A SUMMARY OF THE PHASE II - TITLE I ENGINEERING
ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS
PHILLIPS/UNITED NUCLEAR SITE
AMBROSIA LAKE, NEW MEXICO

MASTER

DECEMBER 1977

PREPARED FOR

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

BY

Ford, Bacon & Davis Utah Inc.

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NOTICE

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

FOREWORD

This report is a summary of a parent report entitled, "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Phillips/United Nuclear Site, Ambrosia Lake, New Mexico". Both reports are authorized under the U.S. Energy Research and Development Administration (ERDA) Contract No. E(05-1)-1658. These reports are part of a series of reports on inactive uranium millsites and address the radiological problems and estimated costs of remedial measures that would reduce exposure of the general public. Title I is not a scientific study but an engineering assessment to determine the relative magnitude of the hazards associated with each site, to identify reasonable remedial action options for each site, and to estimate the remedial action costs. If additional data that may alter or have an impact on a final remedial action decision for any site are required, they can be obtained during the Title II Engineering Effort.

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

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

- (1) The Environmental Protection Agency; for consultation, data, and information from prior surveys and studies with notable assistance from the Office of Radiation Programs, Las Vegas, Nevada
- (2) United Nuclear Corporation; Mr. H. John Abbiss and personnel at the Phillips/United Nuclear mill
- (3) EG&G, Las Vegas, Nevada; Mr. Jack Doyle; for aerial photography
- (4) Center for Health and Environmental Studies, Brigham Young University, Provo, Utah; for hydrology and socioeconomic studies
- (5) Environmental Studies Group at Los Alamos Scientific Laboratory; for field work assistance.

ABSTRACT

Ford, Bacon & Davis Utah Inc. has performed an engineering assessment of the problems resulting from the existence of radioactive uranium mill tailings at the Phillips/United Nuclear site at Ambrosia Lake, New Mexico. The Phase II - Title I services include the preparation of topographic maps, the performance of core drillings sufficient to determine areas and volumes of tailings and radiometric measurements to determine radium-contaminated materials, the evaluation of resulting radiation exposures of individuals and nearby populations, the investigation of site hydrology and meteorology, and the evaluation and costing of alternative corrective actions.

Radon gas release from the 2.6 million tons of tailings at the Phillips/United Nuclear site constitutes the most significant environmental impact, although windblown tailings and external gamma radiation are also factors. The estimated radiological health effects to the general population are considered to be minimal. The two alternative actions presented are: dike stabilization, fencing, and maintenance (Option I); and adding 2 ft of stabilization cover material (Option II). Both options include remedial action at off-site structures and on-site decontamination around the tailings pile. Cost estimates for the two options are \$920,000 and \$2,230,000, respectively.

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

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GLOSSARY

Abbreviations/Terms

Definitions

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

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

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

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

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

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

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

decay of the daughter products RaA, RaB, RaC, and RaC' that are present under equilibrium conditions in a liter of air containing 100 pCi of Rn-222. It does not include decay of RaD (22 yr half-life) and subsequent daughter products.

WLM

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

CHAPTER 1

A SUMMARY OF THE PHASE II - TITLE I ENGINEERING ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS

CHAPTER 1

A SUMMARY OF THE PHASE II - TITLE I ENGINEERING ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS

1.1 INTRODUCTION

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

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

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

In assessing the significance of the conditions existing at the Phillips/United Nuclear site at Ambrosia Lake, evaluations of the following factors were included:

- (a) Exhalation of radon gas from the tailings
- (b) On-site and off-site direct radiation
- (c) Land contamination from windblown tailings

⁽¹⁾ See end of chapter for references.

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

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

- (a) Minimum remedial action, which amounts to improving fencing around the site
- (b) Stabilization with 2 ft of cover for long-term storage at the present site and drainage improvements

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

1.1.1 Background

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

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

Dr. James L. Liverman, testifying for the AEC, proposed that a comprehensive study should be made of all such piles, rather than treating the potential problem on a piecemeal basis. He proposed that the study be a cooperative two-phase undertaking by

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

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

On May 5, 1975, ERDA, the successor to AEC, announced that Ford, Bacon & Davis Utah Inc. of Salt Lake City had been selected to provide the architect-engineering (A-E) services for Phase II. ERDA's Grand Junction, Colorado, office (GJO) was authorized to negotiate and administer the terms of a contract with FB&DU. The contract was effective on June 23, 1975. The Salt Lake City Vitro site was assigned as the initial task, and work began immediately. Field work at the Phillips/United Nuclear site began in July 1976.

