypalon*) or high-density polyethylene
- (g) Bentonite, sand and gravel mixture
- (h) Catalytic airblown asphalt membrane

Of these materials, the rubberized and hydraulic asphalts are judged to be the two most viable candidates at this time.(11)

Other studies(4) are addressing the possibility of conditioning the tailings such that if they were to leach, there would be minimal adverse impact.

6.3 REDUCTION OF RADON EXHALATION

Continuing research is directed toward reduction of radon exhalation from tailings piles.(3,8,9,16,17) While there are materials that can seal or contain the gas on a laboratory scale, their use for permanent coverage of large areas is presently being studied.

From simplified diffusion theory estimates, it can be shown that about 13 ft of dry soil(18,19) 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 depicts the dependence on moisture content of the effective diffusion coefficient for radon in soil. The dramatic decrease of the magnitude of the effective diffusion coefficient as the moisture content increases is responsible for the resulting reduction of radon flux.(20)

The reduction of radon exhalation flux for three soil types versus depth of cover is presented in Figure 6-2 and is based upon the theory and diffusion coefficients presented in the references cited earlier. Further research is currently

*Registered trademark.

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 surface stabilizers and varying thicknesses of stabilizing earth covers and combinations of materials are being investigated. The results may have an important impact in planning radon exhalation control. However, proposed NRC standards for stabilizing inactive mill tailings require a minimum of 3 m of cover over the tailings.⁽¹⁾ The 3-m cover was assumed to be sufficient to meet proposed radon release requirements in remedial action cost estimates presented in this report.

Investigations described in Paragraph 6.1 have shown that cationic asphalt emulsions can be effective in large-scale applications in reducing radon fluxes to required levels.⁽¹¹⁾

Studies of multilayer physical stabilization systems presently in progress are directed at identifying cost effective cover systems to satisfy proposed EPA standards for disposal.⁽¹⁾ These studies have indicated that, under a given set of conditions, a single-material cover would have to be up to about 24 ft (7.2 m) thick to reduce radon flux to the required 2 pCi/m²-s. In contrast, a well designed multilayer cover system of less than 8.5 ft (2.6 m) thickness under the same conditions could satisfy the radon flux requirement.

6.4 REDUCTION OF GAMMA RADIATION

A few feet of cover material have been shown to be sufficient to reduce gamma radiation to background levels.

The reduction of gamma exposure rates resulting from a packed earth covering is given in Figure 6-3.^(8,21) Two feet of cover reduce the gamma levels by about two orders of magnitude. Therefore, an average cover thickness of 3 m should reduce gamma levels from the tailings to background. Multilayer and asphalt cover systems currently under investigation have been shown to effectively attenuate gamma levels to acceptable ranges.

6.5 ASSESSMENT OF APPLICABILITY

Available data indicate that the methods previously used at the inactive sites in attempts to stabilize uranium tailings have not been totally satisfactory and that long-term solutions to uranium tailings site radiation problems have yet to be clearly demonstrated. Consequently, new or combination methods of stabilization are being evaluated. The present remedial action options include physical stabilization of the tailings with at least 3 m of well designed soil cover and 0.3 m of riprap. This action will reduce gamma radiation and wind and water erosion, substantially reduce radon exhalation, minimize infiltration, and allow reestablishment of native vegetation.

If remedial actions are taken, combinations of the methods described in this chapter for preventing erosion, leaching to ground water, radon exhalation, and gamma radiation will be implemented based on climatic, hydrogeological, economic, and demographic factors. The method of stabilizing uranium mill tailings whereby 3 m of well-engineered cover is placed on the pile is apparently the primary method currently available that satisfies both U.S.(1) and Canadian(22) regulatory requirements.

FIGURE 6-1. EXPONENTIAL MOISTURE DEPENDENCE
OF THE DIFFUSION COEFFICIENT

360-17 8/71

FIGURE 6-2. REDUCTION OF RADON EXHALATION FLUX WITH DEPTH OF COVER

360-17 2/81

FIGURE 6-3. REDUCTION OF GAMMA EXPOSURE RATE
RESULTING FROM PACKED EARTH SHIELDING

360-17 2/81

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CHAPTER 7
OFF-SITE REMEDIAL ACTION

CHAPTER 7

OFF-SITE REMEDIAL ACTION

An important objective of this engineering assessment is to estimate the cost of appropriate remedial action for those off-site properties contaminated with radioactive sands.

