MASTER

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

**MONUMENT VALLEY SITE
MONUMENT VALLEY, ARIZONA**

MARCH 31, 1977

PREPARED FOR

**U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
GRAND JUNCTION, COLORADO**

CONTRACT NO. E(05-1)-1658

BY

Ford, Bacon & Davis Utah Inc.

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GRAND JUNCTION, COLORADO

Contract No. E(05-1)-1658

By

FORD, BACON AND DAVIS UTAH INC.
375 Chipeta Way
Salt Lake City, Utah 84108

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, Monument Valley Site, Monument Valley, Arizona." 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 addresses the radiological problems and estimated costs of remedial measures that would reduce exposure of the general public.

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.

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 by the Union Carbide Corporation personnel of the Health Physics Division, Oak Ridge National Laboratory, who provided field radiological measurements and radon diffusion modeling. The preparation of this report could not have been accomplished without the cooperation and assistance of FB&DU's subcontractor, the Center for Health and Environmental Studies at Brigham Young University, Provo, Utah, and also 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 Navajo Tribal Council
- (3) The Navajo Environmental Protection Commission, especially Mr. Daniel Peaches, Chairman, and Mr. Harold Tso, Executive Director
- (4) Utah Navajo Development Corporation, Mr. Cleal Bradford, Director
- (5) The Indian Health Service, Office of Environmental Health (USPHA)
- (6) Bureau of Indian Affairs, Navajo Area
- (7) Arizona State Division of Health, for advice and assistance in the radiological assessment of air and water samples

- (8) Local officials, residents, and business personnel in the Monument Valley site locale
- (9) EG&G; Las Vegas, Nevada; Mr. Jack Doyle, for aerial photography

CONTENTS

<u>Chapter</u>	<u>Title</u>	<u>Page</u>
	Foreword	ii
	Abstract	iv
	Glossary	vii
1	SUMMARY	
1.1	Introduction	1-1
1.1.1	Background	1-2
1.1.2	Scope of Phase II Engineering Assessment . . .	1-3
1.2	Site Description	1-5
1.2.1	Location and Topography . .	1-5
1.2.2	Ownership and History of Milling Operations and Processing	1-6
1.2.3	Present Condition of the Site	1-6
1.2.4	Tailings and Soil Characteristics	1-7
1.2.5	Geology, Hydrology, and Meteorology	1-7
1.3	Radioactivity and Pollutant Impacts on the Environment	1-8
1.3.1	Radiation Exposure Pathways, Contamination Mechanisms, and Background Levels	1-8
1.3.1.1	Radon Gas Diffusion and Transport . . .	1-9
1.3.1.2	Direct Gamma Radiation	1-9
1.3.1.3	Windblown Contami- nants	1-9
1.3.1.4	Ground and Surface Water Contamination	1-10
1.3.1.5	Soil Contamination	1-11
1.3.2	Remedial Action Criteria . .	1-11
1.3.3	Potential Health Impact . . .	1-12
1.4	Socioeconomic and Land Use Impacts	1-14

CONTENTS (Cont)

<u>Chapter</u>	<u>Title</u>	<u>Page</u>
1.5	Recovery of Residual Values	1-14
1.6	Mill Tailings Stabilization	1-15
1.7	Off-Site Remedial Action	1-15
1.8	Long-Term Storage Site Selection .	1-16
1.9	Remedial Actions and Cost-Benefit Analyses	1-16
	1.9.1 Remedial Action Options . .	1-16
	1.9.2 Cost-Benefit Analyses . . .	1-17
Table 1-1	Summary of Conditions Noted at Time of Phase I Site Visits	1-18
Table 1-2	Summary of Remedial Action Options and Effects	1-20
Chapter 1	References	1-21
ADDENDUM	(Figures and Tables)	1-22

GLOSSARY

Abbreviations/Terms

Definitions

absorbed dose	Radiation energy absorbed per unit mass
A-E	Architect-Engineering
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 where the recorded counts per second (c/s) exceed the determined background for that location by 50 or more c/s (as defined in EPA report EPA-520/6-74-006)
aquifer	A water-bearing formation below the surface of the earth; the source of wells
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 radia-

	tion can cause skin burns and beta-emitters are harmful if they enter the body.
BEIR	Biological Effects of Ionizing Radiation
BIA	Bureau of Indian Affairs
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 atom (parent) has undergone 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 (One 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 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 to pollutants from tailings (In this report, one health effect is defined as one case of lung cancer produced from inhalation of radioactive materials.)
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
IHS	Indian Health Service