1.1.2 Scope of Phase II Engineering Assessment

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

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

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

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

following:

- (a) Preparation of an engineering assessment report for each site, and preparation of a comprehensive report suitable for submission to the Congress on reasonable remedial action alternatives and their estimated costs.
- (b) Determination of property ownership in order to obtain release of federal government and A-E liability for performance of engineering assessment work at both inactive millsites and privately owned structures.
- (c) Preparation of topographic maps of millsites and other sites to which tailings and other radioactive materials might be moved.
- (d) Performance of core drillings and radiometric measurements ample to determine volumes of tailings and other radium-contaminated materials.
- (e) Performance of radiometric surveys, as required, to determine areas and structures requiring cleanup or decontamination.
- (f) Determination of the adequacy and the environmental suitability of sites to which mill tailings containing radium can be moved for long-term (>50 yr) storage; and once such sites are identified, perform evaluation and estimate the costs involved.
- (g) Performance of engineering assessments of structures where uranium mill tailings have been used in off-site construction to arrive at recommendations and estimated costs of performing remedial action.
- (h) Evaluation of various methods, techniques and materials for stabilizing uranium mill tailings to prevent wind and water erosion, to inhibit or eliminate radon exhalation, and to minimize maintenance and control costs.
- (i) Evaluation of availability of suitable fill and stabilization cover materials that could be used.
- (j) Evaluation of radiation exposures of individuals and nearby populations resulting from the inactive uranium millsite, with specific attention to:
 - (1) Gamma radiation

- (2) Radon
- (3) Radon daughter concentrations
- (4) Radium and other naturally occurring radio-isotopes in the tailings
- (k) Investigation of site hydrology and meteorology.
- (l) Evaluation of recovering residual values, such as uranium and vanadium in the tailings and other residues on the sites.
- (m) Performance of demographic and land use studies. Investigation of community and area planning, and industrial and growth projections.
- (n) Evaluation of the alternative corrective actions for each site in order to arrive at recommendations, estimated costs, and socioeconomic impact based on population and land use projections.
- (o) Preparation of preliminary plans, specifications, and cost estimates for alternative corrective actions for each site.

Not all of these items received attention at this site.

1.2 SITE DESCRIPTION

1.2.1 Location and Topography

The Phillips/United Nuclear site is located in the northwest portion of New Mexico, in McKinley County. It is 20 mi north of Grants and 85 mi northwest of Albuquerque, New Mexico. The valley in which the tailings are located is about 6,980 ft above sea level. Mesas and steep cliffs surround the valley and reach elevations which are 200 ft higher than the site. Ambrosia Lake is about 20 mi east of the continental divide. The climate is arid and the vegetation is sparse. The site and its relationship to the surrounding area are shown in the aerial photograph, Figure 2-1, Chapter 2.*

1.2.2 Ownership and History of Milling Operations and Processing

The mill originally was built in 1957 and was operated by the Phillips Petroleum Company. United Nuclear Company purchased and operated the mill for a brief period in 1963. United Nuclear shut down milling operations in 1963 but has retained the site ownership to the present. During the 5-yr operational period,

*All figures and tables referenced in this summary are from the parent report and are included in the Addendum.

the mill processed 3 million tons of ore with an average grade of 0.23% U_3O_8 . All the ore came from nearby mines.

1.2.3 Present Condition of the Site

Figure 2-3, Chapter 2, is a descriptive map of the tailings and mill areas of the site as they now exist. The tailings cover approximately 105 acres in an almost square shape with a slightly concave surface, to an average depth of 12 ft. Figure 2-4, Chapter 2, is a cross-section of the tailings pile. The tailings have not been stabilized, although the crust which has formed on the surface resists wind erosion quite well when not disrupted. There is an area of windblown tailings that have migrated through the fence at the eastern edge of the pile. Surface water collects on a large portion of the pile, and at the west side it has eroded away a portion of the pile and dike as it runs off the pile surface. The tailings are fenced with a barbed-wire fence which is broken in several places. Several buildings remain on the mill-site, and the main mill building is being used for the extraction of uranium from mine water.

1.2.4 Tailings and Soil Characteristics

The tailings are white to pink in color and are finely ground sand with some clay content and bulk densities of 100 to 108 lb/ft³. Some 396,000 tons of the tailings have been removed and used as mine fill, leaving 2.6 million tons still on the site. Table 2-1, Chapter 2, indicates the quantity and weight of the tailings.

