ERRATA

A SUMMARY OF THE ENGINEERING ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS; TUBA CITY SITE, TUBA CITY, ARIZONA; SEPTEMBER, 1981; DOE/UMT-0120S, FBDU 360-05S.

Page 1016, First paragraph, Fifth line, should read:

"...6 mi of the Tuba City site is 3.2×10^{-6} per person per year, or about 3%...."

Page 1-16, the table showing cumulative health effects should be as follows:

25-Year Cumulative Health Effects Within 6 Miles of Edge of Pile

Projected Population Growth	Pile-Induced RDC	Background RDC
Constant 0.8% growth rate	0.25	2.0
2.5% declining growth rate*	0.28	2.2
4.9% declining growth rate*	0.33	2.6

Page 1-16, Third Paragraph, Second line should read:

"...than 13%...."

Page 9-9, Figure 9-3 is amended as attached.

Page 9-12, Table 9-2 is amended as attached.

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A SUMMARY OF THE ENGINEERING ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS

TUBA CITY SITE, TUBA CITY, ARIZONA

September 1981

Prepared for

U.S. DEPARTMENT OF ENERGY
ALBUQUERQUE OPERATIONS OFFICE
URANIUM MILL TAILINGS REMEDIAL ACTIONS
PROJECT OFFICE
ALBUQUERQUE, NEW MEXICO

Contract No. DE-AC04-76GJ01658

By

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NOTICE

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

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

FOREWORD

This report is a summary of a parent report (issued under separate cover), entitled "Engineering Asessment of Inactive Uranium Mill Tailings, Tuba City Site, Tuba City, Arizona." Both reports have been authorized by the U.S. Department of Energy (DOE), Albuquerque Operations Office, Uranium Mill Tailings Remedial Action Project Office, Albuquerque, New Mexico, under Contract No. DE-AC04-76GJ01658. These reports are revisions of an earlier report dated March 1977, entitled "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Tuba City Site, Tuba City, Arizona," which was authorized by DOE, Grand Junction, Colorado, under Contract No. E(05-1)-1658.

These reports have become necessary as a result of changes that have occurred since 1977 which pertain to the Tuba City site and vicinity, as well as changes in remedial action criteria. The new data reflecting these changes are summarized in this report. Evaluation of the current conditions is essential to assessing the impacts associated with the options suggested for remedial actions for the tailings.

Ford, Bacon & Davis Utah Inc. (FB&DU) has received excellent cooperation and assistance in obtaining new data to prepare these reports. Special recognition is due Richard H. Campbell and Mark Matthews of DOE, as well as Harold Tso and Ben Benally of the Environmental Protection Commission, Navajo Nation. Officials of the Navajo Nation, Window Rock, Arizona, contributed information, as did several local, county, and state agencies and private individuals.

ABSTRACT

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

Radon gas released from the 0.8 million tons of tailings at the Tuba City site constitutes the most significant environmental impact, although windblown tailings and external gamma radiation also are factors. The four alternative actions presented in this engineering assessment range from millsite decontamination with the addition of 3 m of stabilization cover material (Option I), to removal of the tailings to unspecified disposal sites and decontamination of the tailings site (Options II through IV). Cost estimates for the four options range from about $17,800,000 for stabilization in place, to about $23,100,000 for disposal at a distance of about 15 mi.

Three principal alternatives for the reprocessing of the Tuba City tailings were examined.

(a) Heap leaching

(b) Treatment at an existing mill

(c) Reprocessing at a new conventional mill constructed for tailings reprocessing

Processing the Tuba City tailings by heap leach is not feasible because of the impermeability of the tailings to leach solution. The cost of the uranium recovered would be about $56/lb of U_3O_8 by conventional plant processes. The spot market price for uranium was $25/lb early in 1981. Therefore, reprocessing the tailings for uranium recovery appears to be economically unattractive under present market conditions.

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CHAPTER 1

A SUMMARY OF THE ENGINEERING ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS

CHAPTER 1

A SUMMARY OF THE ENGINEERING ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS

1.1 INTRODUCTION

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

A preliminary survey (Phase I) was carried out in 1974 by the U.S. Atomic Energy Commission (AEC) in cooperation with the U.S. Environmental Protection Agency (EPA) and the affected states. In a summary report,(1) ERDA identified 17 sites in Arizona, Colorado, Idaho, New Mexico, Utah, and Wyoming for which practical remedial measures were to be evaluated. Subsequently, ERDA added five additional sites (Riverton and Converse County, Wyoming; Lakeview, Oregon; Falls City and Ray Point, Texas). More recently, DOE has added a site in Canonsburg, Pennsylvania, one near Baggs, Wyoming, and two sites in North Dakota (Belfield and Bowman), and deleted Ray Point, for a total of 25 sites. DOE continues to investigate the status of the site near Baggs, Wyoming. Most of the mills at these sites produced by far the greatest part of their output of uranium under contracts with the AEC during the period 1947 through 1970. After operations ceased, some companies made no attempt to stabilize the tailings, while others did so with varying degrees of success. Recently, concern has increased about the possible adverse effects to the general public from long-term exposure to low-level sources of radiation from the tailings piles and sites.

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

Evaluations of the following factors have been included in this engineering assessment in order to assess the significance of the radiological conditions that exist today at the Tuba City site:

(a) Exhalation of radon gas from the tailings

(b) On-site and off-site direct radiation

(c) Land contamination from windblown tailings

(d) Hydrology and contamination by water pathways

(e) Potential health impact

(f) Potential for extraction of additional minerals from the tailings

Investigation of these and other factors originally led to the evaluation of four potential practicable remedial action alternatives. Since that time, some remedial action alternatives have been judged unacceptable because of new criteria that have been proposed.

In this report, the remedial action alternatives are revised as follows:

(a) Option I - Stabilization of tailings on site with a 3-m cover

(b) Option II - Disposal at an unspecified site within 5 mi of the Tuba City tailings site

(c) Option III - Disposal at an unspecified site within 10 mi of the Tuba City tailings site

(d) Option IV - Disposal at an unspecified site within 15 mi of the Tuba City tailings site

1.1.1 Background

On March 12, 1974, the Subcommittee on Raw Materials of the Joint Committee on Atomic Energy (JCAE), Congress of the United States, held hearings on S. 2566 and H.R. 11378, identical bills submitted by Senator Frank E. Moss and Representative Wayne Owens of Utah. The bills provided for a cooperative arrangement between the AEC and the State of Utah in the area of the Vitro tailings site in Salt Lake

City.* The bills also provided for the assessment of an appropriate remedial action to limit the exposure of individuals to radiation from uranium mill tailings.

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

Dr. James L. Liverman, testifying for the AEC, proposed that a comprehensive study should be made of all such piles, rather than treating the potential problem on a piecemeal basis. He proposed that the study be a cooperative two-phase undertaking by the states concerned and the appropriate federal agencies, such as the AEC and EPA. Phase I would involve site visits to determine such aspects as their condition, ownership, proximity to populated areas, prospects for increased population near the site, and need for corrective action. A preliminary report then would be prepared which would serve as a basis for determining if a detailed engineering assessment (Phase II) were necessary for each millsite. The Phase II study, if necessary, would include evaluation of the problems, examination of alternative solutions, preparation of cost estimates and of detailed plans and specifications for alternative remedial action measures. This part of the study would include physical measurements to determine exposure or potential exposure to the public.

The Phase I assessment began in May 1974, with teams consisting of representatives of the AEC, the EPA, and the states involved visiting 21 of the inactive sites. The Phase I report was presented to the JCAE in October 1974. Table 1-1, adapted from Reference 1, summarizes the conditions in 1980. Based on the findings presented in the Phase I report, the decision was made to proceed with Phase II.

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

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*The proceedings of these hearings and the Summary Report on the Phase I Study were published by the JCAE as Appendix 3 to ERDA Authorizing Legislation for Fiscal Year 1976. Hearings before the Subcommittee on Legislation, JCAE, on Fusion Power, Biomedical and Environmental Research; Operational Safety; Waste Management and Transportation, Feb 18 and 27, 1975, Part 2. The Phase I report on the Tuba City site appears as Appendix I to Reference 5.

the initial task, and work began immediately. Work at Tuba City was begun early in 1976, and the original Phase II - Title I Engineering Assessment was published in March 1977.[2]

On November 8, 1978, the Uranium Mill Tailings Radiation Control Act of 1978 (PL 95-604) became effective. This legislation provides for state participation with the Federal Government in the remedial action for inactive tailings piles. Pursuant to requirements of PL 95-604, the EPA has the responsibility to promulgate remedial action standards for the cleanup of areas contaminated with residual radioactive material and for disposal of tailings. The U.S. Nuclear Regulatory Commission (NRC) has the responsibility for enforcing these standards.