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 of 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
NECA	Navajo Engineering and Construction Authority
NEPC	Navajo Environmental Protection Commission
NIOSH	National Institute for Occupational Safety and Health
NMEIA	New Mexico Environmental Improvement Agency

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 one 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 1,600 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 uranium or radium in the soil
radon concentration	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 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 what remains in tailings after the uranium (or other mineral) has been removed
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 uranium mills (see tailings). These sands normally contain less radioactive material than the slimes.
scintillometer	A radiation detection instrument used for monitoring small changes in background and for low-level radiation, normally utilizing a NaI crystal as a scintillator
slimes	Extremely fine-grained materials, mixed with small amounts of water, produced along with the sands as waste products of 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.

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 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 completely lacking. 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 Monument Valley site, evaluations of the following factors were included:

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

⁽¹⁾ See end of chapter for references.

- (c) Land contamination from windblown tailings
- (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 potential practical alternatives that were evaluated in detail.

- (a) Minimum remedial action, which amounts to isolating the site by fencing
- (b) Stabilization designed for long-term storage of tailings in their current location

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,

*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.

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, 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. Work on the Monument Valley site began early in 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 and its subcontractor, the Center for Health and Environmental Studies (CHES), at Brigham Young University. 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, gamma surveys, and modelled the radon diffusion from the pile. The EPA staff provided the results of radiation surveys they previously had made at the Monument Valley site.

The specific scope requirements of the Title I assessment are:

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

1.2 SITE DESCRIPTION

1.2.1 Location and Topography

The Monument Valley site, or the Navajo Indian Reservation, covers approximately 90 acres in Cane Valley just east of Monument Valley, Arizona. It is located approximately 20 miles east of U.S. 163 as this road passes through Monument Valley and is about 5 miles south of the Utah-Arizona border. The site and its relationship to the surrounding area are shown in the aerial photo in Figure 2-1,* Chapter 2. The country generally is arid and desertlike with hills, steep ridges and

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

mesas. Red sandstone cliffs are prominent on the west edge of Cane Valley. Vegetation is sparse. The elevation of the site is about 4,400 ft above sea level.

1.2.2 Ownership and History of Milling Operations and Processing

The mill was constructed and operated from 1955 to 1968 by Vanadium Corporation of America, and its successor, Foote Mineral Company.

Before and during the milling operations the site was leased from the Navajo Tribe. When the lease expired in 1968, full control of the site reverted to the Navajo Nation.

The source of ore for the mill was the Monument No. 2 mine, about 1 mi west of the site. From the summer of 1955 through July 1964, the method employed to recover the uranium from the ore was a sand-slime separation process. In October 1964, equipment was installed for batch leaching of the sand fraction that had been stored on the property from the earlier operations. About 1 million tons of the sand tails were treated, and an additional 100,000 tons of low-grade ore were heap-leached. The plant ceased operations in November 1967. Recovery of both uranium and vanadium from the ore while using the aforementioned processes was between 65 and 70%.

Because the radium in the ore was contained mainly in the fine clay fraction, most of the radium was in the upgraded ore concentrates hauled to Durango, CO and to Shiprock, NM. However, some residual radium does remain in the tailings. Therefore, at the request of the Navajo Tribal Council, an environmental radiological survey of the site was performed⁽²⁾ in May 1968. The results of the survey indicated that radiation levels did not exceed guidelines applicable at that time. However, the report did recommend that the tailings be stabilized against wind erosion and that periodic monitoring be continued.

1.2.3 Present Condition of the Site

Figure 2-3, Chapter 2, is a descriptive map of the 90-acre site as it now exists. The tailings are located in two piles and cover approximately 30 acres. The old heap leach pile covers 10 acres to an average depth of 2 to 3 ft. The new tailings pile is cone-shaped, approximately 55 ft high, covers 20 acres, and contains approximately 85% of the tailings at the site. Figure 2-4 is a cross-section of the site.

