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A SUMMARY OF THE ENGINEERING ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS

SPOOK SITE
CONVERSE COUNTY, WYOMING

OCTOBER 1981

MASTER

PREPARED FOR

UNITED STATES 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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SINCE 1894

DISCLAIMER

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Salt Lake City, Utah 84108

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 Assessment of Inactive Uranium Mill Tailings for Spook Site, Converse County, Wyoming." 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 December 1977, entitled "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Spook Site, Converse County, Wyoming," 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 Spook 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 Dick Hornbuckle, property owner at the Spook site. Several local, county, and state agencies and private individuals also contributed information.

ABSTRACT

Ford, Bacon & Davis Utah Inc. has reevaluated the Spook site in order to revise the December 1977 engineering assessment of the problems resulting from the existence of radioactive uranium mill tailings 48 mi northeast of Casper, in Converse County, Wyoming. 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 187,000 tons of tailings at the Spook 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 remote disposal sites and decontamination of the tailings site (Options II through IV). Cost estimates for the four options range from about $710,000 for stabilization in-place, to about $1,950,000 for disposal at a distance of about 15 mi.

Three principal alternatives for the reprocessing of the Spook tailings were examined:

(a) Heap leaching

(b) Treatment at an existing mill

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

The cost of the uranium recovered would be about $40/lb of U_3O_8 by treatment in an existing conventional plant. The spot market price for uranium was $25/lb early in 1981. Therefore, reprocessing the tailings for uranium recovery might be economically feasible if they could be treated as supplementary feed to a nearby operating mill, provided the price of uranium returns to the 1978-1979 levels.

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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 Spook 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 two potential practicable remedial action alternatives. Since that time, these 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 at bottom of open pit, with a 3-m cover

(b) Option II - Removal of tailings to an unspecified site located 5 mi from the Spook tailings site

(c) Option III - Removal of tailings to an unspecified site located 10 mi from the Spook tailings site

(d) Option IV - Removal of tailings to an unspecified site located 15 mi from the Spook tailings site

In addition, if uranium prices were to rise from their presently depressed levels, it could be feasible to process the Spook tailings at the Bear Creek mill, which lies only 2.5 mi north of the Spook 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)

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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 Spook site appears as Appendix I to Reference 4.

services for Phase II. ERDA's Grand Junction, Colorado, Office (GJO) was authorized to negotiate and administer the terms of a contract with FB&DU. The contract was effective on June 23, 1975. The Salt Lake City Vitro site was assigned as the initial task, and work began immediately. Work at the Spook site began on July 30, 1976, and the original Phase II - Title I Engineering Assessment was published in December 1977.[2]

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

In 1979, DOE established the UMTRA Program Office in Albuquerque, New Mexico. Work on the program has since been directed by personnel in that office. The supplementary field work by FB&DU in support of this report was performed during the week of July 21, 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 Spook site.

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

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

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

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

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

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

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

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

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

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

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

    (1) Gamma radiation

    (2) Radon

    (3) Radon daughter concentrations

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

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

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

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

(n) Evaluation of the alternative corrective actions for each site in order to arrive at recommendations, estimated costs, and socio-economic impact based on population and land use projections.

(o) Preparation of preliminary plans, specifications, and cost estimates for alternative corrective actions for each site.

Not all of these items received attention at the Spook site.

1.2 SITE DESCRIPTION

1.2.1 Location and Topography

The Spook millsite and tailings pile are located approximately 48 mi northeast of Casper, in Converse County, Wyoming, and approximately 32 mi northeast of Glenrock, Wyoming.

The site is located among rolling hills at an elevation of about 5,100 ft above sea level in the drainage basin of the Cheyenne River. Vegetation is comprised of sagebrush and native grasses, with cottonwood trees along the creek bottoms. The site and its relationship to the surrounding area are shown in Figure 2-1.*

1.2.2 Ownership and History of Milling Operations and Processing

The Wyoming Mining and Milling Company operated on the site, which is owned by Richard T. Hornbuckle, Pearl R. Hornbuckle, Kirkwood T. Hornbuckle, and Brent B. Hornbuckle.

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

Western Nuclear, Inc., a subsidiary of Phelps Dodge Corporation, is presently responsible for the property.

The upgrader became operational in 1962 and ran until June 1965. Ore from the adjacent open-pit mine averaged 0.12% U_3O_8, and about 187,000 tons were processed. (Some ore was shipped directly to a mill at Jeffrey City, Wyoming.) The ore was acid-leached and the uranium slurry was trucked 165 mi to the Western Nuclear mill at Jeffrey City for further processing.

1.2.3 Present Condition of the Site

Figure 2-5 is a descriptive map of a portion of the site as it now exists. The major structures have been removed. Concrete foundations, machine parts, timbers, overhead electrical equipment, and crusher components remain. The 187,000 tons of tailings rest on the top edge, side slope and bottom of the open-pit mine, and cover about 5 acres. They have not been stabilized and show some signs of water erosion. The most prominent features of the site are the open-pit mine and adjacent pile of mine waste and mine overburden. The pit is approximately 100 ft deep in its deepest point. Figure 2-6 is a cross-section through the tailings pile and mine pit.

About half the surface area of the tailings site is covered by weeds and native grasses. A barbed wire fence surrounds the millsite, open-pit mine, overburden, and tailings areas. A haul road runs north and south immediately to the west of the site; the road is used to haul ore from open-pit mines south of the site to a processing plant 2.5 mi to the north of the site.

1.2.4 Tailings and Soil Characteristics

The tailings are sandy in character, although no measurements of physical properties were performed. The soil on the site is a thin layer of weathered sandstone from the bedrock beneath the site.

1.2.5 Geology, Hydrology, and Meteorology

The Spook tailings pile, millsite, and the Spook mine are located on the slopes of a rolling hillside typical of the southern margin of the Powder River Basin. Bedrock is exposed in the open pit and consists of sandstones and shales of the Monument Hill unit of the Wasatch Formation. The Wasatch Formation is underlain by up to 2,000 ft of sandstones and shales of the Fort Union Formation. The shale and claystone units of the formations act as confining layers that prevent the upward and downward migration of ground waters. Although the strata at the site are virtually flat-lying, regional correlation suggests a very gentle dip of less than 1 deg to the north. A simplified stratigraphic column is shown in Figure 2-7.

The surface waters on or near the site consist of standing water in the pit during some months of the year, an interceptor ditch that diverts storm runoff around the tailings and pit, ephermeral drainage channels, and an intermittent stream south of the pile known as the Dry Fork Cheyenne River. Off-site contamination of surface waters by physical transport of tailings or by chemical leaching is unlikely. This is due to the distance of flowing surface waters from the site, the gentle hydraulic gradient, and the topography and drainage system at the site which limits almost all off-site runoff from reaching the tailings and allows only the precipitation that falls on the site to collect in the pit.

The aquifers of the Powder River Basin System are typically at different depths within the Wasatch and Fort Union Formations, and their water quality and quantity vary considerably. Most of the wells in the area are completed at depths of less than 300 ft. Some of these are flowing wells, others are pumped. In recent years, many of the shallow wells have dried out or slowed down in flow rates. During this time, mining companies have developed deep wells (greater than 1,000 ft) for use in their mining and process activities.

Regional recharge areas for the aquifers are the highland areas. Local recharge areas include higher areas such as the Cheyenne River Divide or locations where permeable formations are intercepted by surface waters. The Spook Mine pit is in permeable strata and can act as a point for ground water recharge. However, this recharge potential is small due to the limited precipitation that is trapped on the site. Should contamination occur due to the tailings, the effects would be minimal. Only stock water wells tap the nearby shallower aquifers. Furthermore, the strata of the pit are the host rock for the uranium ore of the vicinity and any contribution of radionuclides from the tailings would be far exceeded by natural sources.