Discussed in this chapter are those locations where contaminated materials have been transported off site. Such off-site locations are classified as off-site windblown properties and off-site properties other than windblown. Costs associated with the cleanup of on-site contaminated areas, i.e., windblown, radioactive sand piles, millsite, and ore storage, are considered in Chapter 9.

Although the following discussion sometimes refers to uranium mill tailings, it also applies to the radioactive sands and residues on the Lowman site.

7.1 DATA SOURCES

A mobile scanning unit, operated by the AEC under an interagency agreement with the EPA, performed a gamma radiation survey of the Lowman, Idaho, area prior to 1973. Of the 25 structures scanned, 10 anomalies were reported. A joint team from the EPA Office of Radiation Programs, Las Vegas, Nevada, (EPA-ORP-LV) and the Idaho Department of Health performed individual gamma surveys of 13 locations to determine the source of the anomalies and, if the anomalies were due to tailings, how they had been used.⁽¹⁾ High and low inside and outside gamma readings were recorded. A gamma map was drawn if gamma readings inside the structures exceeded 20 μ R/hr.

The 5-pCi/g boundary mentioned in Paragraph 3.4.3 was the data source used for consideration of remedial action for windblown areas.

7.2 REMEDIAL ACTION FOR OFF-SITE PROPERTIES OTHER THAN WINDBLOWN

A follow-up survey of the anomalies⁽¹⁾ indicated that there were eight off-site locations with possible tailings use. One of these locations was a sandpile; the other seven were associated with a commercial establishment. Five of these seven locations were classified as "tailings surrounding and up against", while at two locations tailings were "under and surrounding" the structures.

Two other anomalies were caused by the presence of natural radioactive materials. Additional locations where radioactive residues have been used may be identified during future work.

Costs for remedial action at off-site properties, other than windblown, have been estimated to be \$250,000, exclusive of engineering and contingency allowances, based upon available information and adjusted Grand Junction off-site remedial action costs. This cost includes cleanup, backfill, restoration, and health physics and monitoring services. The estimated cost includes remedial action for the eight locations where definite tailings use has been identified.

7.3 REMEDIAL ACTION FOR OFF-SITE WINDBLOWN PROPERTIES

The extent of windblown radioactive sands and residues is estimated by the 5-pCi/g line in Figure 3-12. Decontamination of the area containing windblown sands consists of removing 6 in. of soil and replacing it with clean fill. The result of this action is assumed to satisfy the remedial action criteria discussed in Paragraph 3.5.

The cost for cleanup and restoration of approximately 11 acres of off-site land contaminated by windblown radioactive sands is estimated to be \$200,000, exclusive of engineering and contingency allowances.

CHAPTER 7 REFERENCES

1. "Community Summary Report for Radiation Surveys, Lowman, Idaho"; EPA; Office of Radiation Programs; Las Vegas, Nevada; 1973.

CHAPTER 8
DISPOSAL SITE SELECTION

CHAPTER 8

DISPOSAL SITE SELECTION

In the December 1977 engineering assessment, it was thought that the radioactive sands at the Lowman site would be stabilized in place as opposed to being transported to an off-site disposal location and therefore no disposal sites were identified in that report. Also, no effort was made to identify specific disposal sites during the 1980 field work.

At this time, however, in order to provide an understanding of the magnitude of remedial action costs if off-site disposal were elected, two unspecified disposal sites have been postulated. It was assumed that two sites that can meet the existing criteria for disposal are available at distances of 15 and 30 mi generally west of the radioactive sands location.

The source of cover material for disposal options was assumed to be located approximately 30 mi west of the present site, at the 30-mi disposal site. The 15-mi disposal site was assumed to be located halfway between the cover material source and the radioactive sands site.