The old mill buildings have been removed, although foundations, rubble, and portions of the old and all of the new tailings piles remain. The site is neither fenced nor posted. The tailings have not been stabilized.

1.2.4 Tailings and Soil Characteristics

The new tailings pile is composed of coarse-grained sand and small pebbles containing less than 2% minus-200-mesh material. The old tailings pile is composed of material which is slightly finer. Bulk densities run between 96.82 and 102.6 lb/ft³. As given in Table 2-1, Chapter 2, there are approximately 1,100,000 tons of tailings on the site.

The soil beneath both piles is mainly fine textured sand containing little moisture. Rock of the Chinle Formation lies beneath this alluvium.

1.2.5 Geology, Hydrology, and Meteorology

The Monument Valley tailings site is located in a strike-valley developed on shale members of the Chinle Formation. On the west the site is bordered by an outcropping of the Shinarump Member of the Chinle Formation and on the east by Comb Ridge, a hogback of resistant sandstones of Triassic and Jurassic age. A stratigraphic cross-section of the area is illustrated in Figure 2-6, Chapter 2.

There are no continually active streams in the area. The site drains naturally into Cane Valley Wash for which stream flow data is not available. Approximately 1000 acres of land is in the drainage basin which passes through the tailings area to the wash. There is some evidence of surface water erosion of the tailings, but because of their coarse-grained nature, little downstream transport of the tailings has occurred. A major flash flood of longer than one hour duration could significantly carry a quantity of the tailings into Cane Valley Wash.

The tailings likely will have very little effect on the radioactive content of the Shinarump aquifer, which surfaces just west of the tailings area, considering that this member has served as the host for uranium mineralization and contains uranium ore bodies throughout the Navajo Reservation. Also, local wells do not receive their water from the Shinarump aquifer.

Unconfined ground water is very near the surface along the main axis of Cane Valley Wash because the area is underlain by impermeable beds of Monitor Butte and Petrified Forest members of the Chinle Formation. These members consist of siltstones and claystones and are about 700 ft thick in the millsite area. The unconfined water moves through the alluvium of Cane Valley Wash and is recovered near the site from shallow wells. These shallow wells and springs are watertable sources and their recharge is from local runoff.

There are no precipitation records at the Monument Valley site, but annual precipitation records at two locations, each 28 miles in different directions from the site show it to be 7.5 and 8.3 in., respectively. The precipitation at the tailings site should be similar to these sources. The maximum 24-hr precipitation at these two sources was 3.6 and 2.5 in. The Monument Valley site could expect to receive a 24 hr maximum precipitation of 1.3 in. once every 2 years, typically during August, September, or October.

Wind data on the site is not available. On site observations show that the prevailing winds in Cane Valley at the tailings location are from the southwest and that periodically there is some movement of the finer tailings material at the northeastern edge of the tailings resulting from these winds. There are no residences within 2 mi of the tailings in this major wind direction.

1.3 RADIOACTIVITY AND POLLUTANT IMPACTS ON THE ENVIRONMENT

About 85% of the total radioactivity originally in uranium ore remains after removal of the uranium. The principal environmental radiological impact and associated health effects arise from the ^{230}Th , ^{226}Ra , ^{222}Rn (a noble gas), and ^{222}Rn daughters contained in the uranium tailings. Although these radionuclides occur in nature, their concentrations in tailings material are several orders of magnitude greater than their average concentrations in the earth's crust.

1.3.1 Radiation Exposure Pathways, Contamination Mechanisms, and Background Levels

The major potential environmental routes of exposure to man are:

- (a) Inhalation of ^{222}Rn and its daughter products, resulting from the continuous radioactive decay of ^{226}Ra in the tailings. Radon is a gas which diffuses from the pile. The principal exposure results from inhalation of the ^{222}Rn daughters. This exposure affects the lungs. For this assessment, no criteria have been established for radon concentrations in the air. However, the pathway for radon and radon daughters accounts for a 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 seven locations in the vicinity of the Monument Valley tailings site. The locations and values of the radon measurements are shown in Figure 3-3, Chapter 3. The average background radon concentration for four 24-hr measurements was 0.6 pCi/l. One set of measurements between the old and new piles indicated an average radon concentration of 6.8 pCi/l for a 24-hr period. Two average values of radon concentration were in the 3 to 4 pCi/l range at measurement locations 0.1 and 0.6 mi north of the tailings site.

