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A SUMMARY OF THE ENGINEERING ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS

MAYBELL SITE
MAYBELL, COLORADO

SEPTEMBER 1981

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

Ford, Bacon & Davis Utah Inc.
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DISCLAIMER

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FORD, BACON & DAVIS UTAH INC.
375 Chipeta Way
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, Maybell Site, Maybell, Colorado." 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 October 1977, entitled "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Maybell Site, Maybell, Colorado," 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 Maybell 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 this report. Special recognition is due Richard H. Campbell and Mark Matthews of DOE, as well as Jim Kirchner of the Union Carbide Corporation. Several local, county, and state agencies contributed information, as did many private individuals.

ABSTRACT

Ford, Bacon & Davis Utah Inc. has reevaluated the Maybell site in order to revise the October 1977 engineering assessment of the problems resulting from the existence of radioactive uranium mill tailings at Maybell, Colorado. 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 2.6 million dry tons of tailings at the Maybell site constitutes the most significant environmental impact, although windblown tailings and external gamma radiation also are factors. The two alternative actions presented in this engineering assessment range from millsite decontamination with the addition of 3 m of stabilization cover material (Option I), to disposal of the tailings in a nearby open pit mine and decontamination of the tailings site (Option II). Cost estimates for the two options are about $11,700,000 for stabilization in-place and about $22,700,000 for disposal within a distance of 2 mi.

Three principal alternatives for the reprocessing of the Maybell 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 $125 and $165/lb of U_3O_8 by heap leach and conventional plant processes, respectively. The spot market price for uranium was $25/lb early in 1981. Therefore, reprocessing the tailings for uranium recovery is not economically attractive at present.

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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 Maybell 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 three potential practicable remedial action alternatives. Since that time, some alternatives have been judged unacceptable because of new criteria that have been proposed. In this report, the remedial action alternatives are the following:

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

(b) Option II - Disposal of the tailings in an open pit mine about 2 mi from the pile

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.

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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 Maybell site appears as Appendix I to Reference 4.

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 the initial task, and work began immediately. The original work at Maybell was performed in May and October 1976, and the original Phase II - Title I Engineering Assessment was published in October 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 August 4, 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 Durango 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 Maybell site.

1.2 SITE DESCRIPTION

1.2.1 Location and Topography

The Maybell millsite and tailings pile are located approximately 25 mi west of the town of Craig, in Moffat County in northwestern Colorado. The site is 5 mi north of the Yampa River in a rolling, sagebrush-covered area. The elevation is 6,220 ft above sea level. The site and its relationship to the surrounding area are shown in the aerial photograph in Figure 2-1.*

1.2.2 Ownership and History of Milling Operations and Processing

Union Carbide Corporation has been the owner and operator of the site since its inception in 1957. The plant became operational in 1957, processed 2.6 million dry tons of ore, and shut down in the fall of 1964. The ore had a grade of 0.098% U_3O_8, and all the concentrate produced was sold to the AEC. The ore came from nearby open pit mines. An upgrader circuit at the processing plant was used to treat low grade ore before leaching. Figure 2-3 shows the present ownership of the site.

1.2.3 Present Condition of the Site

Figure 2-4 is a descriptive map of a portion of the site as it now exists. The site vicinity is characterized by deep open pits from which the ore was extracted, piles of overburden, and the relatively flat yet sloping surface of the 80-acre tailings pile. Figures 2-5A and 2-5B show typical cross-sections of the pile. The tailings are enclosed with a barbed-wire fence.

Although the tailings pile was stabilized by the addition of 6 in. of earth cover and vegetation, erosion has exposed about 20% of the pile's surface and only about 40% of the

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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.

surface is covered with vegetation. Off-pile ditches and a dike on the east side of the pile divert upslope water away from the tailings. Most of the water that collects on the tailings drains off through a drainage system on the pile, and the water is channeled into nearby Johnson Wash.

On another portion of the site, heap leaching operations utilizing low-grade ore are being conducted by Union Carbide Corporation.

1.2.4 Tailings and Soil Characteristics

The tailings are generally of finely-ground sands with some slime and slight clay contents. Bulk densities run between 84 and 97 lb/ft^3. There are approximately 2.6 million dry tons of tailings on the site. The weights and volumes of the tailings, cover material, and contaminated materials are given in Table 2-1.

