A SUMMARY OF THE PHASE II - TITLE I ENGINEERING
ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS
NATURITA SITE, NATURITA, COLORADO

NOVEMBER 1977

MASTER

PREPARED FOR

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

BY

Ford, Bacon & Davis Utah Inc.

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By

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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 (issued under separate cover) entitled, "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Naturita Site, Naturita, Colorado". 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 that address the radiological problems and estimated costs of remedial measures that would reduce exposure of the general public. Title I is not a scientific study but an engineering assessment to determine the relative magnitude of the hazards associated for each site, and to estimate the remedial action costs. If additional information that may alter or have an impact on a final remedial action decision for any site is required, it can be obtained during the Title II Engineering Effort.

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 to 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 radiometric 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) The State of Colorado: Department of Health, Mr. A. J. Hazle and Mr. G. A. Franz
- (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 socioeconomic studies
- (5) Foote Mineral Company: Mr. R. L. Anderson, Mr. A. E. Curtis
- (6) Ranchers Exploration and Development Corporation: Mr. David K. Hogan and Mr. Jamiesen K. Deuel

ABSTRACT

Ford, Bacon & Davis Utah Inc. has performed an engineering assessment of the problems resulting from the existence of radioactive uranium mill tailings at Naturita, Colorado. 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, the performance of radiometric measurements to determine the extent of radium contamination, the evaluation of resulting radiation exposures of individuals and nearby populations, the investigation of site hydrology and meteorology, and the costing of alternative corrective actions.

Radon gas release from the 704,000 tons of tailings at the Naturita site constitutes the most significant environmental impact although windblown tailings and external gamma radiation are also factors.

Ranchers Exploration and Development Company has been licensed by the State of Colorado to reprocess the tailings at a location 3 mi from the present site where they will be stabilized for long-term storage.

The remedial action options include remedial action for structures in Naturita and Nucla (Option I) at an estimated cost of \$270,000 and remedial action for structures and open land adjacent to the tailings site (Option II) at an estimated cost of \$950,000.

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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 1974 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 Naturita site, evaluations of the following factors were included:

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

(1) See end of chapter for references.

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

Investigation of these and other factors led to the detailed evaluation of two alternatives. The first includes only remedial action at off-site structures and the second includes remedial action at off-site structures and cleanup of windblown contamination surrounding the tailings site. The formulation of these options assumes that the tailings will be removed from the site for reprocessing at a different location and that contaminated soil beneath the pile will be removed.

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.

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 piece-meal basis. He proposed that the study be a cooperative two-phase undertaking by the states concerned and the appropriate federal agencies,

*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.

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 summarized 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 Naturita included gamma logging of tailings drill holes on March 10 and 11, 1976, field survey work from May 7 through May 11, 1976, and additional radon measurements on June 5 and 6, 1976, and October 7 through October 10, 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 Naturita 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 clean-up 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 tailings site is located 2 mi northwest of the town of Naturita, Montrose County, Colorado in the San Miguel River Valley. The valley floor is at an elevation of approximately 5,355 ft above sea level. The locale is arid with canyons, mesas, steep cliffs and valleys which are typical of the western slope of the Rocky Mountains. The site and its relationship to the surrounding area is shown in the aerial photograph in Figure 2-1, Chapter 2.*

1.2.2 Ownership and History of Milling Operations and Processing

The portion of the site occupied by the tailings was bought by Ranchers Exploration and Development Corporation of Albuquerque, New Mexico in 1976 from Foote Mineral Company. The balance of the site is owned by Foote Mineral Company, which has leased a portion to General Electric Company for an ore buying depot.

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

The mill was built in 1930 by the Rare Metals Company. It did not become operational until 1939, when Vanadium Corporation of America (VCA) acquired the mill and converted it to a salt-roast, water-leach process for vanadium recovery. The process was modified again in 1942 so that uranium could be extracted. Uranium concentrates were shipped to the AEC until 1958, when the mill was shut down. From 1961 until 1963 an upgrader was operated at the site by VCA. The mill was dismantled in 1963. In 1967, VCA was merged into Foote Mineral Company and site ownership passed to Foote.

During its life the mill processed 704,000 tons of ore. Prior to the 1958 shutdown the ore averaged 0.30% U_3O_8 and 1.8% V_2O_5 . During the upgrader operation, ore averaging 0.25% U_3O_8 and 1.65% V_2O_5 was processed. Ore was received from throughout the Uravan mineral belt and beyond.