The costs associated with remedial action (decontamination of the present site and disposal of the radioactive sands and residues) have been estimated for the two unspecified sites using typical disposal site preparation and haul costs. These cost estimates are presented in detail in Chapter 9. Care must be exercised in the use of these cost estimates because specific characteristics of actual disposal sites are not available and may differ substantially from those assumed for this study.

CHAPTER 9

REMEDIAL ACTIONS AND COST-BENEFIT ANALYSES

CHAPTER 9

REMEDIAL ACTIONS AND COST-BENEFIT ANALYSES

Various remedial action options for the tailings on the Lowman site were identified and investigated. The remedial actions presented are those considered to be the most realistic and practical when evaluated with regard to the present remedial action criteria, technology, and information available. Costs and benefits have been estimated and evaluated for each option considered.

The procedures for decontaminating inactive mill tailings sites have not been well established. Although remedial action criteria have been established tentatively, the methodology of satisfying such standards is still in a state of change. The position has been taken that radiological and industrial safety should be pursued to the extent necessary to satisfy remedial action criteria and to provide assurance to the public and to workers. The public should feel comfortable with the methodologies used.

Since each state where tailings are located must participate in funding for remedial action, it is fair to assume that there will be very strong pressures to assure that costs will be limited to a moderate total.

Remedial actions designed to meet the EPA interim remedial action criteria were investigated. As mentioned in Chapter 8, no specific disposal sites have been identified for the Lowman radioactive sands and residues. However, in order to provide an understanding of the magnitude of the costs involved with disposal of the radioactive sands at typical disposal sites in the Lowman area, it was assumed that two unspecified sites that can meet the present criteria for disposal are available at distances of 15 and 30 mi from the present site. Costs for disposal of the radioactive sands and contaminated materials at these unspecified sites have been estimated using typical disposal site preparation and haul costs and are presented in this chapter. Care must be exercised in the use of these specific cost estimates because exact disposal locations are not identified and actual site characteristics may differ significantly from those of the unspecified sites.

The process of obtaining the necessary permits and the associated costs are considered to be included in the various agency budgets and are not included in this report. Similarly, the radioactive sands site and the unspecified disposal sites have been treated as public lands and no acquisition costs are included.

Costs for future maintenance and radiological monitoring at the location of the radioactive sands are not included in this estimate. Funding for such future costs is assumed to come from separate contracts administered by the Federal Government.

The options for disposal at the unspecified sites would provide for the relocation of all debris and contaminated materials from the site and off-site locations. Thus, in all of the disposal options, the entire site and all off-site areas would be left free of any radioactive sands or contaminated materials in excess of the allowed 5 pCi/g of ^{226}Ra above background.

A discussion of the concepts involved in stabilization of contaminated materials and their applicability to the Lowman site has been detailed in Chapter 6. It was assumed that either vegetation will be established or a 0.3-m riprap cap provided, whether the radioactive sands are stabilized on site or disposed of at a remote location.

9.1 STABILIZATION OF THE RADIOACTIVE SANDS ON SITE WITH A 3-METER COVER (OPTION I)

In this section, the conceptual design of the option to stabilize the radioactive sands and residues at the Lowman site is discussed, and the estimated cost of the corresponding remedial action is presented.

9.1.1 Conceptual Design

Stabilization of the radioactive sands on the present Lowman site is considered as a viable option. In preparing the cost estimate for this option, the possible problem of migration of contamination via ground water was not considered, and the cost does not include the placement of a clay or synthetic liner under the radioactive sands. The cost of this option would increase significantly if the liner were required.

Under this option the contaminated materials would remain on site. The site would be contoured, graded, and stabilized with 3 m of cover material, which has been shown under certain conditions to be adequate to reduce radon flux to less than 2 pCi/m²-s. With the cover material in place, the pile would cover about 10 acres and rise approximately 16 ft above natural grade.

If the Lowman site were stabilized in place, it would have limited future use.

9.1.2 Costs

As shown in Table 9-1, the cost for stabilization at the Lowman site is estimated to be \$2,500,000. Costs include

cleaning up of off-site locations, covering all contaminated materials with 3 m of cover, contouring the surface, establishing vegetation or providing 0.3 m of riprap, and reclaiming of all areas.