In 1979, DOE established the UMTRA Program Office in Albuquerque, New Mexico. Work on the program has since been directed by personnel in that office. The supplementary field work by FB&DU in support of this report was performed during the week of June 22, 1980.

1.1.2 Scope of Phase II Engineering Assessment

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

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

This report is a continuation of the assessment made for Title I requirements and has been prepared by FB&DU. In connection with the field studies made in 1976, the Oak Ridge National Laboratory (ORNL) at Oak Ridge, Tennessee, under separate agreement with DOE, provided measurements of the radioactivity concentrations in the soil and water samples and gamma surveys. The EPA staff provided the results of radiation surveys they previously had made at the Tuba City site.

The specific scope requirements of the Title I assessment may include but are not limited to the following:

(a) Preparation of an engineering assessment report for each site, and preparation of a comprehensive report suitable for submission to the Congress on reasonable remedial action alternatives and their estimated cost.

(b) Determination of property ownership in order to obtain release of Federal Government and A-E liability for performance of engineering assessment work at both inactive millsites and privately owned structures.

(c) Preparation of topographic maps of millsites and other sites to which tailings and other radioactive materials might be moved.

(d) Performance of core drillings and radiometric measurements ample to determine volumes of tailings and other radium-contaminated materials.

(e) Performance of radiometric surveys, as required, to determine areas and structures requiring cleanup or decontamination.

(f) Determination of the adequacy and the environmental suitability of sites at which mill tailings containing radium could be disposed; and once such sites are identified, perform evaluations and estimate the costs involved.

(g) Performance of engineering assessments of structures where uranium mill tailings have been used in off-site construction to arrive at recommendations and estimated costs of performing remedial action.

(h) Evaluation of various methods, techniques, and materials for stabilizing uranium mill tailings to prevent wind and water erosion, to inhibit or eliminate radon exhalation, and to minimize maintenance and control costs.

(i) Evaluation of availability of suitable fill and stabilization cover materials that could be used.

(j) Evaluation of radiation exposures of individuals and nearby populations resulting from the inactive uranium millsite, with specific attention to:

    (1) Gamma radiation

    (2) Radon

    (3) Radon daughter concentrations

    (4) Radium and other naturally occurring radioisotopes in the tailings

(k) Review of existing information about site hydrology and meteorology.

(l) Evaluation of recovering residual values, such as uranium and vanadium in the tailings and other residues on the sites.

(m) Performance of demographic and land use studies. Investigation of community and area planning, and industrial and growth projections.

(n) Evaluation of the alternative corrective actions for each site in order to arrive at recommendations, estimated costs, and 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 the Tuba City site.

1.2 SITE DESCRIPTION

1.2.1 Location and Topography

The Tuba City site is about 105 acres in size, of which 22 acres are covered by the tailings pile and 44 acres are former evaporation ponds. The site is on the Navajo Indian Reservation, 5.5 mi east of Tuba City in Coconino County, Arizona, and 85 mi north of Flagstaff. The site is at 5,000 ft above sea level. The tailings pile and surrounding terrain are shown in the aerial photograph in Figure 2-2.* The site is located in the typical type of terrain found in the desert areas of the American Southwest: occasional dry washes, mesas, and rolling hills; sparse vegetation (about 15 to 20%), and few trees.

1.2.2 Ownership and History of Milling Operations and Processing

The Tuba City mill was built in 1955-1956 by Rare Metals Corporation of America. The company constructed 10 houses and a trailer court on the north side and 16 houses and a trailer court for employees on the south side of U.S. Highway 160 at the millsite. The Rare Metals Corporation merged with El Paso Natural Gas Company in July 1962. Before and during the milling

*Figures and tables referenced in this summary are extracted from Chapters 2 through 9 of the parent report and are in the addendum.

operations, the site land was owned by the Navajo Nation. Shortly after the mill was shut down in 1966, full control of the site reverted to the Navajo Nation.

The mill began operation in 1956 and treated ores obtained principally from the Cameron area, located about 25 mi to the southwest. Initially, the plant processed 300 tons/day using an acid leaching, sand-slime separation, and resin-in-pulp ion-exchange operation. By 1962, the major ore supply was from the Orphan Lode mine located near the village of Grand Canyon, Arizona. This high-lime content ore was not well suited to acid-leaching; consequently, the mill was converted in 1963 to the carbonate leach process. Using this process, approximately 200 tons/day were processed from April 1963 until the plant was closed permanently in September 1966. During its total operating life the Tuba City mill processed 800,000 tons of ore with an average grade of 0.33% U_3O_8, and produced 2,348 tons of U_3O_8 in concentrate.

1.2.3 Present Condition of the Site

Figure 2-5 is a descriptive map of the site as it now exists showing the layout of the tailings area and the locations of the millsite and housing areas. There are 26 houses which are partially occupied, located on both sides of U.S. Highway 160, immediately north of the tailings; the houses are occupied on a random and changing basis. A survey[3] in 1967 found the housing area habitable and no evidence that surrounding ground or surface water had been affected by leaching of radioactive materials from the tailings area.

The kind of material dumped into the area noted as the "emergency dump pit" is not known. All of the mill equipment and some of the buildings have been removed. The shell of the main mill building remains, although it has been severely cannibalized. None of the mill buildings are now in use. The buildings or portions of buildings remaining in the mill area appear structurally sound, but loose sheet metal is a hazard. The site has been fenced, but the fence is covered by sand in places and is undermined or torn down in other places. The fence on the northeast side of the site has been buried in windblown tailings by the prevailing southwesterly winds. The fence along the northwest side of the tailings area has been undermined by wind erosion and only a small portion of this fence remains intact. It appears that the fence was built originally on naturally migrating dune sand, not on tailings. Gates are missing or are open, and no radiation warning signs are readily apparent.

1.2.4 Tailings and Soil Characteristics

The tailings are composed of finely ground particles easily carried by the wind. They have a high-clay content, are relatively impermeable, and can hold water. The tailings were not deposited evenly throughout the pond areas. The subsoil is uniform beneath the entire site and consists mainly of sand and small aggregate eroded from the underlying Navajo Sandstone. Figure 2-6 is a cross-section of the site. Table 2-1 includes weights and volumes of the tailings and materials in the evaporation ponds and dikes.

1.2.5 Geology, Hydrology, and Meteorology

The Tuba City site lies about 2 mi north of Moenkopi Wash. The tailings rest on loose sand derived by wind erosion from the underlying Navajo Sandstone. This loose sand layer varies in thickness from less than 1 ft to 20 ft. The Navajo Sandstone is a weakly cemented, medium-grained, crossbedded sandstone. It dips at a low angle (2 deg) away from the town of Tuba City towards the axis of the Tuba City syncline. This axis runs in a northwest-southeast direction about 1 mi east of the tailings site. The Navajo Sandstone is exposed south of the millsite along Moenkopi Wash. The Kayenta Formation (a series of silty mudstones with intertongues of sandstone) underlies the Navajo Sandstone. A simplified stratigraphic cross-section of the site is illustrated in Figure 2-8.

There are no surface waters of consequence near the Tuba City tailings site. Surface drainage runs to the Moenkopi Wash about 1.5 mi south of the tailings. There is some drainage potential from precipitation falling in the area between the highway and the tailings pile. There is evidence of sheet erosion in this area of steeply sloping land due to thunderstorm runoff, but the erosion has been small. To the north of the highway, a large depression known as Greasewood Lake collects surface runoff in that area. Surface drainage from the Greasewood Lake depression drains to the west-southwest and does not cross the highway until well past the tailings site.

The principal aquifer in the Tuba City-Moenkopi area is a multiple aquifer system consisting of the Navajo Sandstone and some sandstone beds in the underlying Kayenta Formation. This aquifer is recharged by winter and spring precipitation in the Kaibito Plateau highlands some distance north of Tuba City. Water in the multiple aquifer system moves southward from the highlands; its principal discharge area is along Moenkopi Wash. Thus, the tailings are situated in the discharge rather than the recharge area of the aquifer system. Water in this multiple aquifer system is unconfined because the Navajo Sandstone is covered only by windblown sand over almost all of the areas of concern. Most of the water is produced by gravity flow where the water table intersects the land surface along Moenkopi Wash and its tributary gullies. Springs and shallow wells in the vicinity of the site were checked in 1967 by the U.S. Public Health Service for radioactive contamination,[(3)] and results of this sampling showed no contamination in ground water from the mill tailings.