1.3.1.2 Direct Gamma Radiation

Background values of gamma radiation around the Monument Valley site averaged 9 $\mu\text{R/hr}$.⁽³⁾ Previous measurements yielded an average background value of 9.4 $\mu\text{R/hr}$.⁽⁴⁾ The range of values was from 7 to 11 $\mu\text{R/hr}$ although the gamma radiation increased away from the pile toward the west in the vicinity of the Monument No. 2 mine.⁽³⁾ Above the surface of the exposed tailings piles, gamma readings ranged from 23 to 137 $\mu\text{R/hr}$.

1.3.1.3 Windblown Contaminants

The particle size of the new tailings pile is such that it is unlikely that they will be transported by wind any great distance from the tailings pile. Prevailing winds in the area are from the southwest, and there is some drifting of the tailings material at the northeastern edge of the pile. In most directions the maximum distance of tailings transport is about 500 ft. However, in a northerly direction assays of ^{226}Ra in surface soil samples indicate that the tailings material has been moved about 2,000 ft. Tailings or overburden may have been used in the construction of the airstrip in that vicinity. An iso-exposure line due to residual windblown tailings is illustrated in Figure 3-10, Chapter 3.

No particulate measurements were performed at the Monument Valley site during this field survey. Previous measurements⁽²⁾ off the tailings piles indicated that ^{226}Ra , ^{230}Th , and natural uranium were present at the time samples were taken in concentra-

tions one to two orders of magnitude less than the guidelines established in the Code of Federal Regulations, Title 10, Part 20.

1.3.1.4 Ground and Surface Water Contamination

The confined ground water aquifers underlying the site are protected against contamination by both an upward pressure gradient and a thick aquiclude, and there is no possibility of contamination of these aquifers from the tailings. Previous radiometric analyses indicated from 0.1 to 1.5 pCi/l of ^{226}Ra in water from four wells within a 1/2-mi radius of the site and 0.5 pCi/l from a well 4 mi north of the site.⁽²⁾ Five water samples taken in a 7-mi radius from the piles during this assessment contained radium concentrations ranging from 0.05 to 2.9 pCi/l.⁽³⁾ The highest ^{226}Ra concentration was measured in water from the same artesian spring 1/2 mi east of the tailings as the 1.5 pCi/l sample measured previously.⁽²⁾ This water is not used for human consumption. These values are less than the 5 pCi/l level for ^{226}Ra and ^{228}Ra in the EPA Interim Drinking Water Regulation for radionuclides.⁽⁵⁾ Uranium concentrations ranged from 2 to 18 $\mu\text{g/l}$ in these well waters with the highest value in water from a well at the millsite.⁽²⁾

Because the old heap-leach tailings pile is placed over a natural drainage channel which drains about 1,000 acres of relatively steep watershed, there is considerable potential for surface runoff to erode some of the tailings material. Examination of the ground at the west and south edges of the tailings pile shows evidence that some surface drainage has found its way around the tailings pile and has cut a small channel into the tailings. Considering the size, slope, and characteristics of the watershed area, a potential flow of several thousand cubic feet of water per second could occur in the channel at the tailings during a time of extraordinary thunderstorms. An interceptor channel could be provided to divert the drainage around the tailings pile to Cane Valley Wash, thus averting the potential deposition of tailings in the wash.

The near-surface unconfined ground water at the site is found in the Cane Valley Wash alluvium. Recharge is from local runoff. It is not believed that any precipitation falling on the tailings piles will ever reach this shallow unconfined aquifer along the Cane Valley Wash since there is no evidence of surface runoff from the tailings piles.

The Shinarump Conglomerate Member of the Chinle Formation forms the shallowest confined aquifer in the vicinity of the millsite. This rock unit was the source rock for the ore processed at the millsite and contains uranium orebodies throughout the Reservation area. The millsite tailings have little effect on the radioactive content of the Shinarump aquifer. Local wells do not derive their water from this member.