The soil beneath the tailings consists of clayey and silty fine sands, of medium density and dark brown in color.

1.2.5 Geology, Hydrology, and Meteorology

The Maybell tailings pile is located on a gentle south-western slope near the head of a small drainage system. The Browns Park Formation underlies the site and in turn is underlain by the Mancos Shale Formation. The Browns Park Formation primarily is composed of sandstone units, and some shale layers within the formation act as barriers to the downward and upward migration of ground waters. A simplified stratigraphic column is shown in Figure 2-6.

The Yampa River, 5 mi to the south, is the closest perennial stream flowing through the area downdrainage from the site. Drainage at the site includes diversion ditches around the pile and drainage channels into Johnson Wash, a dry tributary of Lay Creek. Lay Creek enters the Yampa River approximately 2.5 mi downstream of Johnson Wash. Other surface water near the site consists of standing water in the inactive Rob Pit.

Contamination from the pile into the area's surface waters is limited because the pile is not subject to flooding, a diversion system protects most of the pile from off-site overland flow, and the dishlike configuration of the pile collects the precipitation that falls on the pile. However, a dike failure during mill operations left about 200 tons of tailings in the wash leading to Johnson Wash.

The unconfined ground waters of the area are within the Browns Park Formation and in unconsolidated valley deposits. The water table at the site is 150 ft below the tailings-soil interface, and the flow gradient is to the west-southwest. The confined ground waters are contained in the lower sections of the Browns Park Formation by shale layers, or are very deep aquifers confined by the thick sequence of Mancos Shale. Increased concentrations of radionuclides are unlikely because percolation through the tailings is limited almost entirely to the precipitation that falls on the site. Another source of radionuclides to the ground water system is the percolation of waters through the ore-bearing strata; compared to this source, any potential contamination from the tailings is insignificant.

There is evidence of both water and wind erosion on the steep eastern slope of the pile. Tailings and cover material have eroded from the pile's eastern edge, and revegetation under present conditions would be difficult. Strong winds are common in the area and tend to blow from the west-southwest. The average annual rainfall at Craig is 14 in. High-intensity rainfall such as that from thunderstorms is infrequent but can occur in the Maybell area from May through October. Such storms could result in further erosion of the eastern margin of the pile and in the transport of contaminated streambed material farther downstream.

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, the ^{226}Ra appears to be 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 the radon exhalation flux from the tailings made in 1976 using the charcoal canister technique(3) ranged from 75 to 99 pCi/m^2-s on the tailings pile. Measurements of the radon exhalation flux from the tailings made in 1980 ranged from about 70 to about 190 pCi/m^2-s, with a mean flux estimated to be about 125 pCi/m^2-s. 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 performed by FB&DU in 1976 with continuous radon monitors supplied by ERDA at four locations in the vicinity of the Maybell tailings pile. The locations and values of the 24-hr radon concentrations, including background, are shown in Figure 3-5. The highest outdoor radon concentration (15 pCi/l) was measured on the pile. Background measurements of atmospheric radon at two locations about 2.5 mi from the site averaged 3.0 pCi/l. Radon above the average background level was detected at 0.5 mi from the site.

1.3.1.2 Direct Gamma Radiation

The lowest value of gross gamma radiation in the area (4,000 ft northwest of the tailings) was 11 μR/hr as measured 3 ft above ground with an energy-compensated Geiger Mueller detector.(4) Above the surface of the tailings pile, the gamma radiation rates ranged to a maximum of 340 μR/hr. In the area surrounding the tailings the gamma radiation rates were higher than twice background, due largely to windblown tailings and stockpiles of low-grade ore nearby.

1.3.1.3 Windblown Contaminants

Prevailing winds in the area are from the west-southwest. Surface soil samples indicate windblown contamination to the east of the pile. At 375 yd east of the pile, a surface soil sample contained 10 times the average ^{226}Ra background concentration of 1.5 pCi/g. Windblown contamination 800 ft toward the east is shown by the 5-pCi/g line illustrated in Figure 3-13. The 5-pCi/g line includes about 50 acres of land outside the site boundaries that are considered to be contaminated by windblown tailings.