The tailings are protected from inflow or outflow of surface water by dikes. The only water that can reach the tailings comes from precipitation directly onto the pile. However, surface runoff from severe thunderstorms can cause erosion of the dikes. Because of the large moisture deficiency in the present tailings and the high rate of evaporation, any rain falling on the pile would penetrate the tailings a few feet at most, then return to the surface as evaporation takes place, causing an upward soil moisture gradient.

The average annual precipitation at Tuba City, as reported by the U.S. Department of Commerce, is 6.1 in. based on a 62-yr period of record. The 24-hr precipitation would be expected to be at a rate of 1.3 in. once every 2 yr, with a "maximum observed" 24-hr storm at Tuba City of 4 in.

Analysis of the records at Tuba City over a 25-yr period indicates that the maximum daily precipitation usually occurs during the 3-mo period of August through October. This pattern is typical of much of the southwest desert area, being the time of most frequent thunderstorm activity.

There are no records of wind measurements at the Tuba City site, but data from Flagstaff, Arizona, have been used in health effects calculations. Dune and cross-bed orientation indicate that past and present wind directions prevail from southwest to northeast. The large area of deposited windblown tailings to the northeast of the site confirms the existence of strong southwesterly winds.

1.3 RADIOACTIVITY AND POLLUTANT IMPACTS ON THE ENVIRONMENT

About 85% of the total radioactivity originally in uranium ore remained in the tailings after removal of the uranium. The principal environmental radiological impact and associated health effects arise from the ^{230}Th, ^{226}Ra, ^{222}Rn, and ^{222}Rn daughters contained in the uranium tailings. Although these radionuclides occur in nature, their concentrations in tailings material are several orders of magnitude greater than their average concentrations in the earth's crust. Because of the chemical treatments these radionuclides have experienced, it appears that ^{226}Ra is more soluble and, therefore, more mobile.

1.3.1 Radiation Exposure Pathways, Contamination Mechanisms, and Background Levels

The major potential environmental routes of exposure to man are:

(a) Inhalation of ^{222}Rn and its daughter products, resulting from the continuous radioactive decay of ^{226}Ra in the tailings. Radon is a gas which diffuses from the pile. The principal exposure results from inhalation of ^{222}Rn daughters.

This exposure affects the lungs. For this assessment, no criteria have been established for radon concentrations in air. However, the pathway for radon and radon daughters accounts for the major portion of the exposure to the population.

(b) External whole-body gamma exposure directly from radionuclides in the 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 that can occur; however, this pathway was not considered in this study.

1.3.1.1 Radon Gas Diffusion and Transport

Measurements of radon flux from the tailings made in 1976[2] using the charcoal canister technique[4] ranged from 11 to more than 400 pCi/m^2-s on the tailings pile. Radon flux depends principally on radium content of tailings; however, it also varies considerably because of moisture, soil characteristics, and climatological conditions.

Short-term radon measurements were made in 1976 with continuous radon monitors supplied by ERDA at two locations in the vicinity of the Tuba City tailings pile. The locations and values of the radon measurements are shown in Figure 3-3. The background ^{222}Rn concentration for a 24-hr period was determined to be 0.7 pCi/l. One set of measurements on the tailings indicated an average ^{222}Rn concentration of about 22 pCi/l for a 24-hr period. At the mill housing area, the ^{222}Rn concentration averaged 1.3 pCi/l for 24 hr. The concentration was 2.1 pCi/l at a location 0.13 mi east of the site during a 24-hr period.

1.3.1.2 Direct Gamma Radiation

Background values of gamma radiation around the Tuba City site averaged 10 μR/hr.[5] The range of background values was between 6 and 13 μR/hr. Above the surface of the tailings and the former evaporation ponds, gamma rate readings ranged from about 20 to 2,600 μR/hr. Background levels of gamma radiation were reached about 200 yd from the tailings pile in the northwest and southwest directions.

1.3.1.3 Windblown Contaminants

Prevailing winds in the area are from the southwest, and there is a large area of windblown tailings northeast of the pile. In most directions the maximum distance of tailings transport is about 200 yd. However, northeast of the site there are indications that the tailings material has been deposited out to about 1 mi. These estimates of the extent of windblown tailings were determined by analyses of soil samples completed as part of the Tuba City effort by ORNL. In 1980, the extent of the area around the site contaminated in excess of 5 pCi/g of ^{226}Ra in soil was estimated as shown in Figure 3-13.

No particulate measurements were performed at the Tuba City site during this field survey. Previous measurements[6] in Tuba City indicated that airborne concentrations of ^{226}Ra, ^{230}Th, and natural uranium were two to three orders of magnitude less than the guidelines established in the Code of Federal Regulations, Title 10, Part 20. Measurements in the downwind direction indicated substantial transport of ^{226}Ra in concentrations exceeding recommended concentration guidelines.

1.3.1.4 Ground and Surface Water Contamination

Four water samples taken within a 2-mi radius from the pile during this assessment contained dissolved ^{226}Ra concentrations ranging from 0.37 to 1.24 pCi/l.[5] These values are less than the 5 pCi/l level for ^{226}Ra and ^{228}Ra in the EPA Interim Primary Drinking Water Regulations for radionuclides.[7]

The only water that can now reach the tailings comes from precipitation directly on the pile. Because of the high upward soil moisture gradient, there is little potential for future infiltration of contaminants to the ground water of this area. However, periodic monitoring of nearby springs and wells should be continued during the next few years to determine if water, which may have been contaminated during the operation of the mill, has seeped into the underlying sand and sandstone.

Surface erosion of tailings due to thunderstorms is possible. Sudden thunderstorms with large runoffs could further erode the tailings dike.

The wind has eroded the tailings material severely, breaching the tailings dikes in several places. The amount of tailings material that has been transported away by the wind is considerable. The light-colored tailings material can been seen over an area as much as 0.5 mi in a northeasterly direction away from the residences along U.S. Highway 160 and in the opposite direction from Tuba City. There are no residences nearby in the northeasterly (downwind) direction.

1.3.1.5 Soil Contamination

The leaching of radium from the tailings into the subsoil has been measured to depths of 2 to 5 ft below the tailings-subsoil interface. In the mill area, soil contamination was generally limited to less than 1 ft deep, although a few locations were found where contamination reached a depth of 2 ft.

1.3.2 Remedial Action Criteria

For the purpose of conducting the original engineering assessment,(2) provisional criteria provided by the EPA were used. The criteria were in two categories, and applied either to structures with tailings present or to land areas to be decontaminated. For structures, the indoor radiation level below which no remedial action was indicated was considered to be an external gamma radiation level of less than 0.05 mR/hr above background and a radon daughter concentration of less than 0.01 WL above background. Land could be released for unrestricted use if the external gamma radiation levels were less than 10 μR/hr above background. When cleanup was necessary, residual radium content of the soil after remedial action should not exceed twice background in the area.

Since enactment of the Uranium Mill Tailings Radiation Control Act of 1978 (PL 95-604), which was effective November 8, 1978, the EPA has published interim (45 FR 27366) and proposed (45 FR 27370) standards for structures and open lands. These standards establish the indoor radon daughter concentration, including background, below which no remedial action is indicated at 0.015 WL. The indoor gamma radiation limit is 0.02 mR/hr above background. The EPA has also published proposed disposal standards for inactive uranium processing sites (46 FR 2556).

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

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

(a) The average annual release of ^{222}Rn from the disposal site to the atmosphere by residual radioactive materials will not exceed 2 pCi/m^2-s.

(b) Substances released from residual radioactive materials after disposal will not cause:

(1) the concentrations of those substances in any underground source of drinking water to exceed the level specified below,* or

(2) an increase in the concentrations of those substances in any underground source of drinking water where the concentrations of those substances prior to remedial action exceed the levels specified below for causes other than residual radioactive materials.*

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

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

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

---

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

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

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

1.3.3 Potential Health Impact

Radon gas exhalation from the pile and the subsequent inhalation of radon daughters account for most of the total dose to the population from the Tuba City site under present conditions. The gamma radiation exposure from the pile is very small since the number of people who live or work within 0.3 mi of the pile (where gamma radiation is above background in all but the northeast direction) is small.