9.2 REMOVAL OF RADIOACTIVE SANDS AND ALL CONTAMINATED MATERIALS FROM THE SITE (OPTIONS II AND III)

Options II and III would provide for the complete transfer of all radioactive sands, contaminated soil, materials, and rubble from the present site and off-site areas to a disposal site. The amount of soil to be removed depends on the depth of contamination. Figure 9-1 is a decontamination plan for the Lowman site and shows the areas that will require cleanup action and the estimated depths of soil removal required in each area to meet cleanup criteria. Removal to depths of 3 ft below the interface under the radioactive sand piles was assumed to reduce residual radium concentration to less than the allowed 5 pCi/g above background levels. Finally, the site would be backfilled to natural grade and released for unrestricted use.

9.2.1 Excavation and Loading of the Radioactive Sands and Contaminated Soils

Existing roadways provide excellent access to the site. Different methods of excavation are possible, with a single-bench open-pit method being the most feasible. However, the remaining concrete foundations of the mill building may necessitate different techniques of excavation and loading than might be used for the radioactive sands and contaminated soils.

To eliminate any possible dispersion of the sands and soils during loading and transportation operations, dust control equipment and washdown facilities would be provided.

The Lowman site would be backfilled to natural grade. Local materials, all of which must be hauled onto the site, would be used as backfill. No special treatments of the final surface other than establishing native grass cover at the decontaminated site are considered in this assessment.

9.2.2 Transportation of the Materials

Railroad transportation is not considered feasible for transport of the contaminated materials since there are no rail facilities in the vicinity.

Slurry pipeline technology was evaluated. While water for this method of transport may be available from Clear Creek and the South Fork Payette River, demands for water in areas downstream from the site could preclude its diversion for radioactive sands transport. Also, because of the need to dewater at the disposal site, slurry technology may not be feasible.

The use of conveyors in transporting the contaminated materials has been investigated briefly to assess its viability. While any conclusive statement is very dependent upon the site- and route-specific parameters, some generalizations can be made about the viability of conveyors in this application:

- (a) The longer the life of the project, the more attractive the use of conveyors becomes.
- (b) The greater the mass to be moved, the more attractive the use of conveyors becomes.
- (c) Conveyors can be more attractive in difficult terrain.

However, there are many complications involved in the use of conveyors, many of which are difficult to quantify. Public acceptance, acquisition of rights-of-way and permits within a reasonable time frame, and environmental impact are considerations that cloud the evaluation of conveyors.

With all of the factors considered, the quantity of materials to be moved does not appear to warrant the use of conveyors, making transportation by truck preferable. At such time as a specific disposal site is chosen, a detailed evaluation would disclose whether this generalization holds true for the selected site and routes.

If trucks could move the materials at the rate of about 4,800 tons/day, working 5 days/wk, all contaminated materials could be removed in less than 3 mo. When remedial action is designed, the most cost-effective removal plan may be determined. Conventional truck-trailer dump trucks would be used. Dust control measures, such as covers and washdown facilities for the trucks, are included as capital costs associated with transportation.

Transportation costs for trucking include all hauling costs associated with the contaminated materials, necessary cover material, and riprap material. No costs are included for repair and maintenance of public roads. Capital costs include development of access roads and maintenance thereof whenever such roads are required.

9.2.3 Disposal at Alternative Sites

Although no specific locations have been identified for disposal of the contaminated materials at Lowman, it was assumed that two unspecified sites that can meet the existing criteria for disposal of radioactive wastes are available at distances of 15 and 30 mi generally west of the present location. However, because the Federal Government, with input

from the State, is ultimately responsible for the selection of disposal sites, there is no assurance that either of the disposal sites considered in this report will be selected.

The costs associated with disposal at an unspecified site located 15 mi from the present location are presented as Option II in Table 9-1, and the costs for an unspecified site located 30 mi away are presented as Option III.