1.2.3 Present Condition of the Site

Figure 2-3, Chapter 2 is a descriptive map of a portion of the site as it now exists. The tailings pile is convex-shaped and covers about 23 acres. Figure 2-4, Chapter 2 is a typical cross-section of the site. The old mill building has been removed, although 17 buildings remain which are used for storage, office space, and by those leasing portions of the site as an ore buying station. The tailings were stabilized in 1969 with approximately 6 in. of earth cover. They now show signs of the erosive action of storms. Vegetation cover is approximately 40%. The site is fenced with a variety of fence types and is posted. There is a partial dike on the site between the tailings and the river. Maintenance and security are provided by the owners.

1.2.4 Tailings and Soil Characteristics

The tailings are mostly fine-grained sand with very little slime. Bulk densities average 111 lb/ft³. There are approximately 704,000 tons of tailings on the site. The weight and volumes of tailings materials are given in Table 2-1, Chapter 2. The soil beneath the pile is composed of alluvial deposits of the San Miguel River.

1.2.5 Geology, Hydrology, and Meteorology

The Naturita site is located on the west bank of the modern flood plain of the San Miguel River, which flows northwestward through the narrow San Miguel River Valley. The tailings lie on approximately 50 ft of alluvium which overlies the shales, sandstones and conglomerates of the Brushy Basin Member of the Morrison Formation. The bedrock strata dip 2 to 4 deg northeastward. The Brushy Basin Member is 100 to 200 ft thick beneath the tailings and is underlain by the sandstones and shales of the Salt Wash Member of the Morrison Formation and the mudstones of the Summerville Formation. A simplified stratigraphic column is shown in Figure 2-5, Chapter 2.

The flowing surface waters adjacent to or near the site consist of the San Miguel River and intermittent streams that drain the neighboring canyons. One of these streams is diverted around the pile, but cloudbursts up the canyon have resulted in the flow of water across the northwestern portion of the pile. Waters have flowed onto the pile from the diversion ditch along the southwestern border of the site and from drainage at the northwest of the site. An intermediate regional flood (100-yr flood) of the San Miguel River or more severe floods would top the riprap protecting the pile and erode cover materials and tailings from the pile. Before the riprap protection was constructed, tailings were eroded from the pile.

The unconfined aquifers in the San Miguel River Valley consist of waters within the recent valley alluvium. Except during flooding season, the water table lies 3 to 10 ft below the tailings-subsoil interface. During an intermediate regional flood or more severe floods, the water table would rise within the alluvium and tailings. Ground waters flowing through the tailings during flood stages, and ground waters at normal levels can be contaminated by precipitation, ponded waters, and flood waters leaching through the pile.

Very little work has been done to identify confined ground water aquifers in the Naturita area. Potential aquifers consist of sandstone strata within the Morrison Formation, and the sandstone units within the Entrada Formation. The Summerville Formation separates the Morrison Formation from the Entrada Formation and prevents downward migration of water. The Morrison Formation is the host rock for much of the uranium ore in the area and is not tapped as an aquifer. It is recharged in the Naturita area and the hydraulic flow gradient is to the northeast of the pile.

Meteorological records from the Hopkins-Montrose Airport, which lies 2.5 mi east of the site but outside the San Miguel River Valley, show that thunderstorm activity and precipitation in the area can be expected from May through October. Average annual precipitation at Naturita totals about 11 in. Cloudbursts at the site or in the canyons above the site have resulted in physical erosion of the tailings. The strongest winds at the site are those that are channeled up and down the canyon.

1.3 RADIOACTIVITY AND POLLUTANT IMPACTS ON THE ENVIRONMENT

About 85% of the total radioactivity originally in uranium ore remains 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 materials are several orders of magnitude greater than their average concentrations in the earth's crust.

1.3.1 Radiation Exposure Pathways, Contamination Mechanisms, and Background Levels

The major potential environmental routes of exposure to man are:

- (a) Inhalation of ^{222}Rn and its daughter products, resulting from the continuous radioactive decay of ^{226}Ra in the tailings. Radon is a gas which diffuses from the piles. The principal exposure results from inhalation of the ^{222}Rn and Rn daughters. This exposure affects the lungs. For this assessment, no criteria have been established for radon concentrations in air. However, the pathway for radon and radon daughters accounts for the major portion of the exposure to the population.
- (b) External whole-body gamma exposure directly from radionuclides in the 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 Naturita 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 0.17 mi north of the Naturita site in the San Miguel River Valley. The radon concentration including background at this location averaged 15.0 pCi/l for a 24-hr period. Indoor radon concentration averaged 7.7 pCi/l at the Foote Mineral Company office 0.11 mi south of the pile.