1.3.1.5 Soil Contamination

The leaching of radium from the tailings into the subsoil reached depths from 1 to 8 ft beneath the new tailings pile as determined by radiometric logging in boreholes and sample assays. The ^{226}Ra concentration reached background levels about 2 ft beneath the old tailings pile in the hard but porous sandstone. (3)

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. (6) 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</u>	<u>Recommendations</u>
Greater than 0.1 mR/hr*	Greater than 0.05 WL**	Remedial action indicated
From 0.05 to 0.01 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

*mR/hr = milliroentgen per hour, a measure of gamma radiation;
1 mR/hr = 1,000 $\mu\text{R/hr}$.

**WL = Working level, a measure of alpha radiation from
short-lived radon daughter elements.

The criteria for land decontamination have the objective to 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 $\mu\text{R/hr}$ above background is used in such circumstances. Average background in the Monument Valley was determined in this study to be 9 $\mu\text{R/hr}$. As a guideline for the land beyond the site, if residual gamma levels are less than 10 $\mu\text{R/hr}$ 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. Therefore, the cost of decontamination to different levels is included in the study.

The ^{226}Ra 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 0.1 mi from the piles, and the gamma exposure to the population within 1 mi from the piles is negligible. Radon gas exhalation from the piles and the subsequent inhalation of radon daughters account for almost all of the total dose to people from the Monument Valley site under present conditions. 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 enroute to the surface and leaves daughter products within the tailings piles. If the diffusion path can be made long enough, then in theory, substantially all the radon and its daughter products can be made to decay before escaping to the atmosphere. (7)

The health significance 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 the 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 basis that the effects are linear. A considerable

amount of information has been accumulated on the high incidence of lung cancer in uranium miners exposed to radon and its daughters in mine air, and provides a basis for calculating the probable health effects of low-level exposure to large populations. (The term "health effect" refers to an incidence of disease; for radon daughter exposure, 1 health effect = 1 case of lung cancer.) This is the basis of the health effects calculations in this report. It should be recognized, however, that there is a large degree of uncertainty in such projections. Among the complicating factors is the combined effect of radon daughters with other carcinogens. As an example, the incidence of lung cancer among uranium miners who smoke is far higher than can be explained on the basis of either smoking or the radiation alone.

The risk estimators used in this report are given in the report of the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR report).⁽⁸⁾ This report presents risk estimators for lung cancer derived from epidemiological studies of both uranium miners and fluor-spar miners. The average of the absolute risk estimator for these two groups is: 6 cancers per year per 10^6 person-WLM exposure. The term WLM means working level month, or an exposure to a concentration of one working level of radon daughter products in air for 170 hr, which is a work-month. A working level (WL) is a unit of measure of radon daughter products which recognizes that the several daughter elements are frequently not in equilibrium with each other nor with the parent radon. Because of the many factors which contribute to natural biological variability, and of the many differences between exposure conditions in mines and residences, this estimator is considered to have an uncertainty factor of about 3.

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 of radon concentrations in excess of background values, it is calculated that the average radon-induced lung cancer risk to the population in the area within 1 mi from the Monument Valley site is 1.8×10^{-5} per person per year, or about 7×10^{-4} health effects per year in the valley. The lung cancer rate for the Navajos from all causes other than pile radon is 1.02×10^{-4} cases per person per year. Thus, the presence of the tailings can be expected to increase the rate of occurrence of lung cancer by 18% for

those persons presently within 1 mi from the piles.

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

<u>Case No.</u>	<u>Description</u>	<u>Cumulative 25-yr Health Effects</u>
1	No population growth	0.02
2	4% annual population growth	0.03

As a result of the low population density, and the low radiation levels of the tailings at the Monument Valley site, the potential health impact of the piles is minimal.

1.4 SOCIOECONOMIC AND LAND USE IMPACTS

Because all Reservation land is owned commonly by the Navajo Tribe there is no conventional market for Navajo properties. However, there are several criteria that might be used to assess the value of the site land. For example, recent exchanges of Tribal land for off-Reservation land is one basis. Lease payments for Navajo lands is another; comparisons with similar use off-Reservation land is another criterion, and the monetary value assigned to sheep production per acre is another. Also, taking into consideration other factors such as the distance of the site from a paved highway and the absence of utilities, the probable value of the site land would be that of agricultural land with a value of no more than \$40/acre.