It was assumed that both sites are presently accessible by using a combination of paved, gravel, and in some cases, dirt roads. It was also assumed that the disposal sites selected can be isolated from drainage basins naturally or by dikes and drainage ditches. Figure 9-2 is a schematic representation of how these disposal sites might be developed.

Disposal site costs consist of preparation of the site, placement of the contaminated materials and cover materials, construction of dikes and contouring, and necessary reclamation of surface areas.

The costs for the disposal options, shown in Table 9-1, are \$6,000,000 for Option II and \$5,700,000 for Option III. The cost difference is due to differences among costs associated with the length of the hauls to the disposal site from the present site and from the cover material locations.

Costs for health physics and radiological monitoring are included in individual component costs (lines 1 through 5, Table 9-1).

In Options II and III the estimated costs include cleaning up of off-site locations and the radioactive sands area; backfilling the former sands area; establishing vegetative cover at and around the decontaminated site; covering all contaminated materials at the disposal site with 3 m of cover material; contouring the stabilized disposal site; and placing 0.3 m of riprap for erosion control.

9.3 ANALYSES OF COSTS AND BENEFITS

9.3.1 Health Benefits

Each of the remedial action alternatives considered in this chapter has an associated health benefit that would be experienced as a result of the remedial action. This health benefit is the reduction of the health effects (number of lung cancer cases) resulting from the remedial action. In Chapter 3 the estimated number of health effects was determined for the Lowman radioactive sands site in its present condition. In order to estimate the number of health benefits attributable to particular remedial actions, the effects of those remedial actions on radon exhalation from the sands must be determined,

because the health effects calculated in Chapter 3 were associated with radon daughters. While there are some benefits associated with actions such as fencing, these have not been quantified in this assessment of health benefits.

In this evaluation, the health benefit of each option is calculated from the reduction in radon exhalation that is expected for that option. In accordance with proposed requirements for stabilization of uranium mill tailings, radon fluxes were assumed to be reduced from their predicted values under present conditions (as conservatively calculated in Paragraph 3.6.2) to less than 2 pCi/m²-s for Option I. In the other options, radon flux was assumed to be reduced to zero by the removal of the radioactive sands. Since health effects are proportional to radon flux, the present health effects rate was estimated to be reduced by more than 99% with stabilization in-place and by 100% with removal of the radioactive sands.

The potential cancer cases avoided (health benefits) for each option are given as a function of time in part A of Table 9-2. The cost per potential cancer case avoided for each option is included as part B in Table 9-2.

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

9.3.2 Land Value Benefits

Much of the land surrounding the site is under U.S. Forest Service control. The value of the land surrounding the site is not depressed by the presence of the radioactive sands and millsite, and therefore would not increase significantly as a result of the remedial actions described under any of the options in this report.

If the remedial actions described under Option I were implemented, the land on which the radioactive sands and residues are located would continue to have limited uses and its values would not increase significantly. However, if the remedial actions of Options II or III were implemented, the entire 37-acre site could be released for unrestricted use and its current value of about \$370/acre could increase to approximately \$12,500/acre (as property for recreational homesites). These figures represent a total increase of from about \$13,700 to about \$462,500 for the entire 37-acre site.

FIGURE 9-1. AREA DECONTAMINATION PLAN

FIGURE 9-2. SCHEMATIC OF TYPICAL TAILINGS DISPOSAL SITE

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

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TABLE 9-1
SUMMARY OF STABILIZATION AND DISPOSAL COSTS^a

	Options		
	I	II	III
1. Radioactive Sands Site	1.0	0.5	0.5
2. Off-Site Other than Windblown	0.3	0.3	0.3
3. Off-Site Windblown	0.2	0.2	0.2
4. Transportation			
a. Capital Costs	--	0.1	0.1
b. Haul Costs	--	2.2	2.0
5. Disposal Site	--	0.8	0.8
6. Total Cleanup ^b (sum of lines 1 through 5)	1.5	4.1	3.8
7. Engineering Design and Construction Management (30% of the difference between lines 6 and 4b)	0.4	0.6	0.6
8. Total ^b (sum of lines 6 and 7)	1.9	4.6	4.4
9. Contingency (30% of line 8)	0.6	1.4	1.3
10. GRAND TOTAL ^b (sum of lines 8 and 9)	2.5	6.0	5.7

^aCosts are presented in millions of year 1980 dollars.