Gamma radiation can be reduced effectively by shielding with any dense material. However, experience has shown that it is very difficult to control the movement of radon gas through porous materials. Once released from the radium-bearing minerals in the tailings, the gaseous radon diffuses by the path of least resistance to the surface. The radon has a half-life of about 4 days, and its daughter products are solids. Therefore, part of the radon decays en route to the surface and leaves daughter products within the tailings pile. If the diffusion time can be made long enough, then, theoretically, virtually all of the radon and its daughter products will have decayed before escaping to the atmosphere. Calculations using the theoretical techniques of Kraner, Schroeder, and Evans[8] earlier indicated that 13 ft of earth cover would be required to reduce the radon diffusion from the Tuba City tailings by 95%. Later experimental work[9] has demonstrated that 2 to 3 ft of compacted clay may be sufficient to reduce radon flux to less than 2 pCi/m^2-s, assuming the continued integrity of the clay cover.

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

The risk estimators used in this report are given in the report of the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR-III report).[10] This report presents risk estimators for lung cancer derived from epidemiological studies of both uranium miners and fluorspar miners. The average of the age-dependent absolute risk estimator for these two groups as applied to the population at large is 150 cancers per year per 10^6 person-WLM of continuous exposure, assuming a lifetime plateau to age 75. The term WLM means working level months, or an exposure to a concentration of one working level of radon daughter products in air for 170 hr, which is a work-month. A working level (WL) is a unit of measure of radon daughter products which recognizes that the several daughter elements are frequently not in equilibrium with each other or with the parent radon. Because of the many factors that contribute to natural biological variability and of the many differences between exposure conditions in mines and residences, this estimator (150 cancer cases per year per 10^6 person-WLM of continuous exposure) is considered to have an uncertainty factor of about 3. Another means of expressing risk is the relative risk estimator, which yields risk as a percentage increase in health effects per 10^6 person-WLM of continuous exposure. However, this method has been shown to be invalid[11] and is not considered in this assessment.

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

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

For continuous exposure:

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

On the basis of predictions of radon concentrations in excess of the background value under present conditions, it was calculated that the average lung cancer risk attributable to radon released from the tailings pile in the area within 6 mi of the Tuba City site is 9.2×10^{-7} per person per year, or about 1% of the average lung cancer risk due to all causes for the Navajo Nation (1.02×10^{-4}).[12]

The 25-yr health effects were calculated for three population projections using the present population of about 2,800 in the 0- to 6-mi area. The results for pile-induced radon and background radon for this area were as follows:

25-Year Cumulative Health Effects Within 6 Miles of Edge of Pile

Projected Population Growth	Pile-Induced RDC	Background RDC
Constant 0.8% growth rate	0.066	1.9
4% declining growth rate*	0.083	2.3
6.4% declining growth rate*	0.10	2.9

Pile-induced radon daughter health effects are less than 4% of the background radon daughter health effects for the 0- to 6-mi area. The exposure and consequent risk will continue as long as the radiation source remains in its present location and condition.

1.3.4 Nonradioactive Pollutants

Ground and surface water in the vicinity of the tailings pile contained only selenium in concentrations above the level specified in the EPA Interim Primary Drinking Water Regulations (0.01 mg/l). The high selenium content was found in all water samples located in drainage areas above and below the tailings indicating a natural condition not attributable to the presence of the tailings.

1.4 SOCIOECONOMIC AND LAND USE IMPACTS

Because all reservation land is owned in common 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 is another criterion, and

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

the monetary value assigned to sheep production per acre is another. The site has highway frontage along U.S. Highway 160, but so do thousands of acres of similar land for which there is little pressure for other than agricultural purposes. By using the aforementioned criteria, it is estimated that the land at and around the Tuba City site, which is primarily grazing land, is worth between $55 and $65/acre.

1.5 RECOVERY OF RESIDUAL VALUES

Only a few samples of tailings were obtained during this study. Consequently, calculations based on these samples would not be statistically representative. Estimates of the Tuba City tailings from AEC records show an average of 0.032% U_3O_8.

There are, however, five factors that can be employed to evaluate whether reprocessing Tuba City tailings to extract 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

Three principal alternatives for the reprocessing of the Tuba City tailings were examined:

(a) Heap leaching

(b) Treatment at an existing mill

(c) Reprocessing at a new conventional mill constructed for tailings reprocessing

Processing the Tuba City tailings by heap leach is not feasible because of the impermeability of the tailings to leach solution. The cost of the uranium recovered would be about $56/lb of U_3O_8 by conventional plant processes. The spot market price for uranium was $25/lb early in 1981. Therefore, reprocessing the tailings for uranium recovery appears to be uneconomical under present market conditions. However, if the market for U_3O_8 reaches levels which existed 2 yr ago, reprocessing might be economically attractive.

1.6 MILL TAILINGS STABILIZATION

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

Migration of contaminants into ground water systems must be limited under the NRC and EPA criteria. Control of water percolating through the tailings can be accomplished by stabilizing chemically, by physically compacting the cover material, and by contouring the drainage area and tailings cover surface. Isolation of the tailings from underlying ground water systems can be accomplished by lining a proposed disposal site with natural or artificial impermeable membranes.

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

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

1.7 OFF-SITE REMEDIAL ACTION

A mobile scanning unit, operated by the AEC under an interagency agreement with the EPA, performed a gamma radiation survey of the Tuba City area in 1972. Fourteen anomalies above the background criteria were discovered. In a subsequent field radiation survey, also performed in 1972, four locations were found with tailings more than 10 ft from a structure and tailings were found within 10 ft of two houses. These six locations are assumed to require remedial action based upon incomplete radiological measurements. A sum of $9,000 has been included in the various remedial action options to account for the cost of possible off-site remedial work for structures.

1.8 DISPOSAL SITE SELECTION

In this report, three of the alternative remedial action options include moving the Tuba City tailings to unspecified disposal sites at various distances from the tailings site.

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

1.9 REMEDIAL ACTIONS AND COST-BENEFIT ANALYSES

1.9.1 Remedial Action Options

The remedial action options examined include stabilization of the tailings pile in its present location, and removal of all radioactive materials to an area where these materials could be isolated from the public. The options for which cost estimates were made include stabilization on the present site with 3 m of cover material and the removal of tailings to unspecified locations at three distances from the tailings pile. The options are summarized in Table 1-2. The basis for comparison, from which the cost effectiveness of remedial alternatives can be judged, is the present condition of the site with no remedial action.

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

1.9.2 Cost-Benefit Analyses

As summarized in Table 9-1, the total costs for the four remedial action options vary from about $17,800,000 to about $23,100,000. Each of these options would have associated health and monetary benefits. The options are identified by number in Paragraph 1.1.

The number of cancer cases avoided per million dollars expended for each option is given in Figure 9-3. The curves in

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

TABLE 1-1

SUMMARY OF CONDITIONS NOTED AT TIME OF 1980 SITE VISITS

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

TABLE 1-1 (Cont)

	Condition of Tailings[a]	Condition of Structures On Site[b]	Mill Housing[c]	Adequate Fencing, Posting, Security	Property Close to River or Stream	Houses or Industry within 0.5 Mi	Evidence of Wind or Water Erosion	Possible Water Contamination	Tailings Removed for Private Use	Other Hazards On Site
PENNSYLVANIA										
Canonsburg	P	B-O	N	Yes	Yes	Yes	No	Yes	Yes	Yes
TEXAS										
Falls City	P	B-O	N	Yes	No	No	Yes	No	No	No
UTAH										
Green River	S	B-Y	N	Yes	Yes	Yes	Yes	Yes	No	No
Mexican Hat	U	PR-UO	E-O	No	No	Yes	Yes	Yes	No	No
Salt Lake City	U	R	N	No	Yes	Yes	Yes	Yes	Yes	Yes
WYOMING										
Converse County	U	R	N	Yes	No	No	No	No	No	No
Riverton	S	PR-O	N	No	No	Yes	No	No	No	No

[a]S - Stabilized but requires improvement

P - Partially stabilized

U - Unstabilized

RMS - Reprocessed, moved and stabilized - contamination remaining

R - Removed - contamination remaining

[b]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

[c]N - None

E - Existing

O - Occupied

P - Partially occupied

TABLE 1-2

SUMMARY OF REMEDIAL ACTION OPTIONS AND EFFECTS

Option Number	Site Specific Cost ($000)	Description of Remedial Action	Benefits	Adverse Effects
I	17,800	The pile would be stabilized in place with 3 m of local earth cover. A riprap cover would be provided and on-site contaminated soil would be cleaned up.	A-D,F	P
II	22,600	The tailings, contaminated soil and rubble would be removed by truck to an unspecified disposal site, located about 5 mi from the tailings site. The tailings site would be decontaminated as in Option I and released for unlimited use.	B-F	--
III	22,600	Same as Option II, except tailings removed to an unspecified disposal site, located about 10 mi from the tailings site.	B-F	--
IV	23,100	Same as Option II, except tailings removed to an unspecified disposal site, located about 15 mi from the tailings site.	B-F	--

TABLE 1-2 (Cont)

Notes

1. All options include on- and off-site remedial action.

2. For Options II through IV, costs include removal of 3 ft of contaminated earth below the tailings.

Definition of Benefits

A. Access to the tailings site controlled by fencing and posting
B. Off-site windblown and water-eroded tailings cleaned up
C. Wind and water erosion controlled
D. Gamma radiation reduced
E. Unrestricted development possible on the tailings site
F. Radon gas exhalation greatly reduced or eliminated

Definition of Adverse Effects

P. Housing within close proximity of tailings pile

CHAPTER 1 REFERENCES

1. "Summary Report, Phase I Study of Inactive Mill Sites and Tailings Piles"; AEC; Grand Junction, Colorado; Oct 1974.