There is a substantial amount of land in the Cane Valley area which has greater accessibility to water and roads than does the Monument Valley site; therefore, the pressure to use the actual tailings location for any purpose is relatively low. In addition, the lack of buildings and utilities at the site, the lack of accessibility by rail, air, or paved road, and the poor potential for discovery of any further minerals resources in the vicinity will keep pressure low to utilize the tailings area.

1.5 RECOVERY OF RESIDUAL VALUES

Historical records available to FB&DU that provide reliable data on the specific mineral contents of the Monument Valley tailings site are limited. Only a few samples of tailings were obtained during this study. Consequently, calculations based on these samples would not be statistically representative.

There are, however, five factors that can be employed to evaluate whether reprocessing the Monument Valley tailings to extract residual uranium and other 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 Monument Valley tailings does not appear to be a practical economic consideration at this time.

1.6 MILL TAILINGS STABILIZATION

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

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

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

1.7 OFF-SITE REMEDIAL ACTION

Following the Phase I study, EPA performed a radiation survey in the Monument Valley, Arizona area in August of 1975. (4) Sixteen structures with anomalous radiation levels were identified among the 37 which were surveyed. Tailings were used in the construction of several buildings and short-term WL measurements were made in many of the residential structures. Several wells were located in which tailings had been used in the well structure.

Windblown and water-eroded tailings have contaminated adjacent open areas, primarily to the north and east of the site. A sum of \$206,000 has been included in the various remedial action options to cover the possible off-site remedial work and cleanup of windblown tailings both on- and off-site.

1.8 LONG-TERM STORAGE SITE SELECTION

No alternative disposal site has been considered for the tailings. With implementation of Option II described in paragraph 1.9 the tailings can be isolated hydrologically and stabilized to meet the criteria for long-term storage.

1.9 REMEDIAL ACTIONS AND COST-BENEFIT ANALYSES

1.9.1 Remedial Action Options

The two remedial action options selected are summarized in Table 1-2. The base case, from which the comparative cost and effectiveness of the other remedial alternative is judged, is Option I. The cost of this option is estimated at \$585,000. Option I includes the following remedial work:

- (a) Installation of a heavy-duty 6-ft chainlink security fence
- (b) Road and drainage bypass work
- (c) Annual maintenance and monitoring work
- (d) Off-site remedial action at structures in Cane Valley

These actions would reduce direct exposure to individuals off the site and would discourage further removal of tailings from the site for use in construction. However, this option would not stop wind and water erosion nor reduce radon exhalation from the tailings.

Option II includes all the tasks of Option I in addition to the following work:

- (a) Mill area decontamination
- (b) Decontamination of windblown areas
- (c) Reshaping of the new pile to form gentler slopes
- (d) Stabilization of the piles with 2 ft of cover material
- (e) Placement of riprap around the base of the piles at appropriate areas to prevent erosion by water

The cost of Option II is \$1,165,000. These actions would largely eliminate wind and water erosion of the tailings and would reduce gamma radiation to background levels on the tailings.

1.9.2 Cost Benefit Analyses

The principal reason for the adoption of one of the remedial options is to reduce further deterioration of site conditions through control of erosion and to limit access so that no further tailings are removed from the site for use in construction. 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

	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.

TABLE 1-2

SUMMARY OF REMEDIAL ACTION OPTIONS AND EFFECTS

<u>OPTION NUMBER</u>	<u>COST (\$000)*</u>	<u>DESCRIPTION OF REMEDIAL ACTION</u>	<u>BENEFITS</u>	<u>ADVERSE EFFECTS</u>
I	\$585	Minimal Remedial Action: Road and drainage work, security fencing, monitoring and maintenance, off-site structures remedial action.	A B E	N O P Q R
II	1,165	Site decontamination, road and drainage bypass work, pile reshaping to eliminate steep slopes, 2-ft earth stabilization, fencing, maintenance and monitoring, remedial action for off-site structures and open land areas.	A B C D E F	O Q R