^bTotals may differ from the sum of component costs because of round-off.

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TABLE 9-2

POTENTIAL CANCER CASES AVOIDED
AND COST PER POTENTIAL CASE AVOIDED

A. Number of Potential Cancer Cases Avoided

Options:	I	II	III
Option Cost (million \$)	2.5	6.0	5.9
Years After Remedial Action			
25	<0.0023	0.0023	0.0023
50	<0.0053	0.0053	0.0053
75	<0.0082	0.0082	0.0082
100	<0.011	0.011	0.011

B. Cost Per Potential Cancer Case Avoided (Million \$)

Options:	I	II	III
Option Cost (million \$)	2.5	6.0	5.9
Years After Remedial Action			
25	>1,100	2,600	2,500
50	> 470	1,100	1,100
75	> 310	730	700
100	> 230	550	520

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GLOSSARY

GLOSSARY

Terms/Abbreviations

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 materials. 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 radiations (α, β, γ), hence is not dangerous unless alpha-emitting substances have entered the body.
amenability	The relative ease with which a mineral 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 the 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.
Curie (Ci)	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).
EPA (USEPA)	Environmental Protection Agency.
ERDA (USERDA)	Energy Research and Development Administration.

ERDA-GJO

Energy Research and Development
Administration-Grand Junction
Office.

erg

A basic unit of work or energy
in the centimeter-gram-second
system (1 erg = 7.4×10^{-8}
ft-lb, or 10^{-7} joule).

external gamma radiation
(EGR)

Gamma radiation emitted from a
source(s) external to the body,
as opposed to internal gamma
radiation emitted from ingested
or inhaled sources.

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.

fixed alpha

Particulate alpha emitting
isotopes which have become
imbedded in otherwise non-
radioactive surfaces and which
cannot be removed by standard
decontamination techniques.

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 (γ)

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 Primary Drinking Water Regulations	Title No. 40 of the Code of Federal Regulations, Chapter 1, Part 141, dated Dec 24, 1975 and effective June 24, 1977.
iso-exposure line	A line drawn on a map to connect a set of points having the same exposure rate.
isotope	One of two or more species of 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.
man-rem (person-rem)	A unit used in health physics to compare the effects of different amounts of radiation on groups

	of people. It is obtained by summing individual dose equivalent values for all people in the population.
$\mu\text{R/hr}$	Microrentgen per hour (10^{-6} R/hr).
mR/hr	Milliroentgen per hour (10^{-3} R/hr).
MeV	Million electron volts.
maximum permissible concentration (MPC)	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 (10^{-12} Ci/l)
pCi/g	Picocurie per gram (10^{-12} Ci/g)
$\text{pCi/m}^2\text{-s}$	Picocurie per square meter per second (10^{-12} Ci/ $\text{m}^2\text{-s}$)

PHS (USPHS)	Public Health Service.
quality factor (QF)	An assigned factor that denotes the modification of the effectiveness of a given absorbed dose by the linear energy transfer.
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 background radiation.
radon	A radioactive, chemically inert gas. The nuclide ^{222}Rn has a half-life of 3.8 days and is formed as a daughter product of radium (^{226}Ra).
radon background	Low levels of radon gas found in air resulting from the decay of naturally occurring 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).

radon daughter concentration (RDC)

The concentration in air of short-lived radon daughters, expressed either in pCi/l or 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/m²-s).

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
(roentgen equivalent man)

The unit of dose equivalent 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 protective layer of broken rock.
roentgen (R)	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 of air.
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 a lower concentration of 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). The highest concentration of radioactive material remaining in tailings is found in the slimes.
tailings	The remaining portion of a metal-bearing ore after the desired metal, such as uranium, has been extracted. Tailings also may contain other minerals or metals not extracted in the process (e.g., radium).
UMTRA	Uranium Mill Tailings Remedial Action
working level (WL)	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.

working level month (WLM)

One WLM is equal to the exposure received from 170 WL-hours.