Five 24-hr measurements of atmospheric radon indicated an average background concentration of 2.0 pCi/l for the Naturita area.

1.3.1.2 Direct Gamma Radiation

The range of natural background values in the Naturita area

was between 7 and 12 $\mu\text{R/hr}$, averaging 10 $\mu\text{R/hr}$ as measured 3 ft above ground with an energy-compensated Geiger Mueller detector. (2) Above the surface of the tailings pile, gross gamma radiation rates were measured as high as 780 $\mu\text{R/hr}$. Across the road at the former ore stockpile area, gamma radiation reached a maximum of 380 $\mu\text{R/hr}$.

1.3.1.3 Windblown Contaminants

Prevailing winds in the area follow the San Miguel River Valley and therefore tend to be northwest and southeast winds. Concentrations of ^{226}Ra in surface soil samples and the EPA gamma survey were used to determine the extent of windblown tailings. Gamma radiation surveys indicate windblown tailings as far as 0.7 mi to the northwest of the Naturita tailings pile. Iso-exposure lines due to residual windblown tailings are illustrated in Figure 3-10, Chapter 3.

1.3.1.4 Ground and Surface Water Contamination

Three water samples taken from the San Miguel River during this assessment contained ^{226}Ra concentrations ranging from 0.4 to 1.7 pCi/l. (2) These samples appeared to indicate a small, localized contamination of the San Miguel River immediately adjacent to the tailings pile; however, these values are less than the EPA Interim Drinking Water Regulation for radionuclides. (3)

1.3.1.5 Soil Contamination

The leaching of radium from the tailings extends into the subsoil an average of 5 ft before reaching the twice average background radium concentration in the soil (1.5 pCi/g). The range of contamination is from 3 to 6 ft beneath the tailings-subsoil interface.

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 six 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 Naturita area was determined in this study to be 10 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 ²²⁶Ra 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 north-northwest direction in which the gamma radiation is still twice background 0.8 mi from the pile; however, there are no inhabitants in this direction.

The gamma exposure and the inhalation of radon daughters from the tailings pile under present conditions account for almost all of the dose derived from the tailings to the people living in the Naturita area 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 piles. If the diffusion path can be made long enough, then, theoretically, substantially all the radon and its daughter products can be made to decay before escaping to the atmosphere. Calculations using the techniques of Kraner, Schroeder, and Evans⁽⁴⁾ indicate that 13 ft of earth cover theoretically would be required to reduce the radon diffusion from the Naturita tailings by 95%.

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

The risk estimators used in this report are given in the report of the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR report).⁽⁵⁾ 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.⁽⁶⁾

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 measurements and predictions of radon concentrations in excess of background values, it is calculated that the average pile radon-induced lung cancer risk to the population in the area within 4 mi from the Naturita tailings site is 2×10^{-6} per person per year, or about 4×10^{-3} health effects per year in the area. The health effect rate for background radon is approximately 8.9×10^{-5} per person per year, or about 0.17 effects per year in the area. The average cancer risk due to all causes for Colorado residents is 1.8×10^{-4} per person per year.⁽⁷⁾ Within 4 mi of the pile the average lung cancer risk due to the pile is about 1% of the cancer risk due to all causes.

The cumulative health effects over a 25-yr period were calculated for three population projections. The results are as follows:

25-yr Cumulative Health Effects 0-4 Mi from Edge of Pile

<u>Projected Population Growth</u>	<u>Pile-Induced RDC</u>	<u>Background RDC</u>
Static population	0.10	4.3
2% annual population growth ^a	0.12	5.1
4% annual population growth ^a	0.14	6.1

^aThe growth rate decreases linearly with time to zero in 25 yr.

As a result of the low population density, the low radiation levels of the tailings at the Naturita site, and the relatively high background radon levels, the potential health impact of the pile is minimal for persons not working or living directly on or adjacent to the site.

1.3.4 Nonradioactive Pollutants

There are other potentially toxic materials in the tailings. Chemical analyses of tailings samples from drill holes on the Naturita tailings pile showed selenium at about 0.5 ppm, lead and arsenic between 40 and 60 ppm, and chromium concentration up to 3.5 ppm. Three samples of surface waters in the area surrounding the Naturita tailings pile containing selenium in concentrations above the EPA Interim Drinking Water Standards. The selenium content of the San Miguel River increased about 30% as it passed the Naturita tailings pile to about 1.2 times the EPA standard of 0.01 mg/l. San Miguel River samples both up and downstream contained chromium at or above the EPA standard for drinking water. However, standing water which had flowed off the tailings did not contain any measurable chromium.