2. "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Tuba City Site, Tuba City, Arizona"; GJT-5; Ford, Bacon & Davis Utah Inc.; Mar 1977.

3. R.N. Snelling and S.D. Shearer, Jr.; "Environmental Survey of Uranium Mill Tailings Pile, Tuba City, Arizona"; Radiological Health and Data Reports; Nov 1969.

4. R.J. Countess; "^{222}Rn Flux Measurement with a Charcoal Canister"; Health Physics; Vol 31, p. 455; 1976.

5. F.F. Haywood, et al.; "Radiological Survey of the Inactive Uranium-Mill Tailings at Tuba City, Arizona"; ORNL-5450; Oak Ridge National Laboratory; Oak Ridge, Tennessee; Jan 1980.

6. J.M. Hans, Jr.; private communication of preliminary data; EPA-ORP-LVF; Las Vegas, Nevada.

7. Federal Register, Part II; EPA Interim Primary Drinking Water Regulations; EPA; July 9, 1976.

8. 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.

9. Argonne National Laboratory and Ford, Bacon & Davis Utah Inc.; "Characterization of Uranium Tailings Cover Materials for Radon Flux Reduction"; NUREG/CR-1081 (FBDU-218-2); Mar 1980.

10. "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; 1980.

11. B.L. Cohen; "The BEIR Report Relative Risk and Absolute Risk Models for Estimating Effects of Low Level Radiation"; Health Physics; Vol 37, p. 509; 1979.

12. H. Siegle; Navajo Area Indian Health Service; letter to Ford, Bacon & Davis Utah Inc.; Oct 14, 1976.

ADDENDUM

FIGURES AND TABLES

(The figures and tables contained on the following pages have been extracted from Chapters 2 through 9 of the parent report.)

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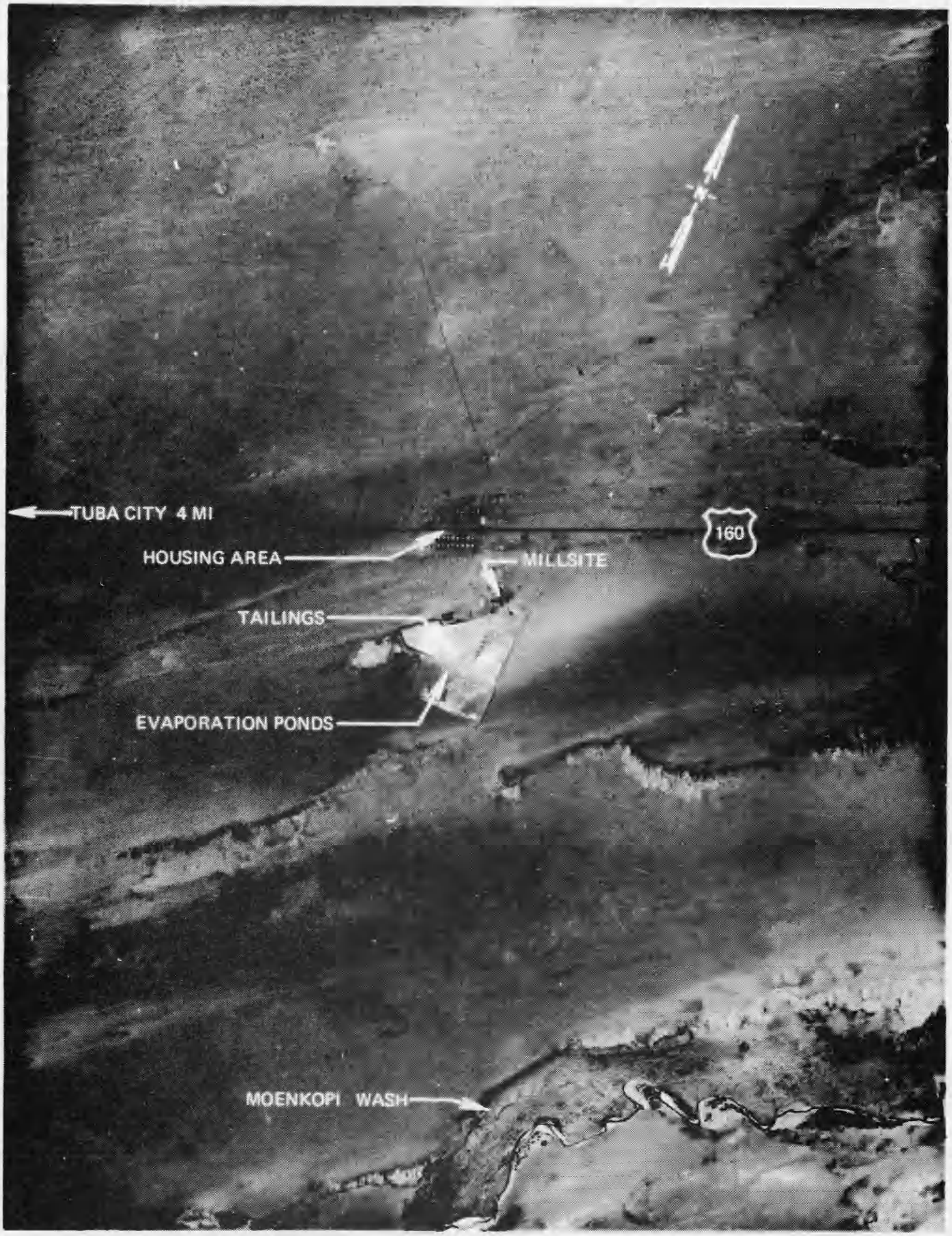