1.3.1.4 Ground and Surface Water Contamination

Three water samples, taken upstream and downstream in Lay Creek and at the confluence of Lay Creek and Johnson Wash, contained ^{226}Ra concentrations of 0.18, 0.19, and 0.16 pCi/l, respectively.(4) These concentrations are well below the limit for radionuclides in the EPA Interim Primary Drinking Water Regulations (5 pCi/l of combined ^{226}Ra and ^{228}Ra).

A water sample from the wash just off the tailings contained 12.8 pCi/l of ^{226}Ra, and a sample from Johnson Wash, 0.5 mi downstream of the pile, had a ^{226}Ra concentration of 0.02 pCi/l.

A well-water sample from a cased 150-ft monitoring well west of the tailings contained 10.4 pCi/l of ^{226}Ra. This 150-ft well was drilled into the Browns Park Formation, the host rock for the uranium deposits in this vicinity. Contamination of the water in this formation cannot be attributed to the tailings pile.

The quality of the Yampa River was monitored from 1961 to 1970, and the ^{226}Ra concentration downstream of the site averaged 0.08 pCi/l.(1)

Considering the existing data and the distance between Maybell and the tailings site, the tailings do not appear to have increased the ^{226}Ra content of the water at Maybell.

1.3.1.5 Soil Contamination

The leaching of radium from the tailings into the subsoil extends to a depth of 2 to 5 ft before reaching background ^{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.*

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*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.

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 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 Maybell site under present conditions. The gamma radiation exposure from the pile is virtually zero since there are very few people who live or work within 0.4 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 piles. 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 Maybell 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, it was calculated that the average lung cancer risk attributable to radon released from the tailings pile in the area within 5 mi of the Maybell site is 3.3×10^{-7} per person per year, or less than 1% of the average lung cancer risk due to all causes for Colorado residents (1.8×10^{-4}).(9) For those within 0.5 mi of the pile, the average lung cancer risk due to the pile is less than 10% of the cancer risk due to all causes.

The 25-yr health effects were calculated for three population projections using the present population of 100 people in the 0- to 5-mi area. The results for pile-induced radon and background radon for the area were as follows:

25-Year Cumulative Health Effects within 5 Miles of Edge of Pile

Projected Population Growth	Pile-Induced RDC	Background RDC
0.3% constant growth rate	0.0008	0.3
15% declining growth rate[a]	0.0033	1.2
20% composite growth rate[b]	0.0060	2.2

Pile-induced radon daughter health effects are less than 1% of the background radon daughter health effects for residents within 5 mi of the tailings site. 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

There are other potentially toxic materials in the tailings. Chemical analyses of tailings samples from drill holes on the Maybell pile showed barium, chromium, and lead in concentrations between 5 and 30 ppm. The highest selenium concentration was 24 ppm and arsenic concentration was 3 ppm. Vanadium was present at about 40 ppm.

Water from a well west of the tailings that taps the Browns Park Formation had concentrations of iron, arsenic, lead, and selenium above the limits of the EPA Interim Primary Drinking Water Regulations. The Browns Park Formation is the host rock for the uranium in this area and is not used as a potable water supply.

A surface water sample taken from a wash near the pile contained above-acceptable levels of iron, lead, and selenium. This water is runoff from the pile that traverses areas of bare tailings where erosion has occurred.

1.4 SOCIOECONOMIC AND LAND USE IMPACTS

Except for the mineral-related activity near the pile, virtually all the land near the tailings site is used for grazing. There are two small population centers in the vicinity, including about 20 dwellings and commercial buildings at Maybell, and four trailers and one house east of Maybell near the Yampa River bridge.

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

[b]Holds constant at 20% for 8 yr, then declines linearly over 5 yr from its initial value to zero and remains constant at zero thereafter.

The Federal Government administers several sections of land near the site. Most of the remaining area is held by 12 private or corporate groups. All the land surrounding the Maybell site was assessed in 1974 and is listed at a market value of $7/acre.

The presence of the tailings restricts the use of the site itself; i.e., it cannot now be used for grazing. This loss of usable land is minimal, however, compared with the much larger loss caused by areas disrupted by open pit mines, overburden, and ore stockpiles. If the tailings were not present there would be virtually no change in land uses and values in the surrounding areas.

As part of a new program, the Federal Coal Leasing Program, several large tracts of land near Maybell would be leased to private individuals or groups for mining purposes. Also, a hydroelectric project known as the Juniper-Cross Mountain Dam is planned for the Yampa River near Maybell. This project would include construction of two separate electricity-generating dams.