The tailings are vulnerable to strong winds that are typical of the area and tend to blow from the southwest. Annual precipitation averages about 13 in. Thunderstorms are common occurrences and are sometimes accompanied by severe hail or tornado activity as well as by wind and rain.

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

Short-term radon measurements were performed by FB&DU in 1976 with continuous radon monitors supplied by ERDA[3] at three locations in the vicinity of the Spook tailings pile. The locations and values of the 24-hr radon concentrations are shown in Figure 3-4. The highest outdoor radon concentration was measured on the pile (17 pCi/l). Background atmospheric radon at a location 2 mi from the site measured 1.1 pCi/l. Radon above the average background level was detected at 0.4 mi from the site.

1.3.1.2 Direct Gamma Radiation

The average external gamma radiation (EGR) within a few feet of the pit was about 128 μR/hr. The highest EGR level, around 650 μR/hr, was measured in the pit along a southwesterly traverse originating at the northwestern edge of the tailings pile. This high reading was also associated with a correspondingly high soil concentration of ^{226}Ra and is probably due to residual ore.

In the area surrounding the tailings, the gamma radiation rates were greater than twice background due largely to the open-pit uranium mine and mine waste. Beyond the mine and mine waste area, the gamma radiation decreased to background within 0.2 mi.

1.3.1.3 Windblown Contaminants

Prevailing winds in the area are from west-southwest. The results of the EPA gamma radiation survey around the tailings pile are shown in Figure 3-10. Figure 3-12 shows the locations and measurements of ^{226}Ra along traverses throughout the site area. Not all of the apparent contamination is due solely to the presence of the tailings; the high natural background levels of uranium and radium, and the large quantities of radioactive overburden surrounding the millsite, almost certainly contribute to elevated levels of surface contamination at some distances away from the tailings. With this qualification in mind, the boundary of the area assumed to be contaminated by tailings was drawn as shown in Figure 3-12.

1.3.1.4 Ground and Surface Water Contamination

Three water samples were taken from the Dry Fork Cheyenne River, which is an intermittent stream. All of these samples (upstream, downstream, and at the confluence with a wash that drains the southern mine waste) contained 0.1, 1.27, and 0.16 pCi/l of ^{226}Ra, respectively.[4] All of these levels are below the EPA Interim Primary Drinking Water Regulations for radioactive contaminants.

A water sample from a stagnant pond south of the tailings pile just off a pile of mine waste contained 21.7 pCi/l of ^{226}Ra. However, this water has little chance of reaching the Cheyenne River. Two well water samples from wells south and east of the tailings contained 0.24 and 0.22 pCi/l of ^{226}Ra, respectively.

Considering the distance between the tailings and a flowing stream and the naturally occurring radioactivity in the area, the tailings have little potential for increasing the ^{226}Ra content of off-site water.

1.3.1.5 Soil Contamination

The leaching of radium from the tailings into the subsoil averaged 3 ft but extends from 2 to 5 ft before reaching background levels of ^{226}Ra concentration. The profile of radium concentration in the tailings was determined with a gamma probe and by core sample analyses.[4]

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.

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.

Since the passage of PL 95-604, the NRC has published final regulations for uranium mill tailings licensing in the Federal Register (45 FR 65521). They include the requirement that the stabilization method must include an earth cover of at least a 3-m thickness and sufficient to reduce the radon emanation rate from the tailings to less than 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.

*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.

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 Spook site under present conditions. The gamma radiation exposure from the Spook pile is virtually zero past 0.2 mi. There are few people who live or work within 1.5 mi of the pile, where gamma radiation is above background.

Gamma radiation can be reduced effectively by shielding with any dense material. However, experience has shown that it is very difficult to control the movement of radon gas through porous materials. Once released from the radium-bearing minerals in the tailings, the gaseous radon diffuses by the path of least resistance to the surface. The radon has a half-life of about 4 days, and its daughter products are solids. Therefore, part of the radon decays en route to the surface and leaves daughter products within the 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(5) earlier indicated that 13 ft of earth cover would be required to reduce the radon diffusion from the Spook tailings by 95%. Later experimental work(6) has demonstrated that 2 to 3 ft of compacted clay may be sufficient to reduce radon flux to less than 2 pCi/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).(7) This report presents risk estimators for lung cancer derived from epidemiological studies of both uranium miners and fluorspar miners. The average of the age-dependent absolute risk estimator for these two groups as applied to the population at large is 150 cancers per year per 10^6 person-WLM of continuous exposure, assuming a lifetime plateau to age 75. The term WLM means working level months, or an exposure to a concentration of one working level of radon daughter products in air for 170 hr, which is a work-month. A working level (WL) is a unit of measure of radon daughter products which recognizes that the several daughter elements are frequently not in equilibrium with each other or with the parent radon. Because of the many factors that contribute to natural biological variability and of the many differences between exposure conditions in mines and residences, this estimator (150 cancer cases per year per 10^6 person-WLM of continuous exposure) is considered to have an uncertainty factor of about 3. Another means of expressing risk is the relative risk estimator, which yields risk as a percentage increase in health effects per 10^6 person-WLM of continuous exposure. However, this method has been shown to be invalid(8) and is not considered in this assessment.

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

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

For continuous exposure:

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

On the basis of predictions of radon concentrations in excess of the background value under present conditions, it was calculated that the average lung cancer risk attributable to radon released from the tailings pile in the vicinity within 4.5 mi of the Spook site is 2.6×10^{-8} per person per year, or less than 0.02% of the average lung cancer risk due to all causes for Wyoming residents (2.1×10^{-4}).(9)

The 25-yr health effects were calculated for three population projections using the present population of 86 in the 0- to 4.5-mi area. The results for pile-induced radon and background radon for the area (0 to 4.5 mi) were as follows:

25-Year Cumulative Health Effects Within 4.5 Miles of Edge of Pile

Projected Population Growth	Pile-Induced RDC	Background RDC
Constant 0.8% growth rate	0.000063	0.10
Constant 3% growth rate	0.000083	0.13
8.8% declining growth rate*	0.00013	0.20

1.3.4 Nonradioactive Pollutants

There are other potentially toxic materials in the tailings. Chemical analyses of tailings samples from auger holes in the Spook pile showed barium, chromium, and lead in concentrations between 3 and 50 ppm. The highest selenium concentration was 270 ppm, and arsenic concentration was about 90 ppm. Vanadium was present at about 26 to 350 ppm. It has been speculated that high concentrations of selenium in the overburden, resulting in correspondingly high levels of that element in the vegetation, were responsible for the deaths of cattle grazing on site about 12 to 15 yr ago.

Six water samples were taken from the vicinity of the Spook site and chemically analyzed; four samples from stagnant ponds south of the millsite, and two ground water samples from wells east and south of the site. The locations of these samples are shown in Figure 3-11 and the analyses of these samples are presented in Table 3-4. All water samples contained selenium above the EPA Interim Primary Drinking Water Regulations. In addition, some of the samples contained arsenic and cadmium above the drinking water regulations.

While there is some water contamination near the Spook mine and millsite, it is mainly due to mine waste and not mill tailings. The tailings have been deposited within the open-pit mine and precipitation which falls on the tailings is mostly confined in the pit. The possibility of seepage from the pile degrading the surface water quality is unlikely because of the distance from the tailings to flowing surface waters and other natural sources of contamination.