FIGURE 2-2. AERIAL PHOTOGRAPH OF SITE

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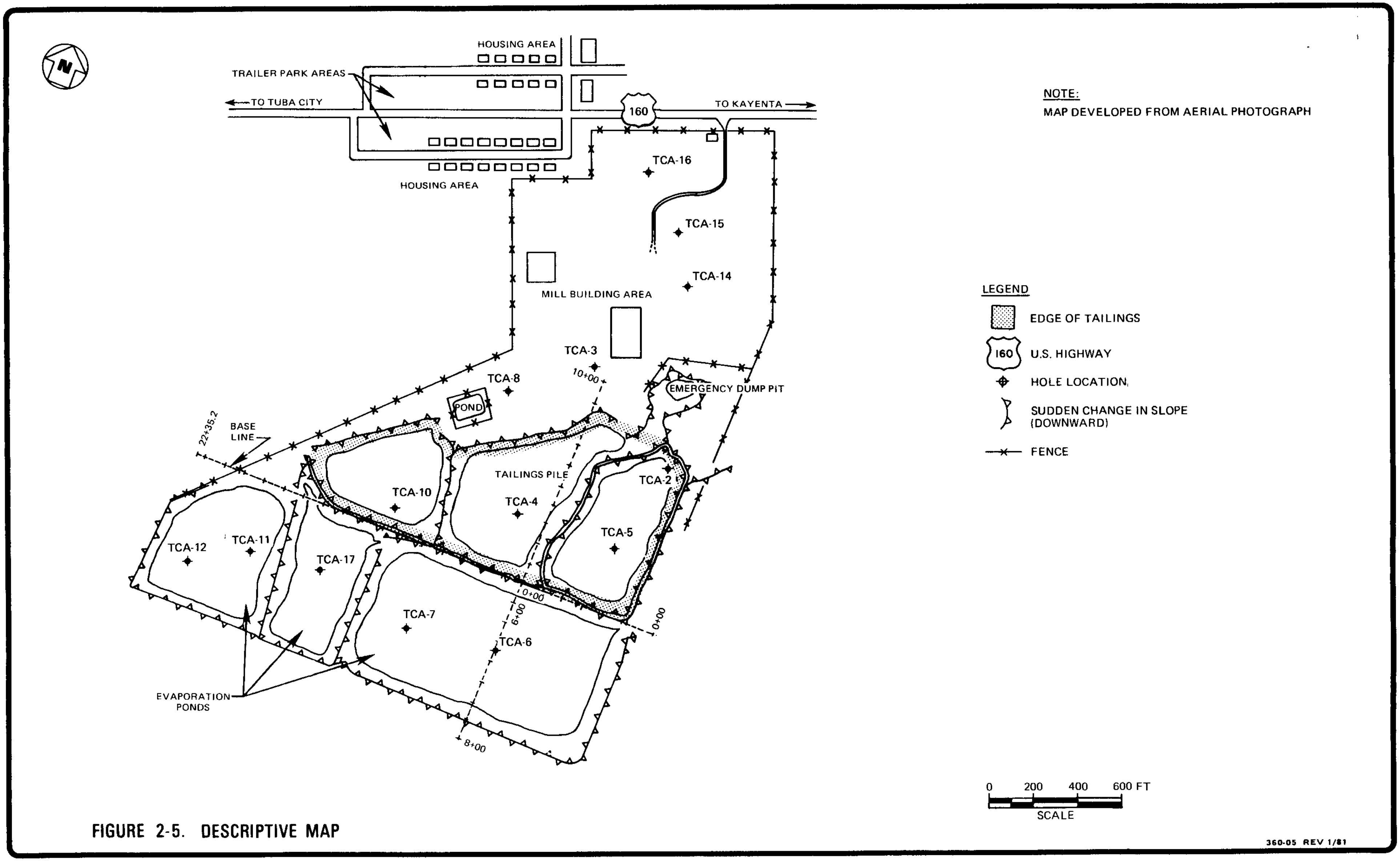

FIGURE 2-5. DESCRIPTIVE MAP

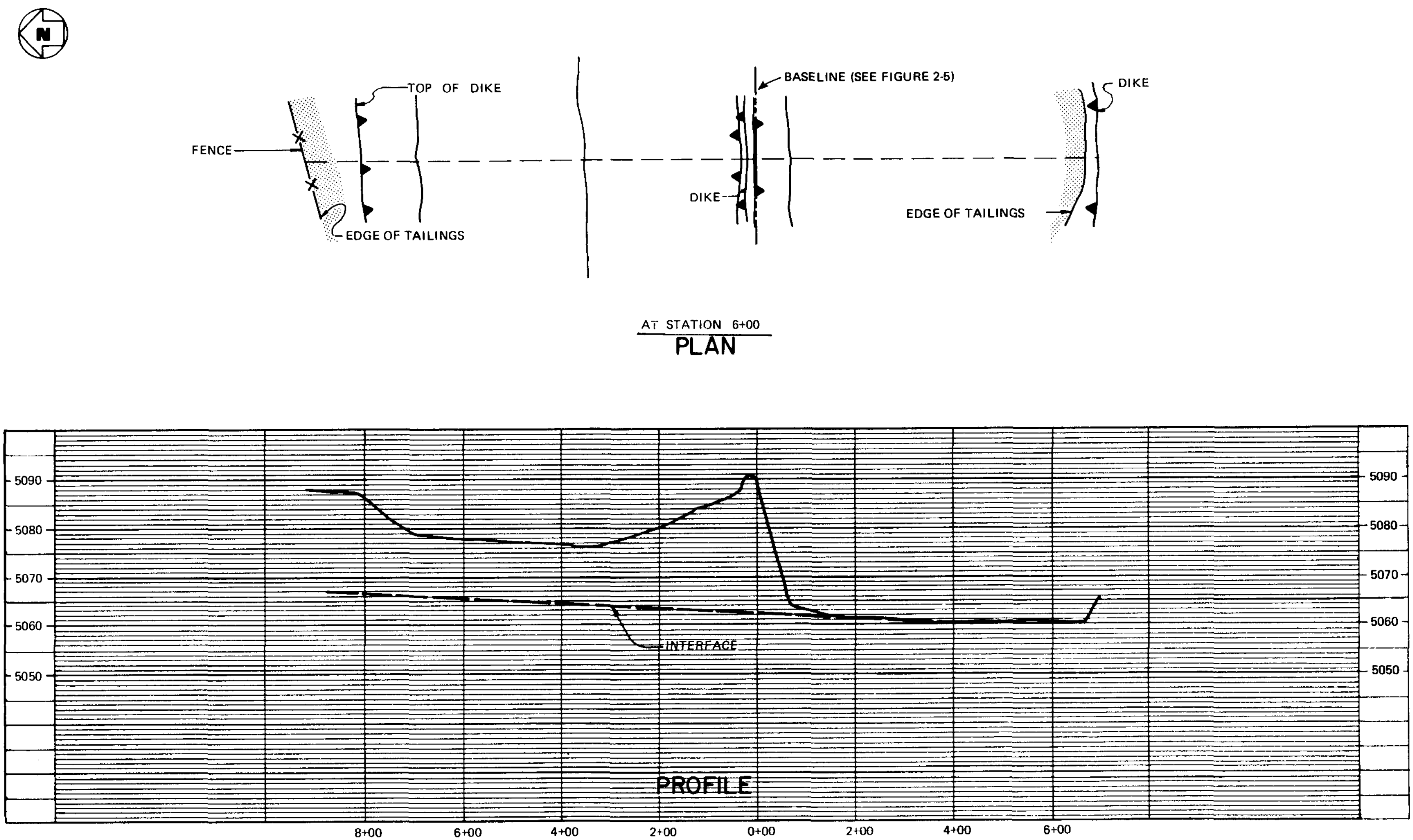

FIGURE 2-6. CROSS-SECTION AT STATION 6+00

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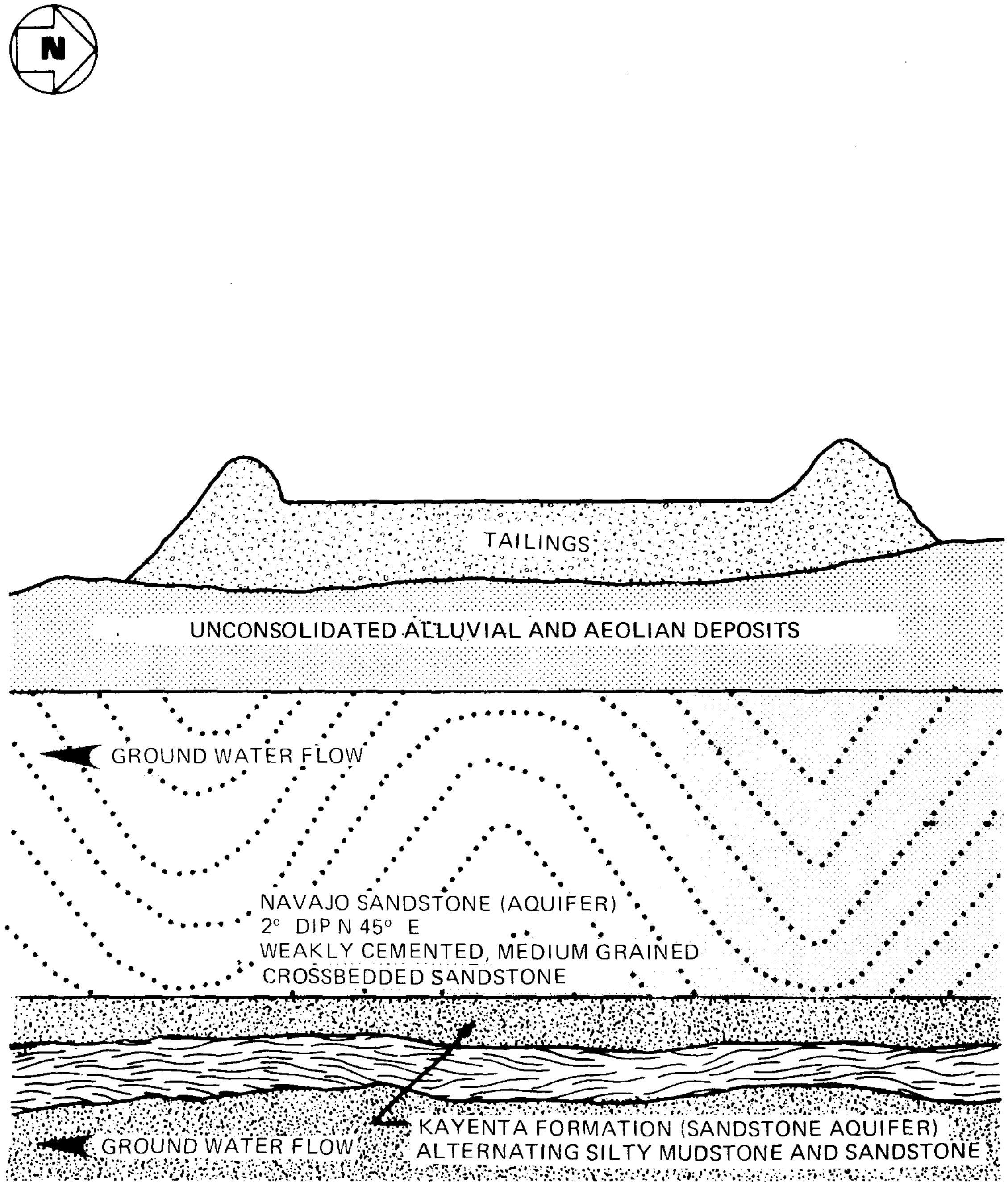