The surface material beneath the tailings consists of a thin alluvial layer of clay and silt derived from the surrounding highlands.

1.2.5 Geology, Hydrology, and Meteorology

The Phillips/United Nuclear tailings pile and millsite are located on a pediment that slopes southwestward from the base of San Mateo Mesa. The underlying Mancos Shale bedrock dips gently toward the northeast, opposite to the direction of surface drainage. The Mancos Shale acts as a barrier to the downward and upward migration of ground water in bedrock. The unconsolidated materials separating the tailings pile from bedrock are composed of clays and silts, contain some water, and do not exceed 15 ft in thickness. A simplified stratigraphic column is shown in Figure 2-5, Chapter 2.

There are no perennial surface streams near the Phillips/United Nuclear millsite. Dry washes drain near the site and some runoff can flow toward the site. A dike protecting the northern boundary of the pile from off-site drainage has been breached by storm runoff. Other surface waters near the site include ponded water on the tailings pile itself and ponded waters near the mill used as process water. Contamination of surface waters in the area is unlikely because there are no regularly flowing surface waters in the vicinity. However, tailings have been eroded from

the pile by storm runoff.

The tailings lie on unconsolidated materials which contain some unconfined ground waters. Seepage through the pile is possible, but unlikely. The confined ground waters of the area are protected by Mancos Shale from the downward flow of contaminants from the tailings pile. The Dakota Sandstone underlies the Mancos Shale and is a potential aquifer. The Westwater Canyon Sandstone Member of the Morrison Formation is tapped as the major aquifer in the area which is unusual as it serves as the chief uranium-bearing horizon of the vicinity. Contamination of this aquifer by the tailings is virtually impossible. The Grants area is under continuing surveillance by the U. S. Environmental Protection Agency to monitor the impact of uranium mining and milling activities on the quality of local surface and ground waters.

The tailings are vulnerable to erosion by strong winds and by high-intensity rainfall. The strongest winds are from the northwest and there is evidence of wind erosion at the eastern edge of the pile. Annual precipitation at Ambrosia Lake is estimated at 10 in. Water erosion of the tailings has occurred at the western and northern edges of the pile.

1.3 RADIOACTIVITY AND POLLUTANT IMPACTS ON THE ENVIRONMENT

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

1.3.1 Radiation Exposure Pathways, Contamination Mechanisms, and Background Levels

The major potential environmental routes of exposure to man are:

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

- (c) Inhalation and ingestion of windblown tailings. The primary health effect relates to the alpha emitters ^{230}Th and ^{226}Ra , each of which causes exposure to the bones and lungs.
- (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 which can occur; however, this pathway was not considered in this study.

1.3.1.1 Radon Gas Diffusion and Transport

Short-term radon measurements were performed with the ERDA-supplied continuous radon monitors at 11 locations in the vicinity of the Phillips/United Nuclear tailings pile. The locations and values of the radon measurements are shown in Figure 3-3, Chapter 3. The highest outdoor radon concentration off the pile was measured 0.13 mi east of the pile at the guard station. The radon concentration at this location averaged 28 pCi/l for a 24-hr period. Indoor radon concentration at the guard station was 19 pCi/l during the same period.

Three 24-hr measurements of atmospheric radon indicated an average background concentration of 4.3 pCi/l for the Ambrosia Lake area. This value is high as a result of the numerous active mines and another tailings pile in the area.

1.3.1.2 Direct Gamma Radiation

The range of natural background values in the Ambrosia Lake area was between 13 and 18 $\mu\text{R/hr}$, averaging 15 $\mu\text{R/hr}$ as measured with an energy-compensated Geiger Mueller detector.⁽²⁾ Above the surface of the tailings pile, gamma radiation rates were measured as high as 1,140 $\mu\text{R/hr}$. At the former ore stockpile area, between the mill and the large pond, gamma radiation reached a maximum of 420 $\mu\text{R/hr}$.

1.3.1.3 Windblown Contaminants

Prevailing winds in the area are from the northwest. Background gamma radiation rates were reached 0.2 mi to the northwest and southwest of the pile. Toward the east there are additional sources of radiation, from mine wastes, contamination in the ore storage area, and the mill itself, that do not allow a unique determination of the extent of windblown contamination to be made. The results of the EPA gamma radiation survey around the tailings pile are shown in Figure 3-10, Chapter 3.