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

1.4 SOCIOECONOMIC AND LAND USE IMPACTS

Except for the mineral, oil, and gas exploration and development near the site, virtually all the land near the tailings site is used for grazing. A haul road just west of the site is used regularly for transporting ore to the Bear Creek uranium millsite, a few miles north of the site. The population centers closest to the site are some 30 to 40 mi south of the site. There is only one ranch house within 2 mi of the site, and there are about 90 persons living within 15 mi of the site. The land surrounding the site is all in private ownership.

There is ongoing drilling and exploration for minerals within the area. Two local mining companies intend to mine adjacent to the northern and eastern boundaries of the site.

The presence of the tailings restricts the use of the site to only a minor degree. The acreage occupied by the tailings is less than 5 acres, most of which is adjacent to an open-pit mine. This loss is minimal compared with the much larger area occupied by the open pit, mine waste, and overburden piles. If the tailings were not present, there would be virtually no change in land uses and values in the surrounding areas.

1.5 RECOVERY OF RESIDUAL VALUES

Available historical records that provide reliable data on specific mineral contents of the Spook 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. Estimates of the Spook tailings from AEC records show an average of 0.023% U_3O_8.

There are, however, five factors that can be considered to evaluate whether reprocessing Spook 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 Spook tailings were examined:

(a) Heap leaching

(b) Treatment at an existing mill

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

The cost of the uranium recovered would be about $40/lb of U_3O_8 by treatment in an existing conventional plant. The spot market price for uranium was $25/lb early in 1981. Therefore, reprocessing the Spook tailings for uranium recovery might be economically feasible if they were treated as supplementary feed to a nearby operating mill. Construction of reprocessing facilities for the sole purpose of reprocessing the Spook tailings would be infeasible due to the quantity and grade of the tailings.

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

There are no off-site locations other than windblown where tailings have been used, and therefore no such areas to decontaminate.

It is difficult to assess windblown contamination attributable to the tailings pile alone since there are other prevalent radioactive sources in the vicinity. The estimated boundaries of windblown tailings are shown in Figure 9-1. The cost of cleanup of the estimated 11 acres of off-site land contaminated by windblown tailings is estimated to be $50,000, exclusive of engineering and contingency allowances.

1.8 DISPOSAL SITE SELECTION

In this report, three of the alternative remedial action options include moving the Spook tailings to unspecified disposal sites. The responsibility for disposal site selection lies with the Federal Government, with input from the State. At such time as tentative selections are made, site-specific costs may be estimated.

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 or vegetation established 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 in the pit adjacent to the tailings site, and removal of all radioactive tailings materials to areas where these materials could be isolated from the public. 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 pile at the bottom of the open pit and with the addition of a 3-m depth of cover. Radon exhalation would be reduced to not more than 2 pCi/m^2-s above background. The tailings site would have limited future use.

Costs for tailings disposal at three unspecified sites at distances of 5, 10, and 15 mi from the Spook tailings were evaluated. Since the market for uranium is presently depressed, the possibility of reprocessing the tailings at the Bear Creek mill was not addressed, even though this might be an alternative solution if the price for uranium concentrate were to rise significantly.

1.9.2 Cost-Benefit Analyses

As summarized in Table 9-1, the total costs for the four remedial action options vary from about $710,000 to about $1,950,000. 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 9-2. The curves in Figure 9-2 indicate an increase in health 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.

As indicated in Chapters 2 and 3, the mill and tailings site are located directly at the mine, and are adjoined by the open-pit mine and various piles of overburden which exhibit radioactivity levels well above the proposed standards for millsite and tailings pile stabilization. These mining wastes would continue to have an impact on the contamination levels of the site and therefore on its future utility. However, the cleanup of radioactive contamination resulting from mining operations per se is a separate problem that is not within the scope of the remedial action activities described in this report.

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 Contamination	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	710	The pile would be stabilized at the bottom of the open pit with 3 m of local earth cover. Natural vegetation would be established or a riprap cover provided. On- and off-site contaminated materials would be cleaned up as necessary.	A-D,G,H	X
II	1,510	The tailings, contaminated soil and rubble would be removed by truck to an unspecified site located about 5 mi from the tailings site. The tailings site would be decontaminated and released for unlimited use.	B-F,H	--
III	1,700	Same as Option II, except tailings removed to an unspecified site located about 10 mi from the tailings site.	B-F,H	--
IV	1,950	Same as Option II, except tailings removed to an unspecified site located about 15 mi from the tailings site.	B-F,H	--

Notes

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

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

TABLE 1-2 (Cont)

Definition of Benefits

A. Access to the tailings site controlled by fencing and posting
B. Off-site windblown tailings cleaned up
C. Wind and water erosion controlled
D. Gamma radiation reduced
E. The source of gamma radiation and radon gas removed from the area
F. No building restrictions on or near site
G. The prime use of the final disposal location unchanged
H. A reduction in rate of radon exhalation to not more than 2 pCi/m^2-s

Definition of Adverse Effects

X. Limited use of the tailings site

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, Spook Site, Converse County, Wyoming"; GJT-15; Ford, Bacon & Davis Utah Inc.; Dec 1977.

3. M.E. Wrenn, H. Spitz, and N. Colen; "Design of a Continuous Digital-Output Environmental Radon Monitor"; IEEE Transaction of Nuclear Science; Vol NS-22; Feb 1975.

4. F.F. Haywood, et al.; "Radiological Survey of the Inactive Uranium-Mill Tailings at the Spook Site, Converse County, Wyoming"; ORNL-5460; Oak Ridge National Laboratory; Oak Ridge, Tennessee; May 1980.

5. 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.

6. 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.

7. "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.

8. 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.

9. Vital Statistics of the U.S.; Vol II; Mortality; National Center for Health Statistics; HEW; 1968.

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.)