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.

There are, however, five factors that can be employed to evaluate whether reprocessing Maybell 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 Maybell 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 $125 and $165/lb of U_3O_8 by heap leach and conventional plant processes, respectively. The spot market price for uranium was $25/lb early in 1981. Therefore, reprocessing the Maybell tailings for uranium recovery is not economically attractive under present market conditions.

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

In the Maybell vicinity, no off-site structures that require remedial action have been identified. However, a mobile scanning unit operated by the AEC performed a gamma radiation survey of the Craig, Colorado, area in 1973. Eighty-six anomalies with levels above background criteria were discovered. Natural radioactive materials were found at 46 locations, radioactive materials in instruments or ore were found at seven locations, roof eave drip from fallout from the Chinese weapons tests was presumed to be the cause of five anomalies, and the source of 25 other anomalies could not be verified. The remaining three anomalies were caused by tailings use.

The results of a gamma survey showed that a total of about 50 acres of off-site property has been contaminated as a result of windblown tailings.

1.8 DISPOSAL SITE SELECTION

In this report, one of the alternative remedial action options includes moving the Maybell tailings to a disposal site. The disposal site was selected after consultation with local, State of Colorado, and federal agencies; concerned individuals; and personnel in industry. The site was evaluated to a limited extent on the bases of hydrology, meteorology, geology, ecology, economics, and proximity to population centers. Since the responsibility for disposal site selection lies primarily with the Federal Government, with input from the State, the disposal site evaluated in this work must be considered only as tentative.

The site corresponding to Option II in Table 1-2 is shown in Figure 8-1. In this option, the tailings would be emplaced in one or more open pit mines, contoured, and covered with 3 m of soil. The surface would then be covered with 0.3 m of riprap or vegetation established for erosion control, and the entire site would be 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 a 3-m depth of cover material, and the removal of tailings to an open pit mine about 2 mi from the present site. 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 more completely in its present location with the addition of a 3-m depth of cover. This option is considered a viable one because the present site can probably meet tailings stabilization criteria. Radon exhalation would be reduced to less than 2 pCi/m^2-s above background. The site would be available for restricted use only.

1.9.2 Cost-Benefit Analyses

As summarized in Table 9-1, the total costs for the two remedial action options are about $11,700,000 for stabilization in place and about $22,700,000 for disposal in the open pit mine. 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.

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	11,700	The pile would be stabilized in place with 3 m of local earth cover. Natural vegetation would be established or a 0.3-m cover of riprap would be provided. On- and off-site contaminated materials would be cleaned up as necessary.	A-E,H,J	Z
II	22,700	The tailings, contaminated soil, and rubble would be removed by truck to an open pit mine located about 2 mi from the tailings site. The tailings site would be decontaminated and released for unlimited use.	A,C-K	--

Notes

1. All options include on- and off-site remedial action.
2. For Option II, costs include removal of 4 ft of contaminated earth below the tailings.

TABLE 1-2 (Cont)

Definition of Benefits

A. Off-site structures decontaminated
B. Access to the site controlled by fencing and posting
C. Off-site windblown tailings cleaned up
D. Wind and water erosion controlled
E. Gamma radiation reduced
F. The source of gamma radiation and radon gas removed from the area
G. No building restrictions on or near site
H. The prime use of the final disposal location unchanged
I. Disposal site maintenance required only on a limited basis; minimal possibility of contaminating air or water supplies
J. A reduction in rate of radon exhalation to at least 2 pCi/m^2-s
K. Maintenance and fencing of tailings site eliminated

Definition of Adverse Effects

Z. Limited use of the property

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, Maybell Site, Maybell, Colorado"; GJT-11; Ford, Bacon & Davis Utah Inc.; Oct 1977.