A surface soil sample taken 0.5 mi directly east of the pile contained 15 pCi/g of ^{226}Ra . All samples taken within 0.5 mi from

the site contained more than 4 times the average background concentration of ^{226}Ra (1.0 pCi/g).

1.3.1.4 Ground and Surface Water Contamination

There are no perennial surface water flows in the vicinity of the tailings pile, but several process water ponds were sampled. Analyses indicated all samples contained ^{226}Ra well in excess of the EPA Interim Drinking Water Regulation of 5 pCi/l of combined ^{226}Ra and ^{228}Ra . In addition, many of the samples contained ^{226}Ra in excess of the 30 pCi/l limit specified in the New Mexico Ground Water Regulations.

An EPA study of ground water in the Ambrosia Lake area stated that seepage from the Phillips/United Nuclear tailings is present in shallow ground waters. In the present work water from drill holes off the pile also exceeded the EPA Interim Regulations for ^{226}Ra content. Contamination of the deep bedrock aquifer (Westwater Canyon Member) by tailings is unlikely because of thick layers of Mancos Shale overlying the aquifer.

1.3.1.5 Soil Contamination

The leaching of radium into the subsoil beneath the tailings extends to 3 to 4 ft below the tailings-subsoil interface before reaching twice the average background level of radium concentration in local soil samples (1.0 pCi/g).

1.3.2 Remedial Action Criteria

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

- (a) Criteria applicable to structures with tailings underneath them or within 10 ft
- (b) Criteria pertaining to the mill tailings site and open land

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

The recommended graded levels are as follows:

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

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

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

^cWL = working level, a measure of alpha radiation from short-lived radon daughter elements.

The criteria for land decontamination have the objective of reducing residual gamma radiation to levels which are as low as practicable. However, topographic and economic considerations frequently preclude complete decontamination. A provisional maximum of 40 μ R/hr above background is used in such circumstances. Average background in the Ambrosia Lake area was determined in this study to be 15 μ R/hr. As a guideline for the land beyond the site, if residual gamma levels are less than 10 μ R/hr above background, the land may be released for unrestricted use. Where cleanup is necessary the radium content of the soil should be reduced to no more than twice the radium background in the area. If the radioactive tailings material is stabilized in place, the same criteria apply but control of gamma radiation would be by an earth covering. However, the area should be designated a controlled area, be fenced to limit access, and be restricted as to human occupancy. The numerical guidelines provide a basis for the engineering assessment, but are subject to review based on the overall findings of Phase II.

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

1.3.3 Potential Health Impact

The gamma radiation levels are in the background range within 0.2 mi from the pile, except in the easterly direction where the mill is located. The gamma exposure and the inhalation of radon daughters from the tailings pile under present conditions account for almost all of the total dose to the people living and working near the Phillips/United Nuclear site at the present time. It is

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

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

The risk estimators used in this report are given in the report of the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR report).⁽⁴⁾ This report presents risk estimators for lung cancer derived from epidemiological studies of both uranium miners and fluorspar miners. The average of the absolute risk estimator for these two groups is: 6 cancers per year per 10^6 person-WLM exposure. The term WLM means working level month, or an exposure to a concentration of one working level of radon daughter products in air for 170 hr, which is a work-month. A working level (WL) is a unit of measure of radon daughter products which recognizes that the several daughter elements are frequently not in equilibrium with each other nor with the parent radon. Because of the many factors which contribute to natural biological variability, and of the many differences between exposure conditions in mines and residences, this estimator (6 cancer cases per year per 10^6 person-WLM)

is considered to have an uncertainty factor of about 3. The relative risk estimator can be several factors larger than the absolute risk estimator.⁽⁵⁾

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

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

For continuous exposure:

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

On the basis of predictions of radon concentrations in excess of background values, it is calculated that the pile radon-induced lung cancer risk to individuals 1.5 mi from the Phillips/United Nuclear tailings site is 5.0×10^{-5} per person per year. The health effect rate for background radon is approximately 1.9×10^{-4} per person per year, or about 4 times that attributable to pile radon. The average risk due to all causes for New Mexico residents is 1.7×10^{-4} per person per year.⁽⁶⁾ At 1 mi from the edge of the tailings pile, the lung cancer risk due to pile radon is about 20% of the average risk to residents of New Mexico from all causes.