1.4 SOCIOECONOMIC AND LAND USE IMPACTS

Based on site inspection and census records, 18,366 persons are assumed as the 1970 population base of Montrose County, and 1,914 persons are assumed to be living within 4 mi of the pile. Calculations of population projection could be misleading because of the area's small population base and its extreme dependence on mining. The limited water supply, lack of potential for tourism, and isolation of the area make sustained population expansion unlikely.

Virtually all the land near the tailings pile is devoted to low density grazing and other agricultural uses. Three residential communities are within a 5-mi radius of the pile, East Vancorum, West Vancorum and Naturita. There are 34 occupied units at West Vancorum, 4 occupied units at East Vancorum, and unoccupied units and trailer sites at both locations. The nearest commercial activity is at Naturita.

The assessed values of the properties near the site range from \$7.59/acre to \$8.33/acre, including improvements. The Foote Mineral Company property is listed at \$28,533.33 with improvements. The presence of the tailings restricts the use of the tailings area itself. However, the loss of grazing or crop land is minimal and the presence of the tailings has not affected the land use or values of surrounding property. In general, the land surrounding the site has a market value of about \$1,000/acre.

1.5 RECOVERY OF RESIDUAL VALUES

Samples of tailings obtained during this study were composited and analyzed. Data obtained from the AEC indicated the Naturita pile contains 0.047% U₃O₈. Using the AEC estimate, the Naturita tailings contain 662,000 lb of U₃O₈.

There are five factors that should be employed to evaluate whether reprocessing the Naturita 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 Naturita tailings is economically attractive at this time.

1.6 MILL TAILINGS STABILIZATION

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

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

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

The existing cover and vegetation on the Naturita tailings have reduced tailings erosion from wind and rainfall and have provided partial control over gamma radiation, but little control over radon exhalation. A vegetative cover has been established on the Naturita tailings.

1.7 REMEDIAL ACTIONS AND BENEFITS

Two closely related objectives of this engineering assessment are to identify those structures and land areas off site where tailings are located and, based upon the Surgeon General's guidelines and on criteria established for this assessment, to estimate the costs of appropriate remedial actions. Some tailings have been transported off the site by individuals, and some by wind and water erosion.

The remedial options at the Naturita site are limited as a result of unique conditions existing there. Ranchers Exploration and Development Company is responsible for removing contaminated soil beneath the pile under the State of Colorado license that

was granted to Ranchers for reprocessing the tailings. Thus, remedial action options need not consider decontamination of the present tailings area. However, measurements of the extent of subsoil contamination have been made and are shown in Figure 7-1, Chapter 7. Also given in the figure are the estimated costs per foot to remove the contaminated subsoil. The southeastern portion of the site is under lease to General Electric Company and currently contains an active ore storage area. Therefore, decontamination of this area is not possible.

Given these conditions, two alternative remedial action options were formulated to include decontamination of off-site structures and windblown areas adjacent to the tailings site. Costs are also identified for removal of the tailings and contaminated subsoil to another location.

1.7.1 Remedial Action for Structures (Option I)

This option includes millsite building decontamination and remedial action at off-site structures where tailings have been identified. A mobile scanning unit, operated by the AEC under an interagency agreement with EPA, performed gamma radiation surveys of the Naturita and Nucla, Colorado areas in 1971. Follow-up gamma surveys of the 33 anomalies at Naturita and the 13 anomalies at Nucla found 10 tailings use locations in Naturita and 3 in Nucla.

The cost for remedial actions at these structures under Option I is estimated at \$270,000.

An extended series of measurements, such as required in the full application of the Grand Junction Remedial Action Criteria, might reduce the actual number of locations included in the remedial action. The locations at which tailings are on vacant lands or are greater than 10 ft from structures were not subject to the criteria used in Phase II, but could constitute a problem in the future.

1.7.2 Remedial Action for Open Lands (Option II)

Option II includes cleanup of windblown contamination adjacent to the tailings site in addition to the remedial actions for structures that constitute Option I. The extent of windblown tailings is illustrated in Figure 3-10, Chapter 3. The area to be decontaminated under this option is shown in Figure 7-2, Chapter 7. The ore buying station on the millsite and ore storage areas are not included in the decontamination effort because they are currently in use.

The cost of Option II is estimated at \$950,000. The costs for moving the tailings and contaminated soil to another location 5 mi away, including site preparation, 2 ft of cover on the tailings after placement, fencing, and an endowment fund for annual maintenance are \$4,500,000.