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

4. F.F. Haywood, et al.; "Radiological Survey of the Inactive Uranium Mill Tailings at Maybell, Colorado"; ORNL 5456; Mar 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 37, 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

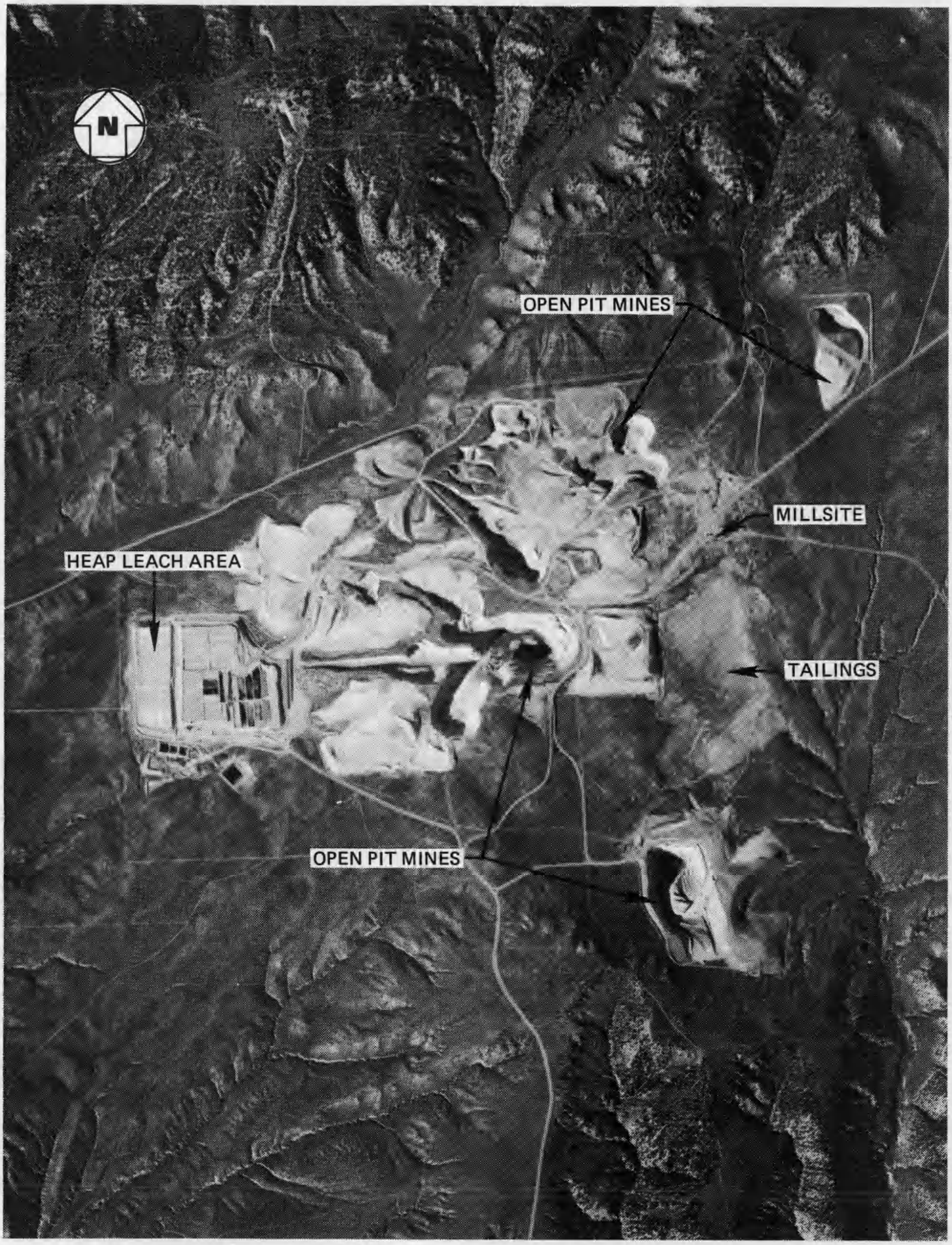

FIGURE 2-1. AERIAL PHOTOGRAPH OF SITE

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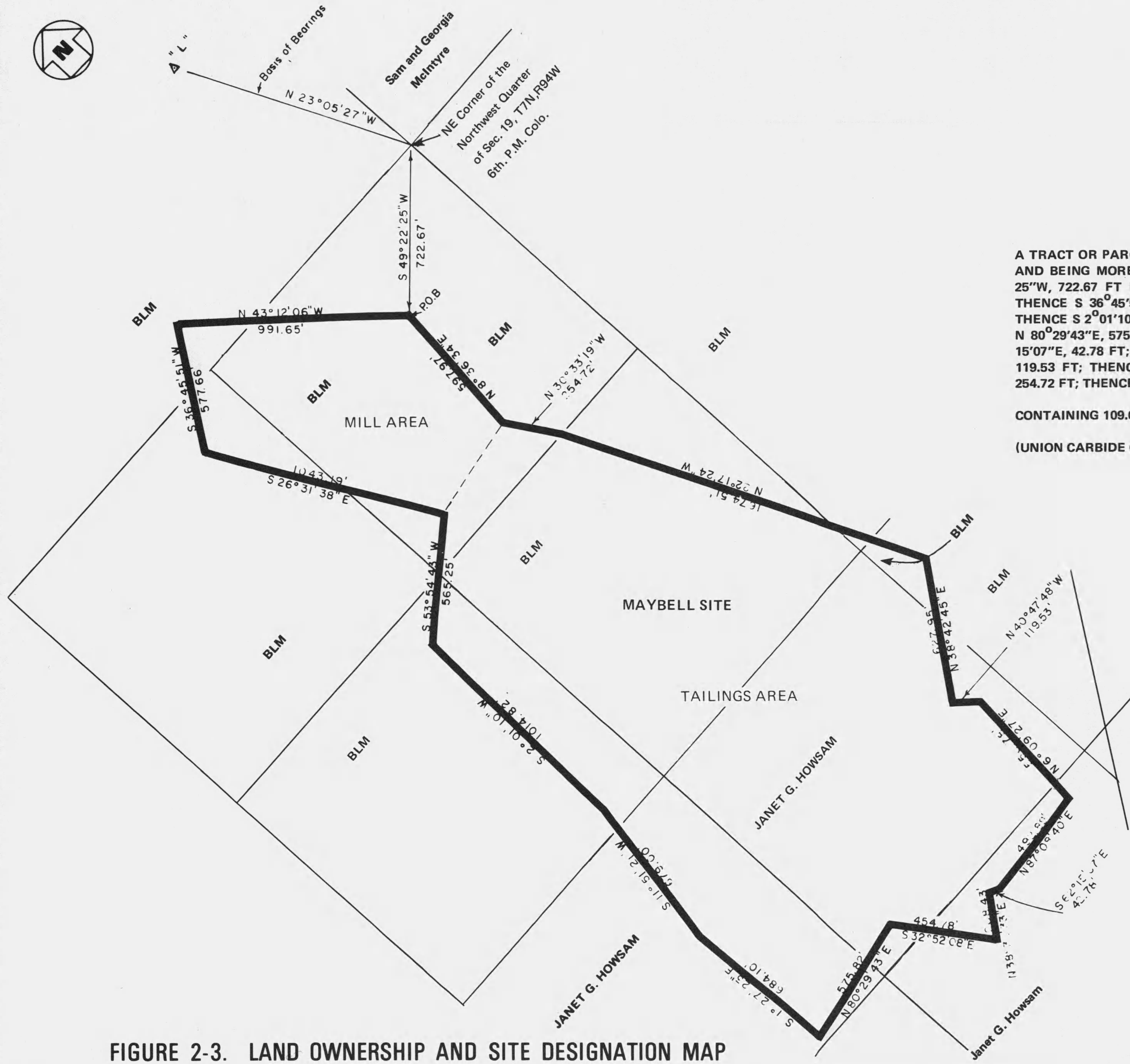

FIGURE 2-3. LAND OWNERSHIP AND SITE DESIGNATION MAP

MAYBELL SITE

A TRACT OR PARCEL OF LAND LOCATED IN SECTION 19 AND SECTION 18, T7N, R94W, 6TH P.M. COLORADO AND BEING MORE PARTICULARLY DESCRIBED AS FOLLOWS: BEGINNING AT A POINT WHICH IS S 49°22' 25"W, 722.67 FT FROM THE NE CORNER OF THE NW ¼ SECTION 19; THENCE N 43°12'06"W, 991.65 FT; THENCE S 36°45'51"W, 577.66 FT; THENCE S 26°31'38"E, 1043.19 FT; THENCE S 53°54'43"W, 565.25 FT; THENCE S 2°01'10"W, 1014.82 FT; THENCE S 11°51'21"W, 679.00 FT; THENCE S 1°27'23"E, 684.10 FT; THENCE N 80°29'43"E, 575.82 FT; THENCE S 32°52'08"E, 454.78 FT; THENCE N 38°32'33"E, 208.43 FT; THENCE S 62° 15'07"E, 42.78 FT; THENCE N 87°08'40"E, 492.89 FT; THENCE N 6°09'27"E, 550.78 FT; THENCE N 40°47'48"W, 119.53 FT; THENCE N 38°42'45"E, 627.95 FT; THENCE N 22°17'24"W, 1674.51 FT; THENCE N 30°33'19"W, 254.72 FT; THENCE N 8°36'34"E, 597.97 FT TO THE POINT OF BEGINNING.