LIST OF FIGURES

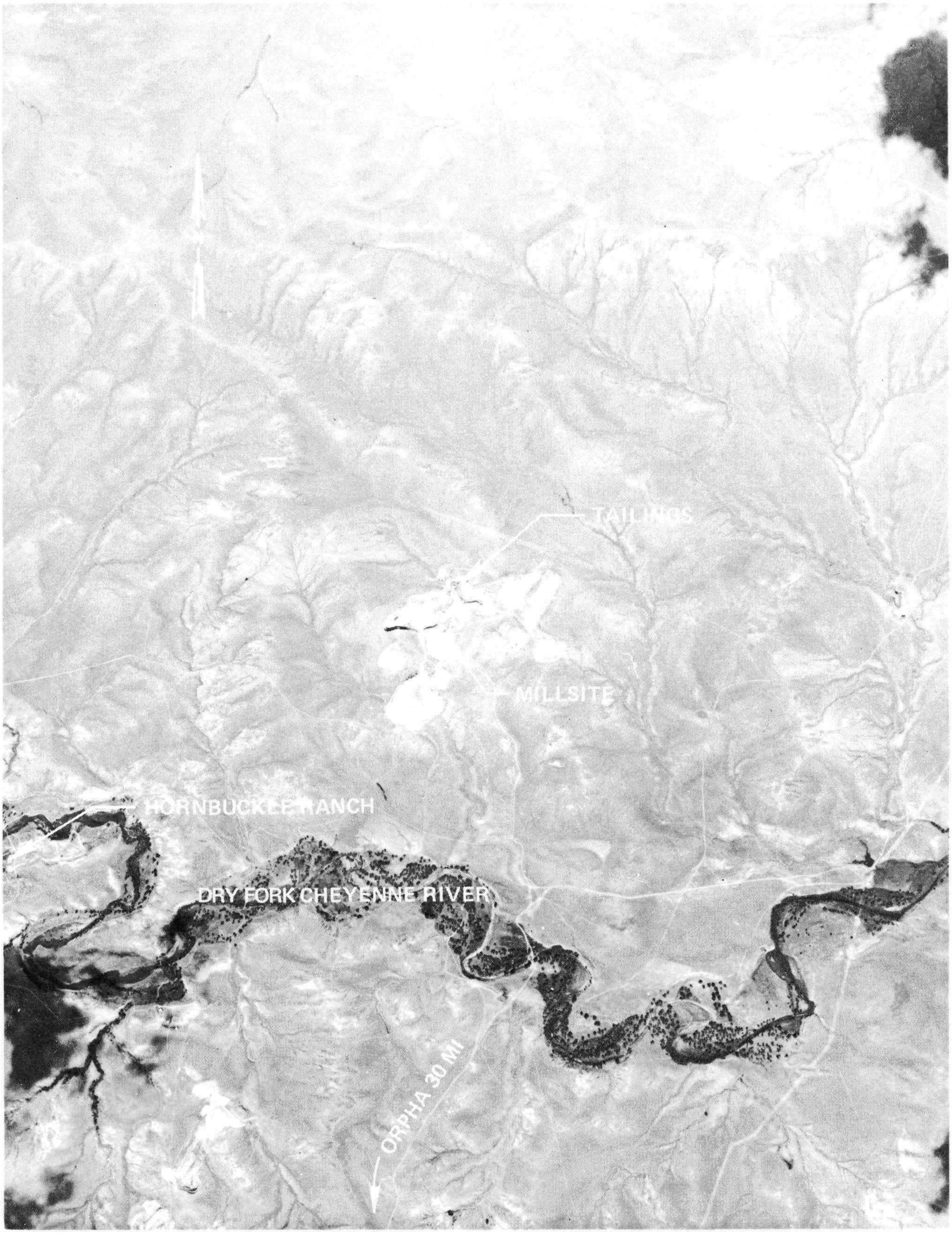

FIGURE 2-1. AERIAL PHOTOGRAPH OF SITE

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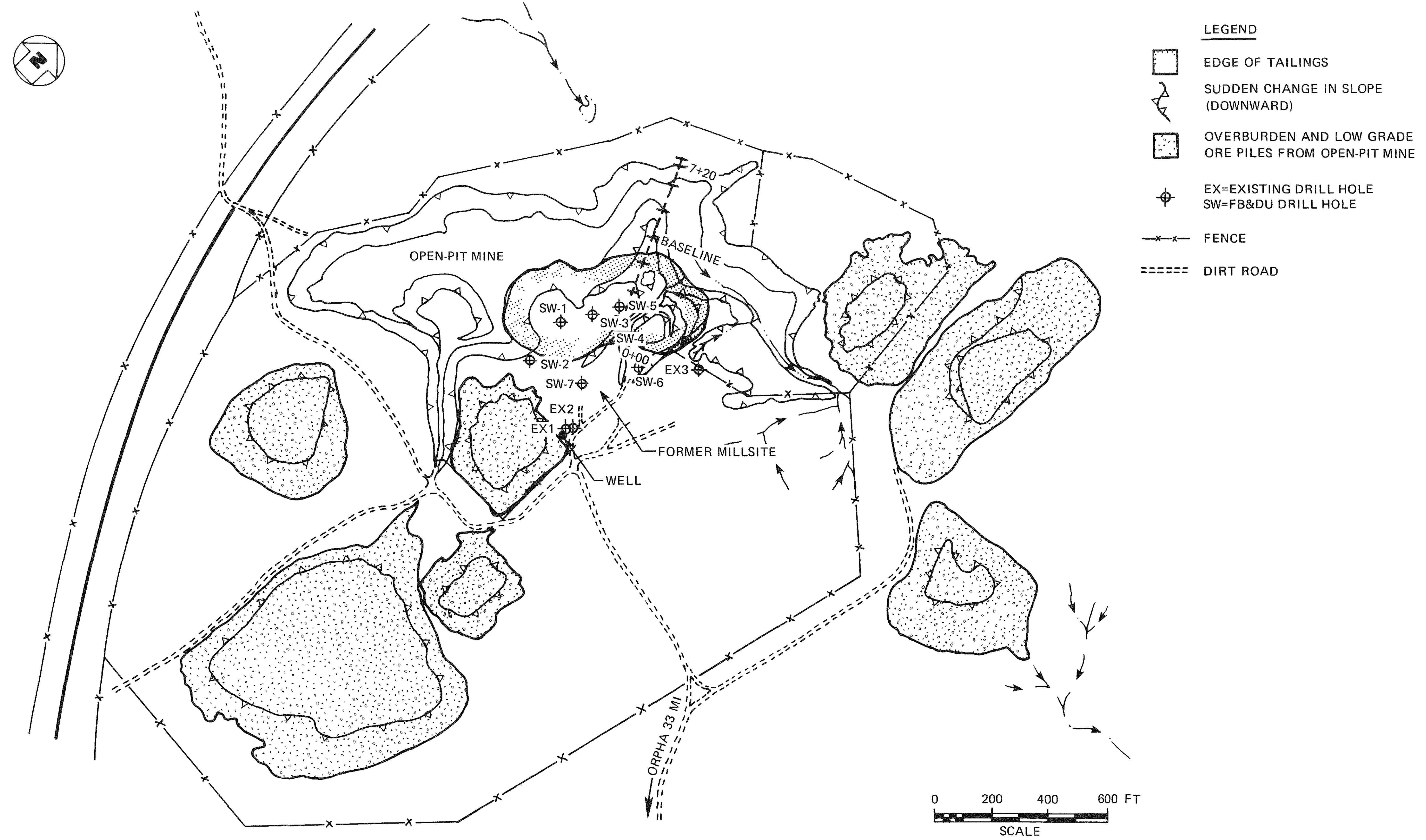