As a result of the low population density, the low radiation levels of the tailings at the Phillips/United Nuclear site, and the relatively high background radon levels, the potential health impact of the pile is minimal.

1.3.4 Nonradioactive Pollutants

There are other potentially toxic materials in the tailings. Chemical analyses of samples from auger holes in the Phillips/United Nuclear tailings indicated barium and lead in concentrations between 60 and 120 ppm. The highest selenium concentration measured was 86 ppm and arsenic concentration was less than 3 ppm.

All six water samples taken on the site from ponds and auger holes contained selenium and arsenic in concentrations above the EPA Interim Drinking Water Regulations. With one exception, they also exceeded the allowable concentration of lead. Two samples contained excessive concentrations of cadmium.

An EPA study of ground water in the Ambrosia Lake area⁽⁷⁾ concluded that mining and milling operations in the area contaminated shallow ground waters with selenium, radium, and nitrates; and this appears to be true of the Phillips/United Nuclear site also.

1.4 SOCIOECONOMIC AND LAND USE IMPACTS

Virtually all the land near the tailings site is used for mineral-related activity or for grazing. A small concentration of mobile homes, a few single-family residences and a small commercial establishment are located about 1 mi west of the tailings. Other mobile homes and commercial units are dispersed in the area to provide support for mining operations. There are approximately 10 residences within a 1.5-mi radius of the tailings pile. Although there are about 3,500 mine and mill workers in the Ambrosia Lake area, most commute daily from outside of McKinley County.

The land near the the tailings pile is divided between a private ranching and mining operator, two mining companies, the federal government, and the State of New Mexico. Land values in the grazing areas range between \$37 and \$60/acre.

The presence of the tailings at the Phillips/United Nuclear site restricts the use of the tailings area itself. The site is not available for grazing but there are no competing uses. The agricultural loss is minimal as the area supports few animals per acre. If the tailings were not present, there would be virtually no change in land uses and values in the surrounding area.

1.5 RECOVERY OF RESIDUAL VALUES

Estimates of the uranium content of the Phillips/United Nuclear tailings by the AEC indicate an average U_3O_8 concentration of 0.018% for the tailings. This concentration is in a range where reprocessing would be marginal.

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

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

Based on the aforementioned criteria, reprocessing of the Phillips/United Nuclear tailings is not a practical economic consideration at this time and will not be until the price of U_3O_8 reaches \$48/lb.

1.6 MILL TAILINGS STABILIZATION

Present practices and technology of mill tailings stabiliza-

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

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

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

Option II includes stabilization of the tailings pile with 2 ft of earth cover. This cover would greatly reduce the wind and water erosion presently occurring. Gamma radiation would be reduced to background levels but radon exhalation would be reduced by only 30% by this thickness of cover material.

1.7 OFF-SITE REMEDIAL ACTION

A mobile scanning unit, operated by the AEC under interagency agreement with the EPA, was used to perform a gamma radiation survey of the Grants, New Mexico area prior to 1972. A subsequent field survey identified five off-site locations where tailings use was suspected and two where tailings use was confirmed within 10 ft of a structure. The use of tailings at off-site structures are not directly attributable to the Phillips/United Nuclear site; however, remedial action at these contaminated off-site structures are included in the option costs. The locations at which tailings are on vacant lands or are greater than 10 ft from structures were not subject to the criteria used in Phase II, but could constitute a problem in the future.

The cleanup of windblown tailings will be limited to the area within the 40 μ R/hr line shown in Figure 3-10 except for the areas around the Anna Lee mine and beyond the road south of the tailings. The costs associated with this work are included in the option costs.

1.8 LONG-TERM STORAGE SITE SELECTION

No alternative disposal sites have been considered for the tailings pile. With implementation of Option II, the tailings would be isolated hydrologically from surface water erosion and stabilized for long-term storage.

1.9 REMEDIAL ACTIONS AND COST-BENEFIT ANALYSES

1.9.1 Remedial Action Options

The two remedial actions selected are summarized in Table 1-2. Option I proposes stabilization of the tailings dike, security fencing around the tailings, and annual monitoring and maintenance. The cost of this option is \$920,000. Remedial actions at off-site structures and open lands adjacent to the site are also included.

Option II includes remedial action at off-site structures and open lands and the security and maintenance tasks of Option I in addition to the contouring and stabilization of the pile with 2 ft of earth cover and the installation of a drainage system to prevent water from collecting on the pile. Prior to stabilization, windblown tailings at the eastern edge of the pile and contaminated soil from the ore storage area would be placed on the pile. Also, the area surrounding the pile would be graded to prevent any upslope drainage from eroding the base of the pile. The estimated cost of this option is \$2,230,000.