CONTAINING 109.623 ACRES.

(UNION CARBIDE OPERATIONAL CONTROLLER)

NOTE: ADAPTED FROM REFERENCE 1

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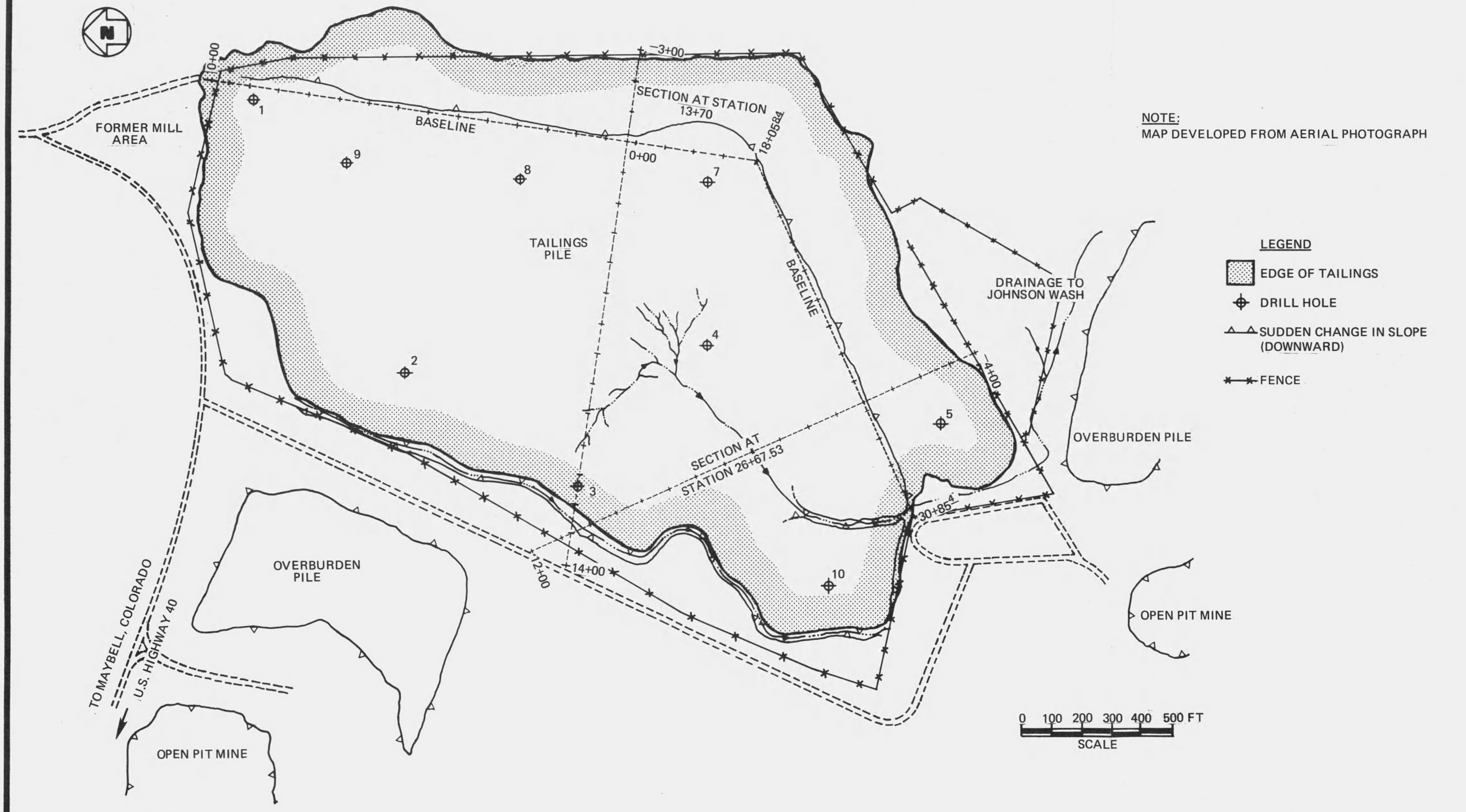