FIGURE 2-5. DESCRIPTIVE MAP

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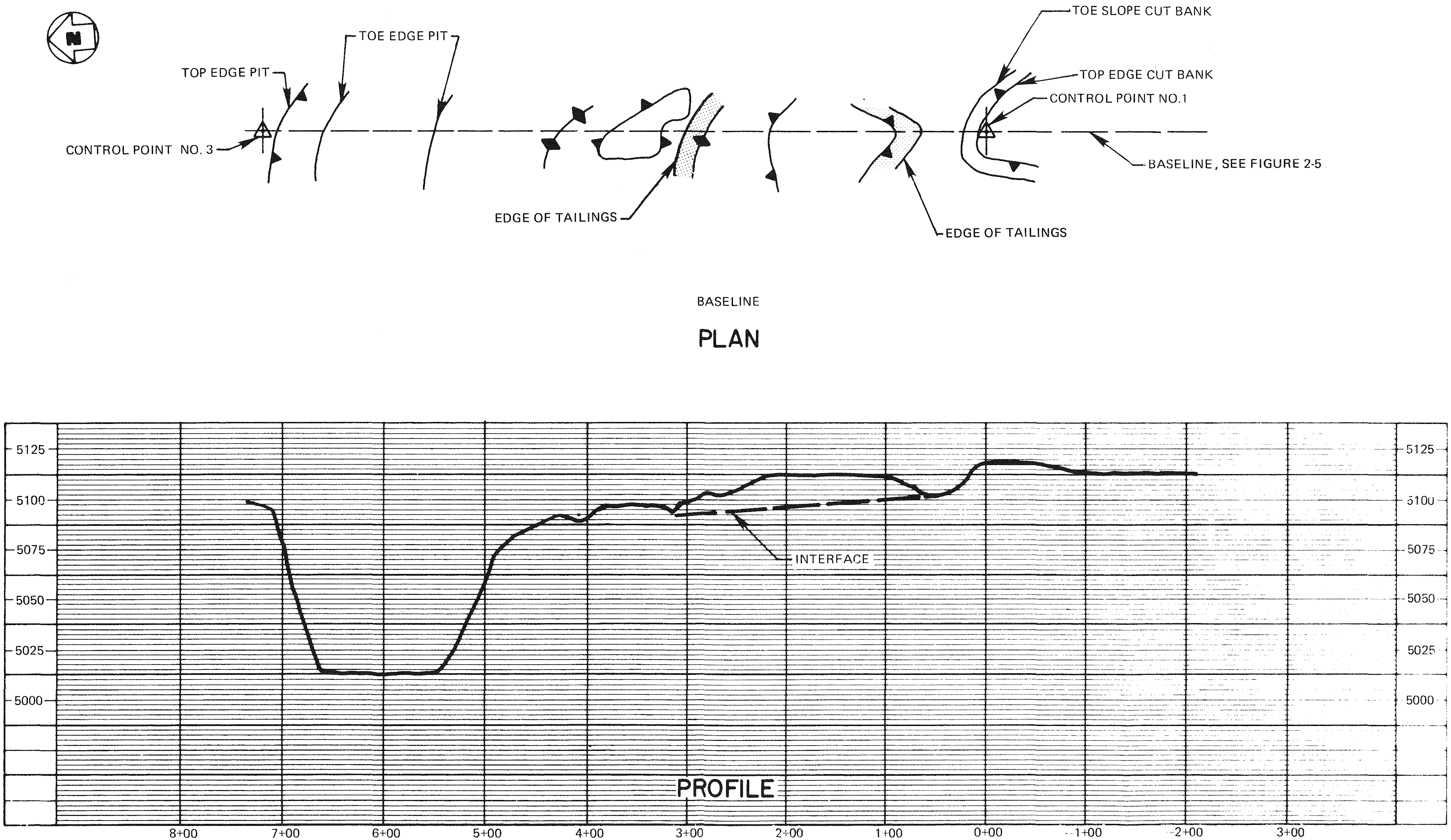

FIGURE 2-6. CROSS-SECTION THROUGH PILE AT BASELINE

360-15 12/77

SYSTEM	FORMATION	THICKNESS	CHARACTER	POSITION OF THE TAILINGS
TERTIARY	WASATCH FORMATION	0-1500 FT	SHALES, SANDSTONES, AND CONGLOMERATES; FORMS VALLEYS SLOPES, AND ROLLING HILLS; SANDSTONES YIELD WATER	CONVERSE TAILINGS ←
	FORT UNION FORMATION	1500-3200 FT	SHALES, SANDSTONES, OCCASIONAL COAL BEDS; FORMS ROLLING HILLS, VALLEYS AND SLOPES; SANDSTONES YIELD WATER	
CRETACEOUS	LANCE FORMATION	1000-2900 FT	SHALES WITH SOME SANDSTONE UNITS AND OCCASIONAL COAL BEDS; FORMS VALLEYS AND SLOPES; AQUICLUDE	
	FOX HILLS SANDSTONE	125-300 FT	SANDSTONES; FORM BENCHES; AQUIFER	
	LEWIS SHALE FORMATION	1150 FT	DARK GRAY MARINE SHALE; FORMS VALLEYS AND SLOPES; AQUICLUDE	
	MESAVERDE FORMATION	500 FT	BUFF SANDSTONES WITH INTERBEDDED SHALES; FORMS BENCHES, RIDGES, AND CLIFFS, AQUIFER	
OLDER SEDIMENTARY ROCKS				

FIGURE 2-7. SIMPLIFIED STRATIGRAPHIC COLUMN UC360-15 12/77

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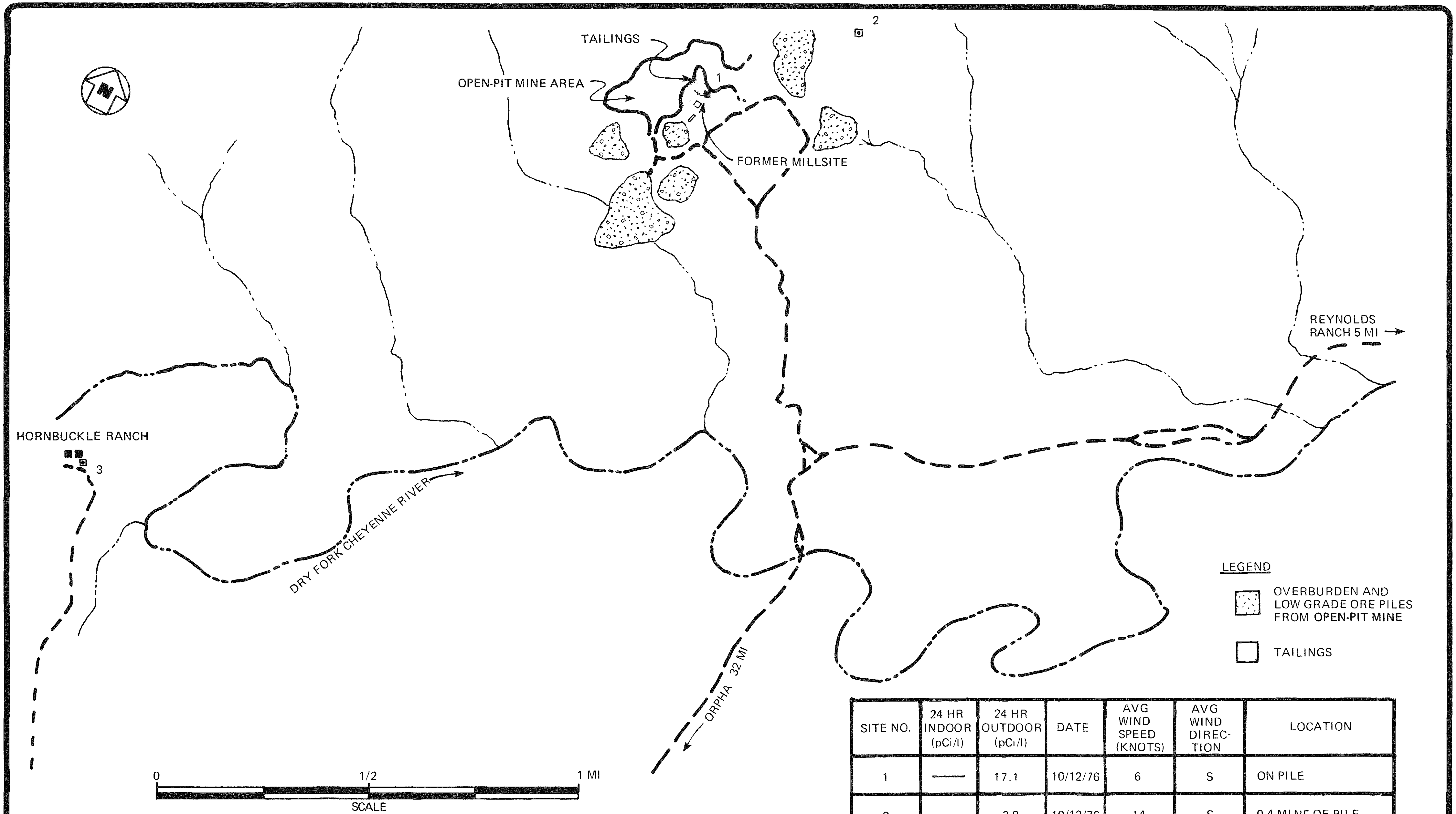