1.7.3 Benefits

Option II and the Ranchers Exploration decontamination beneath the tailings would leave the site in a condition suitable for unrestricted use; however, the presence of the ore stockpile and ore buying station would restrict activities at the site.

Health effects from the Naturita tailings are negligible in their present location and therefore no cost benefit analysis was performed. Generally, remedial action on structures (Option I) has a very favorable health benefit-to-cost ratio.

Land value of the tailings area could increase from a current estimated \$200/acre to a possible \$1,000/acre for a net increase of \$18,400 for the 23 acres.

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

	Cond. of Tailings	Cond. of Structures on Site	Mill Housing	Adequate Fencing, Posting, Security	Property Close by River or Stream	Houses- Industry w/in 1/2 Mile	Evidence of Wind Water Erosion	Possible Water Contami- nation	Tailings Removed for Pri- vate Use	Other Hazards On-site
<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 Action²</u>	<u>Benefits</u>	<u>Adverse Effects</u>
I	270	Off-site remedial action for structures in Naturita and Nucla	A,B,C,E, G	H
II	950	Off-site remedial action for windblown tailings and off-site remedial action for structures	A,B,C,D,E F,G	

Notes

1. Costs are in 1977-value dollars.
2. Assumes tailings will be removed from present site for reprocessing.

Definition of Benefits

- A. Gamma radiation from pile eliminated.
- B. Radon exhalation greatly reduced.
- C. Wind and water erosion of tailings eliminated, no maintenance required.
- D. Windblown tailings removed.
- E. Tailings site available for limited use.
- F. Tailings site and area NW of tailings available for limited use.
- G. Reduction of exposure to individuals in off-site structures.

Definition of Adverse Effects

- H. No reduction in gamma radiation and radon exhalation from windblown tailings.

CHAPTER 1 REFERENCES

1. "Summary Report, Phase I Study of Inactive Uranium Mill Sites and Tailings Piles"; AEC; Grand Junction, Colorado; Oct 1974.
2. F. F. Haywood, et al; "Assessment of Radiological Impact of the Inactive Uranium Mill Tailings Pile at Naturita, Colorado"; ORNL (in preparation).
3. Federal Register, Part II; EPA-Drinking Water Regulations; EPA; Jul 9, 1976.
4. H. W. Kraner, G. L. Schroeder, and R. D. Evans; "Measurements of the Effects of Atmospheric Variables on Radon-222 Flux and Soil-Gas Concentrations"; The Natural Radiation Environment; J. A. S. Adams and W. M. Lowder, eds; University of Chicago Press; 1964.
5. "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation"; Report of Advisory Committee on Biological Effects of Ionizing Radiation; NAS; National Research Council; Nov 1972.
6. "Health Effects of Alpha-Emitting Particles in the Respiratory Tract"; Report of the Advisory Committee on the Biological Effects of Ionizing Radiation; EPA/ORP; EPA-520/4-76-013; Washington, D.C.; Oct 1976.

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

FIGURE 2-3. DESCRIPTIVE MAP

PLAN

FIGURE 2-4. CROSS-SECTION THROUGH TAILINGS PILE

SYSTEM	FORMATION	THICK- NESS (FT)	CHARACTER	POSITION OF THE TAILINGS
CRETACEOUS	MANCOS SHALE	2,000 - 5,000	GRAY SHALE, FORMS VALLEYS AND SLOPES, AQUICLUDE

TABLE 2-1
TAILINGS SITE MATERIALS

<u>Material</u>	<u>Volume (Yd³)</u>	<u>Weight (Tons)*</u>
Tailings	521,000	704,000
Debris and Rubble	5,000	8,000
Stabilization Cover	16,000	22,000
Total	542,000	734,000

*Weight based on average existing densities which contain moisture

FIGURE 3-3 RADON CONCENTRATION IN VICINITY OF PILE

NOTE:
REFERENCE TECHNICAL NOTE
ORP/LV-75-5, 'GAMMA RADIATION
SURVEYS AT INACTIVE URANIUM
MILLSITES', U S E P A , LAS VEGAS,
NEVADA, AUG. 1975
FIG. 12 PAGE 59

FIGURE 3-10. EPA GAMMA SURVEY SURROUNDING MILLSITE

FIGURE 7-1. RADIUM ACTIVITY CONCENTRATION IN CONTAMINATED SUBSOIL

130-07

FIGURE 7-2. AREA DECONTAMINATION PLAN

130-07