*All costs are in 1977 dollars

Definitions of Benefits

- A. Off-site structure decontaminated
- B. Access to site controlled by fencing and posting
- C. Windblown and water eroded tailings cleaned up
- D. Wind erosion reduced
- E. Water erosion reduced
- F. Gamma radiation reduced

Definitions of Adverse Effects

- N. No decrease in gamma radiation
- O. No control of radon gas emissions
- P. No wind erosion control on the tailings
- Q. Restricted use of the property
- R. Maintenance required indefinitely

CHAPTER 1 REFERENCES

1. Summary Report, Phase I Study of Inactive Mill Sites and Tailings Piles, U. S. Atomic Energy Commission; Oct 1974.
2. R. N. Snelling; "Environmental Survey of Uranium Mill Tailings Pile, Monument Valley, Arizona"; Radiological Health Data and Reports; Oct 1970.
3. F. F. Haywood, et al; "Assessment of Radiological Impact of the Inactive Uranium Mill Tailings Piles at Monument Valley, Arizona"; ORNL-TM-5583 (in preparation).
4. J. M. Hans, Jr., and R. L. Douglas; "Radiation Survey of Dwellings in Cane Valley, Arizona and Utah, for Use of Uranium Mill Tailings"; ORP/LV-75-2; EPA, Office of Radiation Programs, Las Vegas, Nevada; Aug 1975.
5. Federal Register, Part II, EPA - Drinking Water Regulations; Jul 9, 1976.
6. Office of the U. S. Surgeon General; Department of Health, Education and Welfare; Jul 1970; and 10CFR12.
7. A. B. Tanner; "Radon Migration in the Ground - A Review"; pp. 161-190; The Natural Radiation Environment; J. A. S. Adams and W. M. Lowder, eds; University of Chicago Press; 1964.
8. "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation"; Report Advisory Committee on Biological Effects of Ionizing Radiation; NAS, National Research Council; p. 150; Nov 1972.

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

<u>Number</u>	<u>Title</u>	<u>Page</u>
2-1	Aerial Photograph of Site	2-7
2-3	Descriptive Map	2-9
2-4	Cross-Section at Station 6+25	2-10
2-6	Simplified Stratigraphic Cross-Section	2-12
3-3	Radon Concentration in Vicinity of Piles	3-16
3-10	EPA Gamma Survey Surrounding Millsite .	3-23

LIST OF TABLES

<u>Number</u>	<u>Title</u>	<u>Page</u>
2-1	Tailings Site Materials	2-15

130-03

FIGURE 2-1. AERIAL PHOTOGRAPH OF SITE

FIGURE 2-3. DESCRIPTIVE MAP

FIGURE 2-4. CROSS-SECTION AT STATION 6+25

FIGURE 2-6. SIMPLIFIED STRATIGRAPHIC CROSS-SECTION (NOT TO SCALE)

TABLE 2-1
TAILINGS SITE MATERIALS

<u>Material</u>	<u>Volume (yd³)</u>	<u>Weight* (tons)</u>
Uranium Tailings		
Old Pile	123,000	165,000
New Pile	<u>697,600</u>	<u>935,000</u>
TOTAL	820,600	1,100,000

*Weight based on average existing field densities which
include moisture

SITE NO.	24 HR OUTDOOR (pCi/l)	LOCATION
1	6.8	BETWEEN OLD & NEW PILES
2	3.2	0.11 MI N E CORRAL
3	4.3	0.60 MI NORTH
4	0.7	0.83 MI NORTH
5	0.4	1.0 MI SOUTH
6	0.5	1.0 MI NORTH
7	0.6	2.2 MI NORTH

FIGURE 3-3. RADON CONCENTRATION IN VICINITY OF PILES

NOTE

REFERENCE: TECHNICAL NOTE
 ORP/LV-75-5, "GAMMA RADIATION
 SURVEYS AT INACTIVE URANIUM
 MILLSITES", USEPA, LAS VEGAS,
 NEVADA, AUG. 1975.

FIGURE 2

PAGE 39

0 100 200 300 400 FT
 A 2 UNCORRECTED DIFFERENTIAL GAMMA READING μ R/h

FIGURE 3-10. EPA GAMMA SURVEY SURROUNDING MILLSITE