FIGURE 2-8. SIMPLIFIED STRATIGRAPHIC CROSS–SECTION

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TABLE 2-1

TAILINGS SITE MATERIALS

Material	Volume (yd^3)	Weight[a] (tons)
Tailings	761,000	800,000
Dikes and Pond Material	74,000	98,000
Contaminated Soil Under Tailings[b]	71,000	96,000
Contaminated Soil Under Ponds[c]	129,000	174,000
Millsite and Ore Storage Contaminated Material[d]	97,000	131,000
Windblown[e]	215,000	291,000
TOTAL	1,347,000	1,590,000

[a]Except for tailings, weight is based on average existing field densities, which include moisture.

[b]Based on 22 acres contaminated to an average depth of 2 ft.

[c]Based on 20 acres contaminated to an average depth of 4 ft.

[d]Based on 30 acres contaminated to an average depth of 2 ft.

[e]Based on 267 acres contaminated to an average depth of 6 in.

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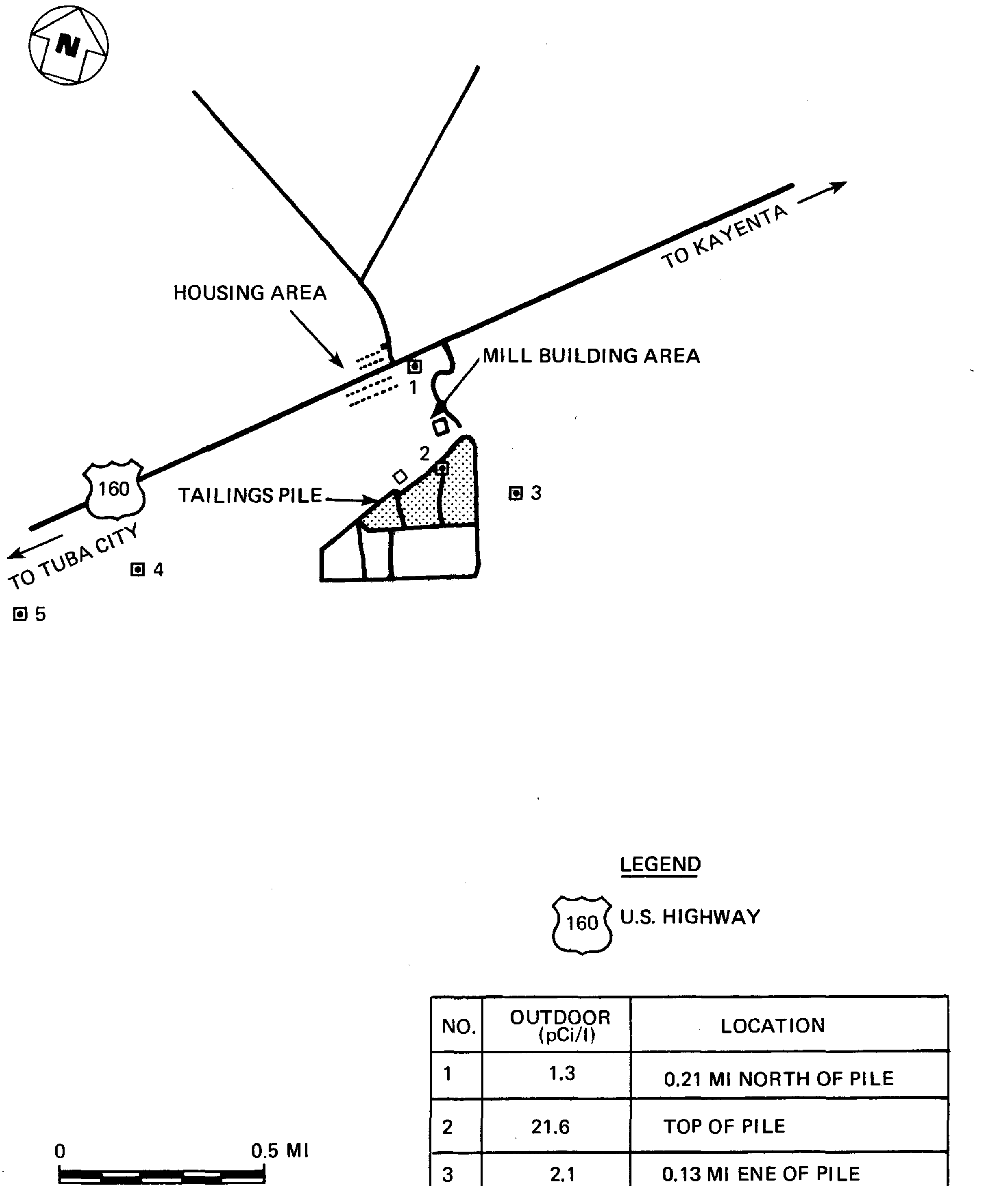

NO.	OUTDOOR (pCi/l)	LOCATION
1	1.3	0.21 MI NORTH OF PILE
2	21.6	TOP OF PILE
3	2.1	0.13 MI ENE OF PILE
4	1.2	0.5 MI WEST OF PILE
5	0.7	5.5 MI WEST OF PILE TUBA CITY COMMUNITY CENTER