SITE NO.	24 HR INDOOR (pCi/l)	24 HR OUTDOOR (pCi/l)	DATE	AVG WIND SPEED (KNOTS)	AVG WIND DIREC-TION	LOCATION
1	—	17.1	10/12/76	6	S	ON PILE
2	—	2.8	10/13/76	14	S	0.4 MI NE OF PILE
3	1.6	1.1 *	10/13/76	14	S	RANCH 2 MI SW OF PILE

*USED FOR BACKGROUND DETERMINATION

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FIGURE 3-4. RADON CONCENTRATION IN VICINITY OF PILE

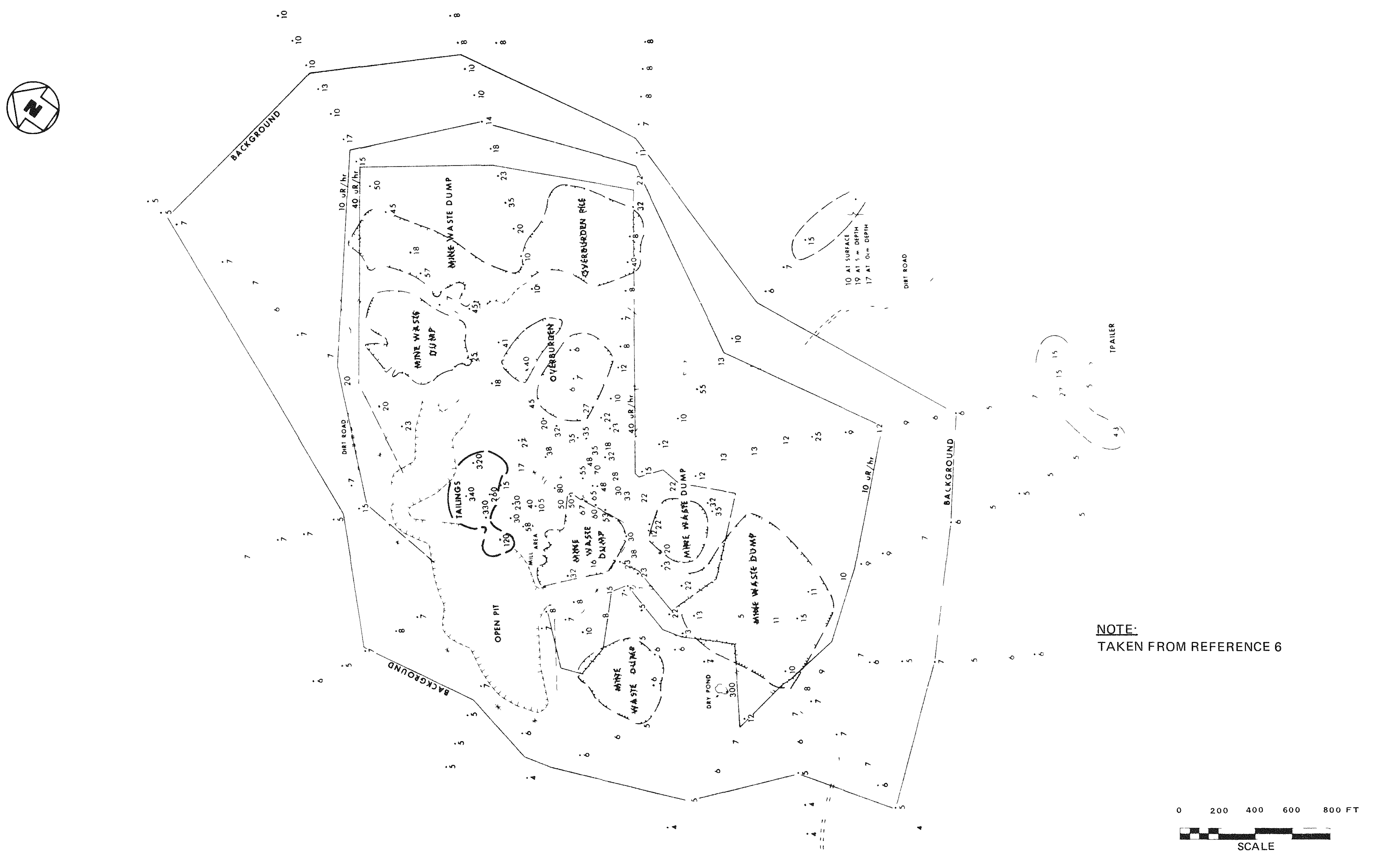

FIGURE 3-10. EPA GAMMA SURVEY SURROUNDING MILLSITE

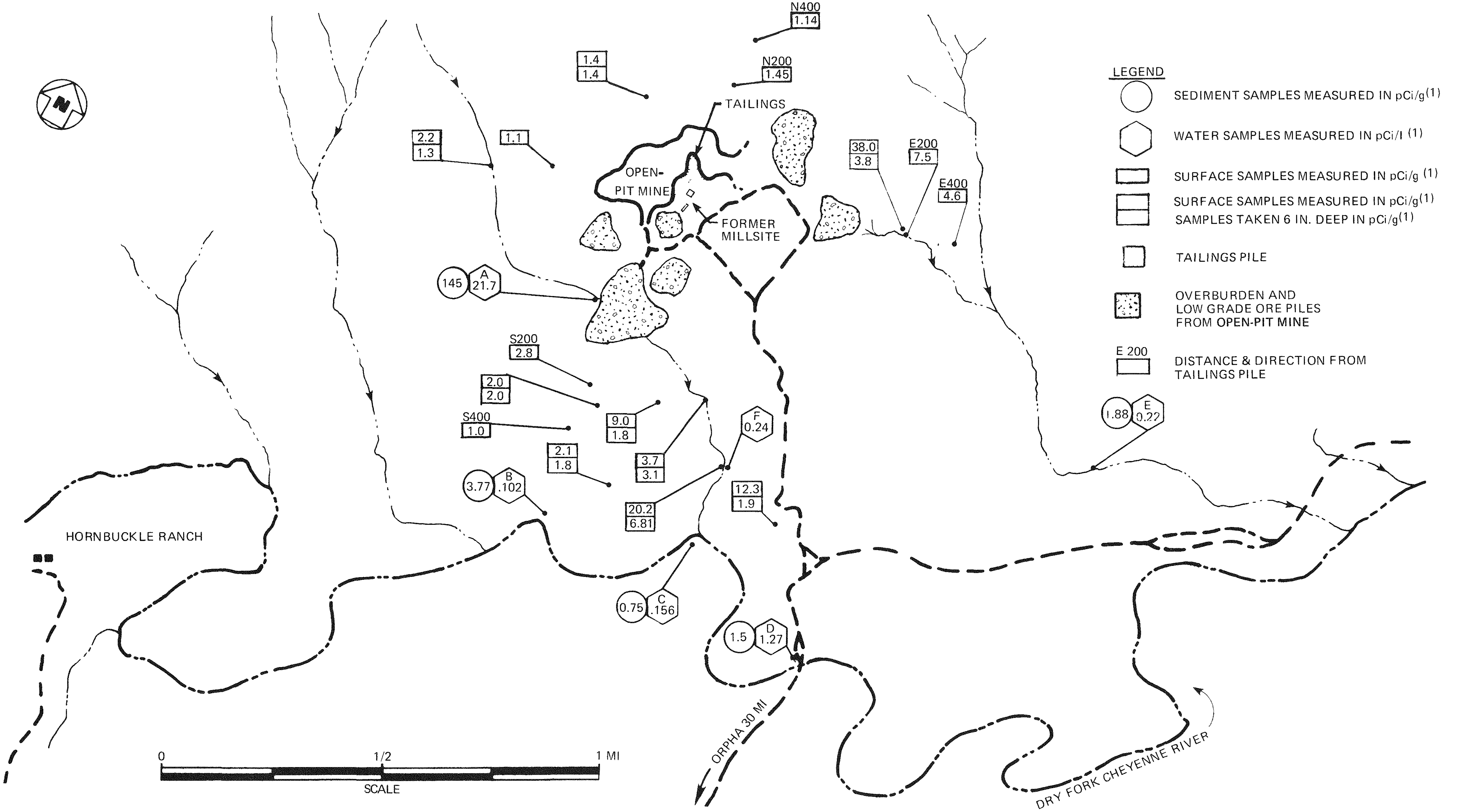

FIGURE 3-11. SURFACE AND SUBSURFACE RADIUM CONCENTRATIONS

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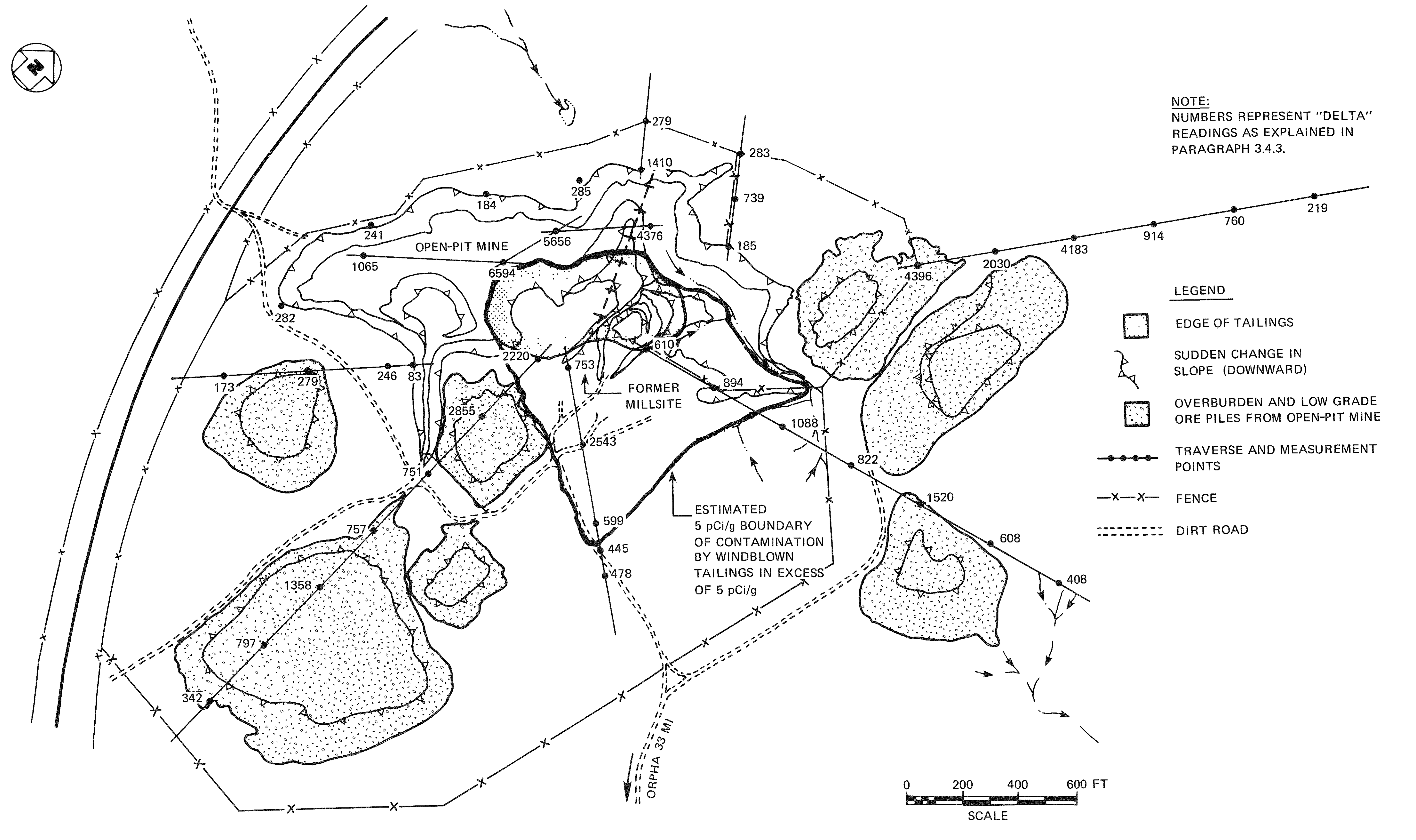

FIGURE 3-12. WINDBLOWN CONTAMINATION SURVEY

TABLE 3-4

CHEMICAL ANALYSES OF CONVERSE COUNTY WATER SAMPLES (mg/l)

Sample[a]	As	Ba	Cd	Cr	V	Fe	Pb	Se
A - Standing water pond	0.034	0.031	0.023	0.001	0.001	30.0	0.059	0.162
B - Pool, 100 yd upstream from west dry wash	0.029	0.20	0.016	0.001	0.001	1.23	0.001	0.087
C - Pool 300 yd downstream from B	0.096	0.45	0.17	0.062	0.001	0.800	0.001	0.29
D - Pool south of pile	0.053	0.33	0.001	0.001	0.001	0.040	0.001	0.217
E - Artesian well	0.019	0.31	0.015	0.038	0.001	0.130	0.001	0.028
F - Well	0.001	0.19	0.024	0.001	0.001	0.007	0.001	0.019
EPA Interim Primary Drinking Water Regulations[b]	0.05	1.0	0.01	0.05	--	0.3[c]	0.05	0.01

[a] See Figure 3-11 for locations.

[b] Federal Register, Dec 24, 1975

[c] Recommended limit from Manual for Evaluating Public Drinking Water Supplies, U.S. Public Health Service, 1969