1.9.2 Cost-Benefit Analyses

The principal reasons for the adoption of the remedial options are to reduce personnel exposure, to limit access so that tailings may not be removed from the site, and to reduce further deterioration of site conditions through control or erosion. Populations and off-pile radiation levels are so small that the health benefits associated with the remedial actions are negligible.

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

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

TABLE 1-1 (Cont)

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

(1) S - Stabilized but requires improvement

P - Partially stabilized

U - Unstabilized.

(2) M - Mill intact

B - Building(s) intact

R - Mill and/or buildings removed

PR- Mill and/or buildings
partially removed

O - Occupied or used

UO- Unoccupied or unused.

(3) N - None

E - Existing

O - Occupied

P - Part occupied.

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

TABLE 1-2

SUMMARY OF REMEDIAL ACTION OPTIONS AND EFFECTS

<u>Option Number</u>	<u>Cost¹ (\$000)</u>	<u>Description of Remedial Action</u>	<u>Benefits</u>	<u>Effects Adverse</u>
I	920	Stabilization of edges of pile, security fencing, monitoring, maintenance, cleanup of open lands, and off-site remedial action	A,B	V,W,X,Y
II	2,230	2-ft stabilization cover, security fencing, monitoring, maintenance, grading to hydrologically isolate the site from surface waters, cleanup of open lands and off-site remedial action	A,B,C,D, E,F,G	V

Definition of Benefits

- A. Reduce personnel access to the tailings pile
- B. Control of erosion from the dikes
- C. Control of erosion from entire pile
- D. Pile protected from upslope flooding
- E. Gamma radiation reduced to near-background levels
- F. Radon exhalation reduced by 30%
- G. Minimum maintenance required

Definition of Adverse Effects

- V. Tailings site not available for any use
- W. No decrease in gamma radiation
- X. No decrease in radon exhalation
- Y. No reduction in tailings erosion

Notes

¹Costs are in 1977-value dollars

CHAPTER 1 REFERENCES

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ADDENDUM

FIGURES AND TABLES

(The figures and tables contained on the following pages have been extracted from chapters of the parent report.)

LIST OF FIGURES

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FIGURE 2-1. AERIAL PHOTOGRAPH OF SITE

130-13

NOTE
MAP DEVELOPED FROM
AERIAL PHOTOGRAPH

- LEGEND
- EDGE OF TAILINGS
 - DRILL HOLE
 - SUDDEN CHANGE IN SLOPE (DOWNWARD)

FIGURE 2-3. DESCRIPTIVE MAP

FIGURE 2-4. CROSS-SECTION THROUGH PILE

SITE NO	24 HR OUTDOOR (pCi/l)	DATE	AVG WIND SPEED (KNOTS)	AVG WIND DIREC TION	LOCATION
1	16.7	11/2/76	3	SW	N EDGE OF PILE
2	9.4	11/3/76	5	N	0.1 MI N OF PILE
* 3	28 *	11/9/76	5	NE	GUARD STATION, 0.13 MI E OF PILE
4	5.1 **	11/4/76	3	W	0.3 MI N OF PILE
5	5.5	11/5/76	4	NE	0.5 MI N OF PILE
6	6.8	11/3/76	5	N	0.6 MI WNW OF PILE
7	7.7	11/5/76	4	NE	0.7 MI NW OF PILE
8	2.9 **	11/6/76	6	NE	0.7 MI N OF PILE
9	5.0 **	11/10/76	5	NW	0.8 MI NW OF PILE
10	11.5	11/10/76	5	NW	2.0 MI S OF PILE
11	5.0	11/9/76	5	NE	3.0 MI NW OF PILE, 0.5 MI S OF LAKE BED

*24 HR INDOOR 19 pCi/l
**USED FOR AVERAGE BACKGROUND CONCENTRATION

FIGURE 3-3. RADON CONCENTRATION IN VICINITY OF PILE

FIGURE 3-10. EPA GAMMA SURVEY SURROUNDING MILLSITE

TABLE 2-1
TAILINGS MATERIALS

	<u>Volume</u> <u>(yd³)</u>	<u>Weight^a</u> <u>(tons)</u>
Tailings	2,000,000	2,600,000

^aWeight based on average existing field densities which include moisture