FIGURE 3-3. RADON CONCENTRATION IN VICINITY OF PILE

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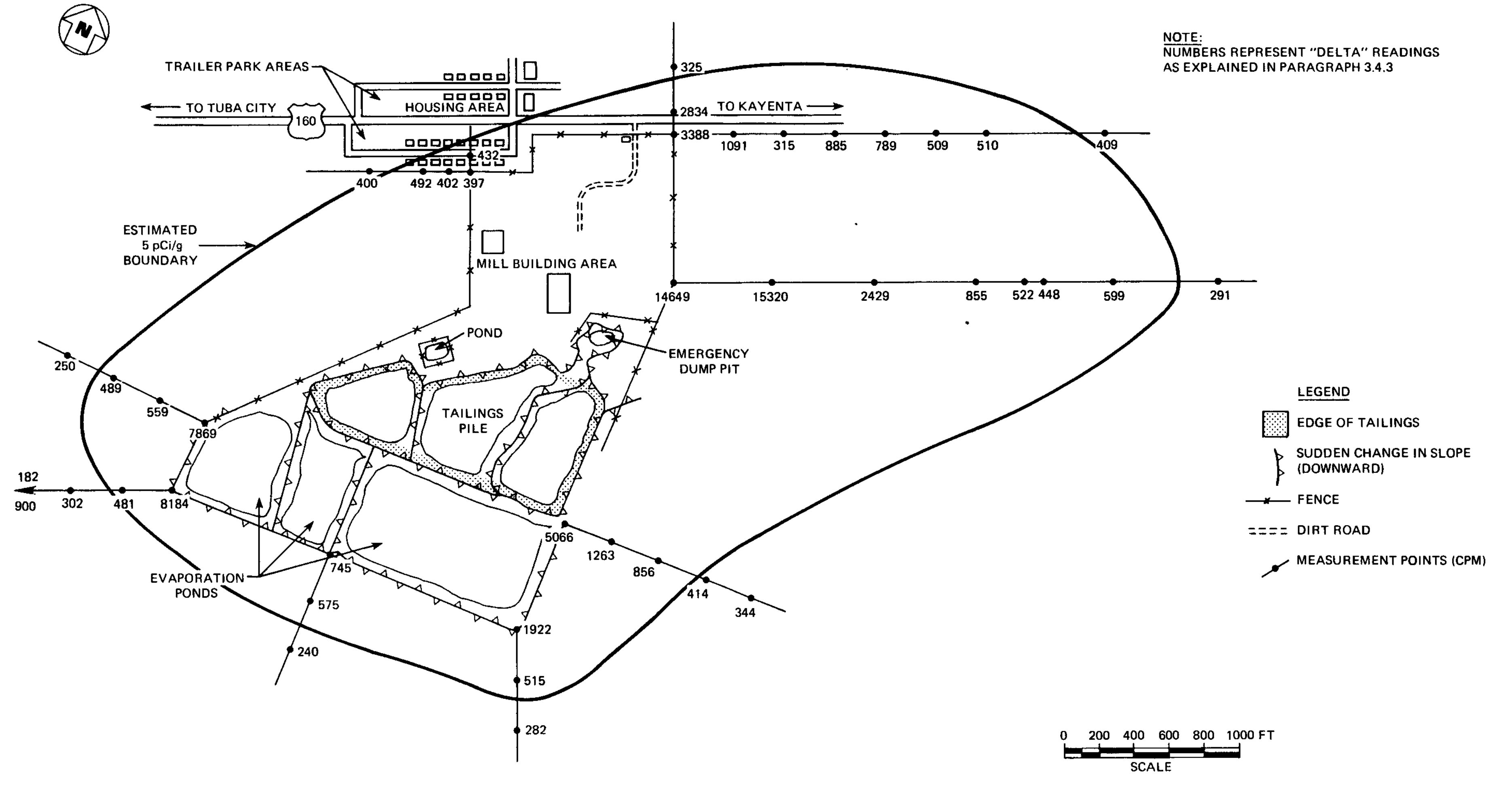

FIGURE 3-13. WINDBLOWN CONTAMINATION SURVEY

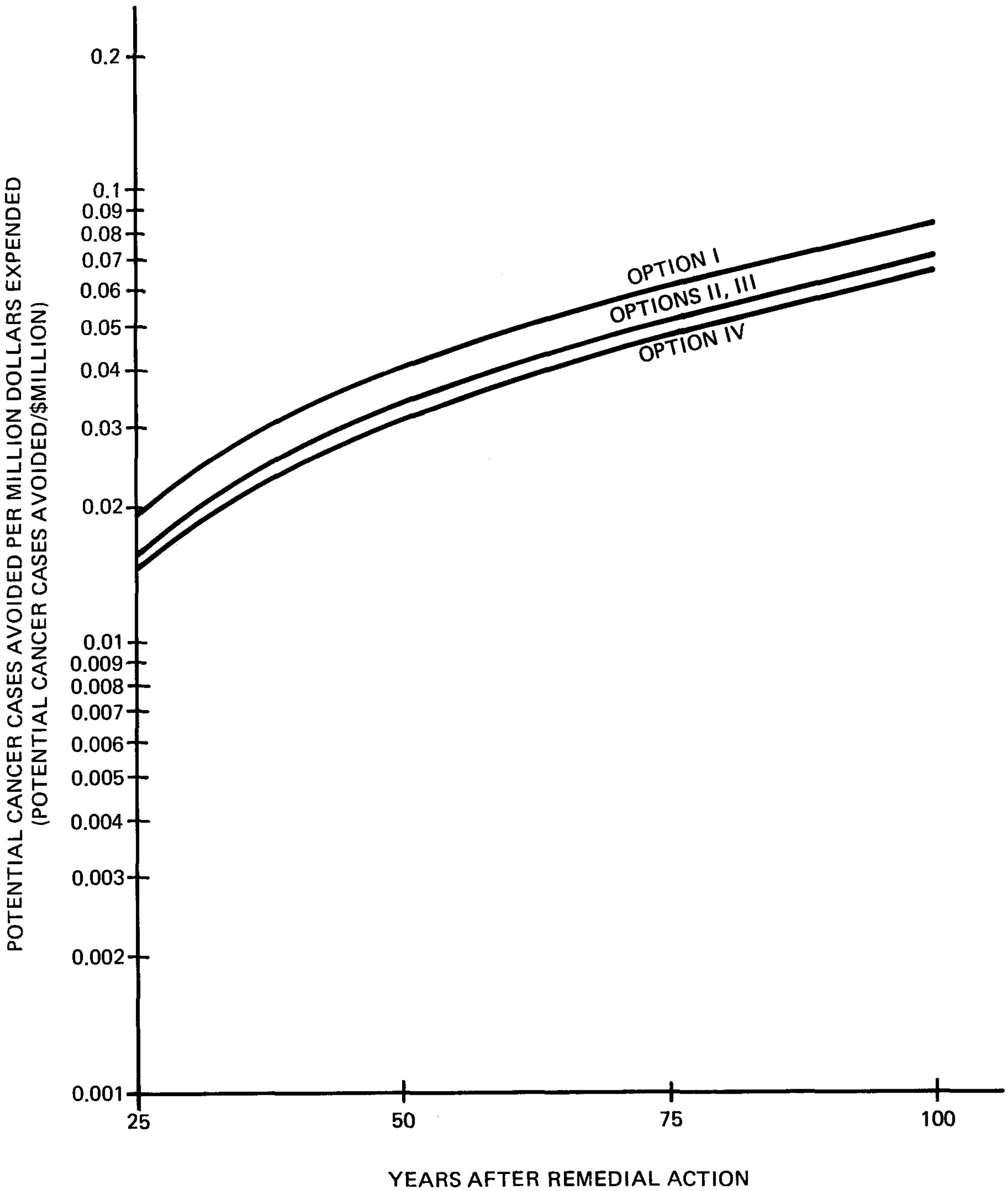

FIGURE 9-3. POTENTIAL CANCER CASES AVOIDED PER MILLION DOLLARS EXPENDED

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TABLE 9-1

SUMMARY OF STABILIZATION AND DISPOSAL COSTS[a]

		Options		
	I	II	III	IV
1. Tailings Site	7.6	3.2	3.2	3.2
2. Off-Site Other than Windblown	0.1	0.1	0.1	0.1
3. Off-Site Windblown[b]	2.8	2.8	2.8	2.8
4. Transportation				
a. Capital Costs	--	0.2	0.2	0.2
b. Haul Costs[c]	--	4.5	5.4	5.6
5. Disposal Site	--	3.0	3.0	3.0
6. Total Cleanup[d] (sum of lines 1 through 5)	10.5	13.8	14.4	15.0
7. Engineering Design and Construction Management (30% of the difference between lines 6 and 4b)	3.2	2.8	2.8	2.8
8. Total[d] (sum of lines 6 and 7)	13.7	16.6	17.2	17.7
9. Contingency (30% of line 8)	4.1	5.0	5.2	5.3
10. GRAND TOTAL[d] (sum of lines 8 and 9)	17.8	21.6	22.3	23.1

TABLE 9-1 (Cont)

[a]Costs are in millions of 1980 dollars.

[b]A savings of about $1,000,000, without engineering and contingency allowances, might be realized, if backfilling decontaminated areas can be dispensed with.

[c]If locally available sandy soil were used to cover the tailings pile, a savings of about $3,000,000, without engineering and contingency allowances, might be realized.

[d]Totals may differ from the sum of component costs because of round-off.

TABLE 9-2

POTENTIAL CANCER CASES AVOIDED
AND COST PER POTENTIAL CASE AVOIDED

A. Number of Potential Cancer Cases Avoided

Options:	I	II	III	IV
Option Cost (million $)	17.8	21.6	22.3	23.1
Years After Remedial Action				
25	<0.34	0.34	0.34	0.34
50	<0.72	0.72	0.72	0.72
75	<1.1	1.1	1.1	1.1
100	<1.5	1.5	1.5	1.5

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

Options:	I	II	III	IV
Option Cost (million $)	17.8	21.6	22.3	23.1
Years After Remedial Action				
25	>52	64	66	68
50	>25	30	31	32
75	>16	20	20	21
100	>12	14	15	15

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