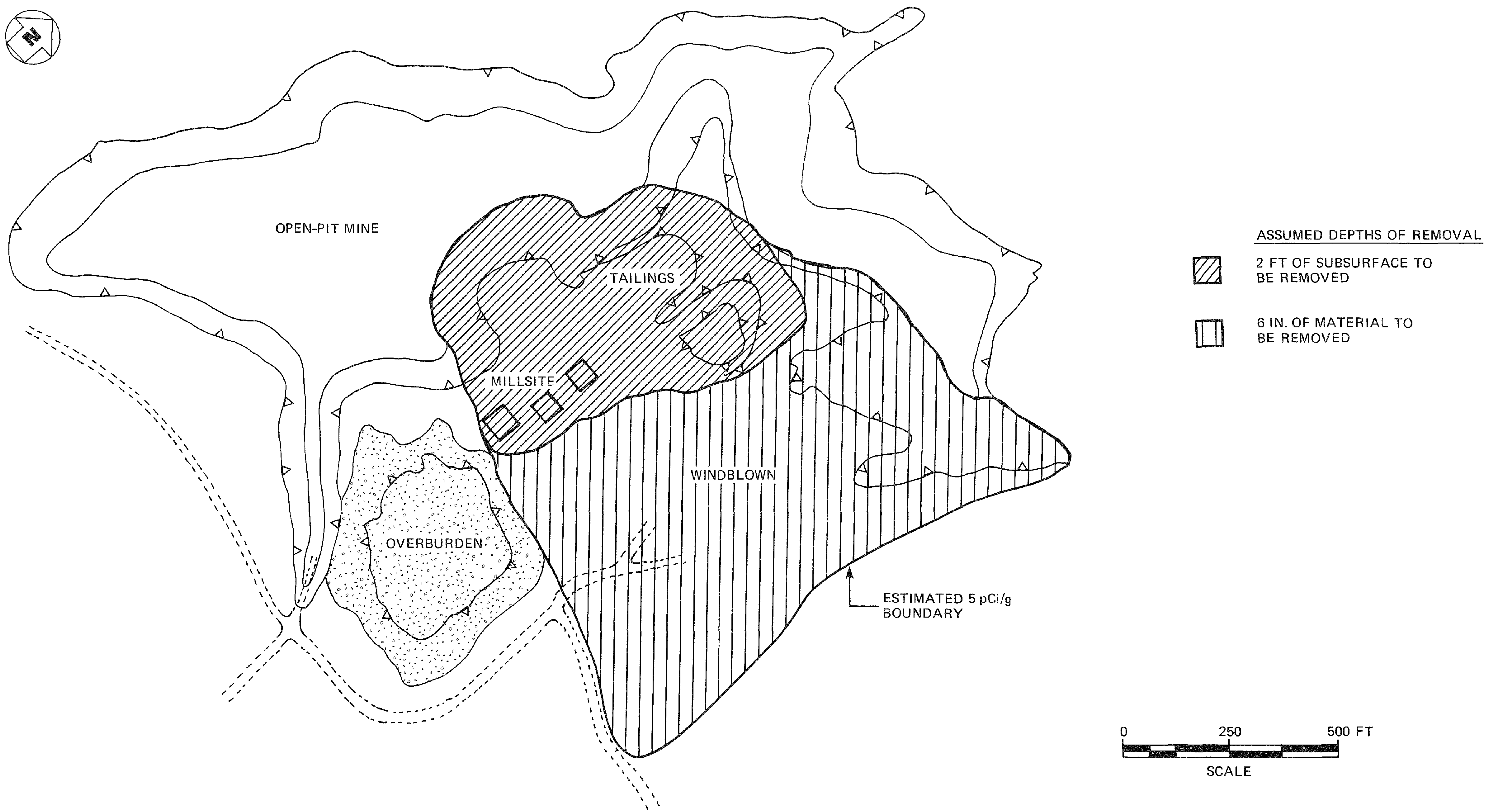

FIGURE 9-1. AREA DECONTAMINATION PLAN

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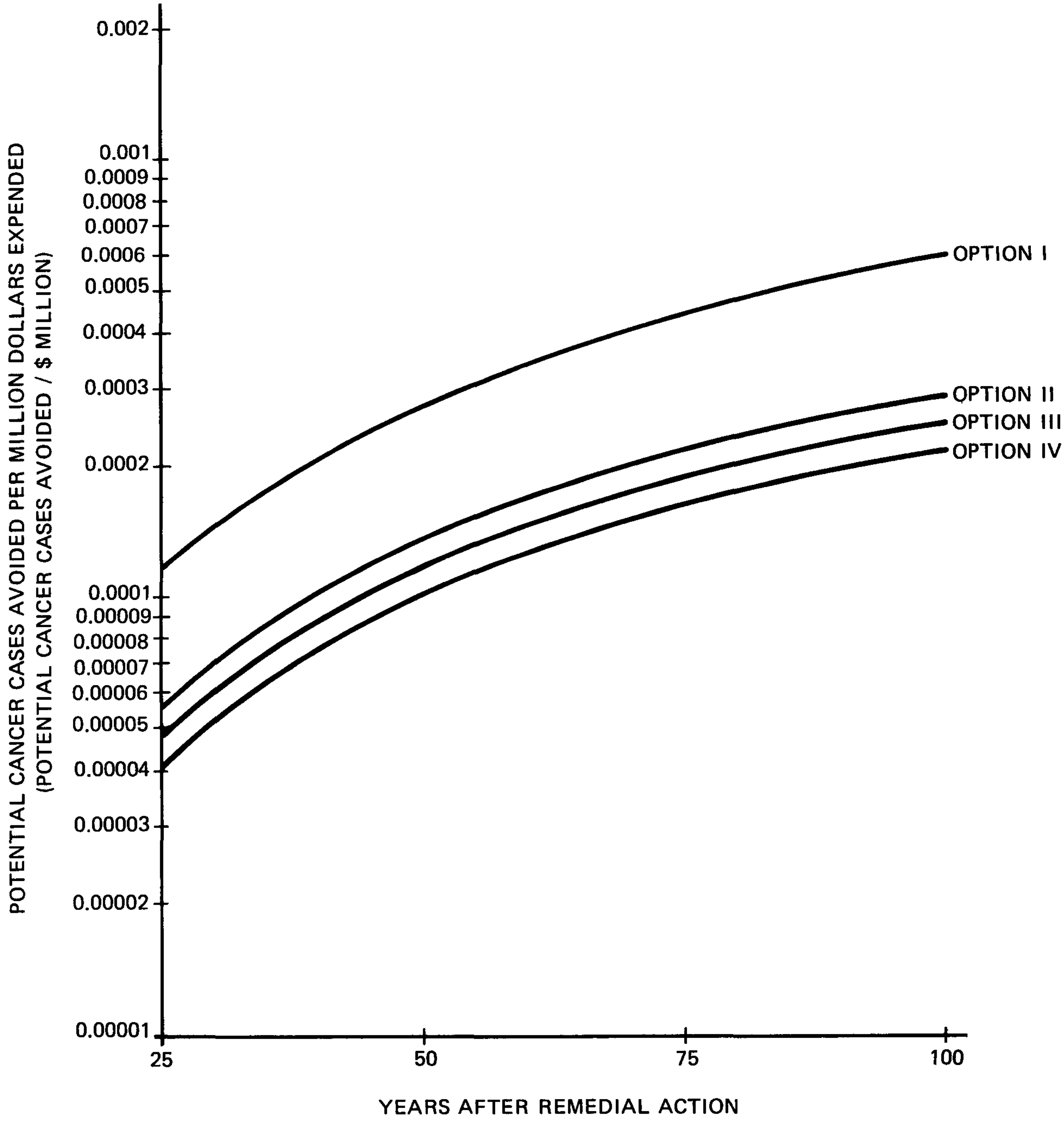

FIGURE 9-2. POTENTIAL CANCER CASES AVOIDED PER MILLION DOLLARS EXPENDED

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TABLE 9-1

SUMMARY OF STABILIZATION AND DISPOSAL COSTS[a]

		Options			
		I	II	III	IV
1.	Tailings Site	380	160	160	160
2.	Off-Site Other than Windblown	--	--	--	--
3.	Off-Site Windblown	50	50	50	50
4.	Transportation				
	a. Capital Costs	--	100	105	110
	b. Haul Costs	--	260	390	570
5.	Disposal Site	--	390	390	390
6.	Total Cleanup[b] (sum of lines 1 through 5)	420	950	1,100	1,280
7.	Engineering Design and Construction Management (30% of the difference between lines 6 and 4b)	130	210	210	210
8.	Total[b] (sum of lines 6 and 7)	550	1,160	1,310	1,500
9.	Contingency (30% of line 8)	160	350	390	450
10.	GRAND TOTAL[b] (sum of lines 8 and 9)	710	1,510	1,700	1,950

[a]Costs are presented in thousands of year 1980 dollars.

[b]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 $)	0.71	1.5	1.7	2.0
Years After Remedial Action				
25	<0.000083	0.000083	0.000083	0.000083
50	<0.00020	0.00020	0.00020	0.00020
75	<0.00032	0.00032	0.00032	0.00032
100	<0.00043	0.00043	0.00043	0.00043

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

Options:	I	II	III	IV
Option Cost (million $)	0.71	1.5	1.7	2.0
Years After Remedial Action				
25	>8,554	18,072	20,482	24,096
50	>3,550	7,500	8,500	10,000
75	>2,219	4,688	5,313	6,250
100	>1,651	3,488	3,954	4,651

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