FIGURE 2-4. DESCRIPTIVE MAP

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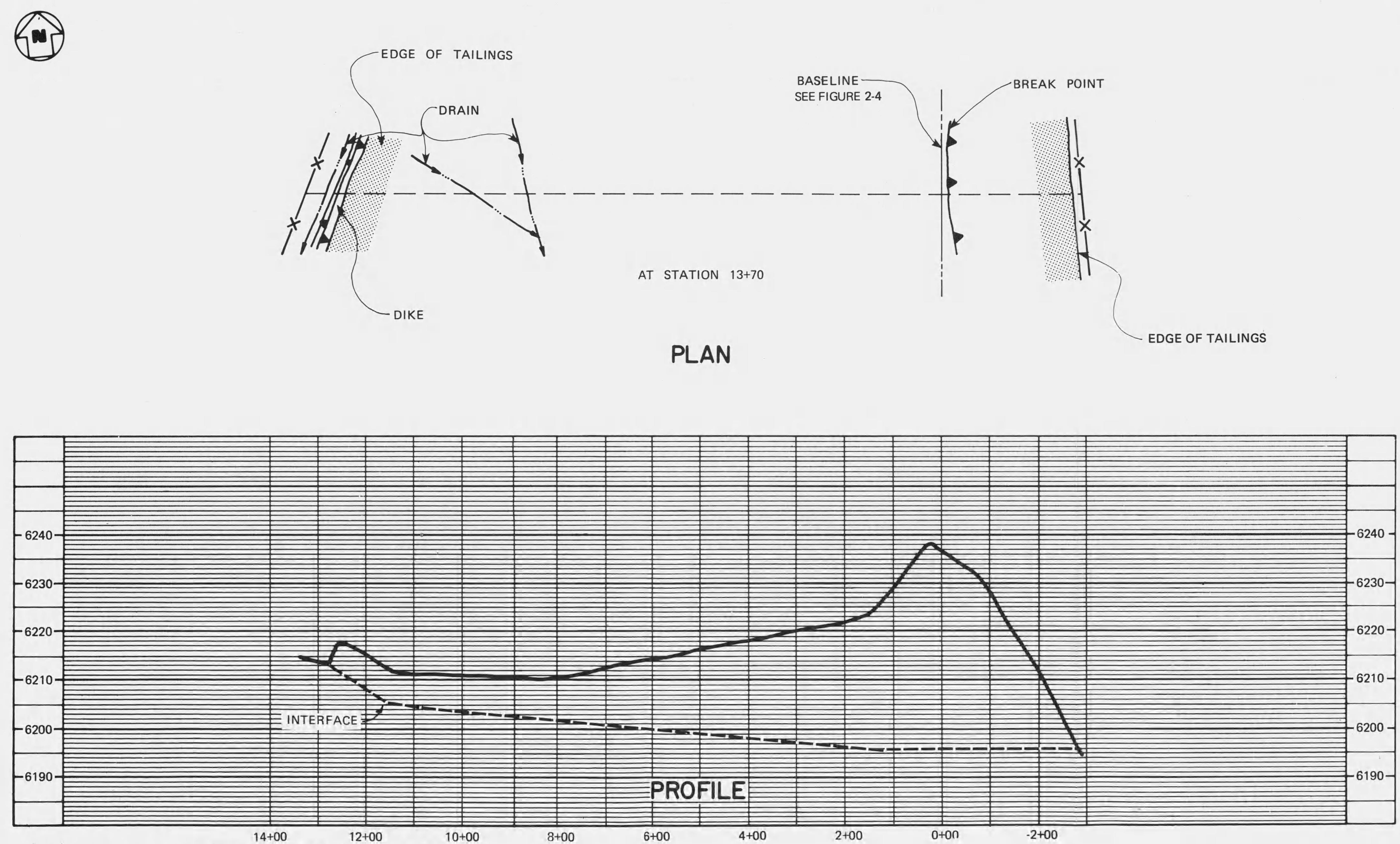

FIGURE 2-5A. CROSS-SECTION AT STATION 13+70

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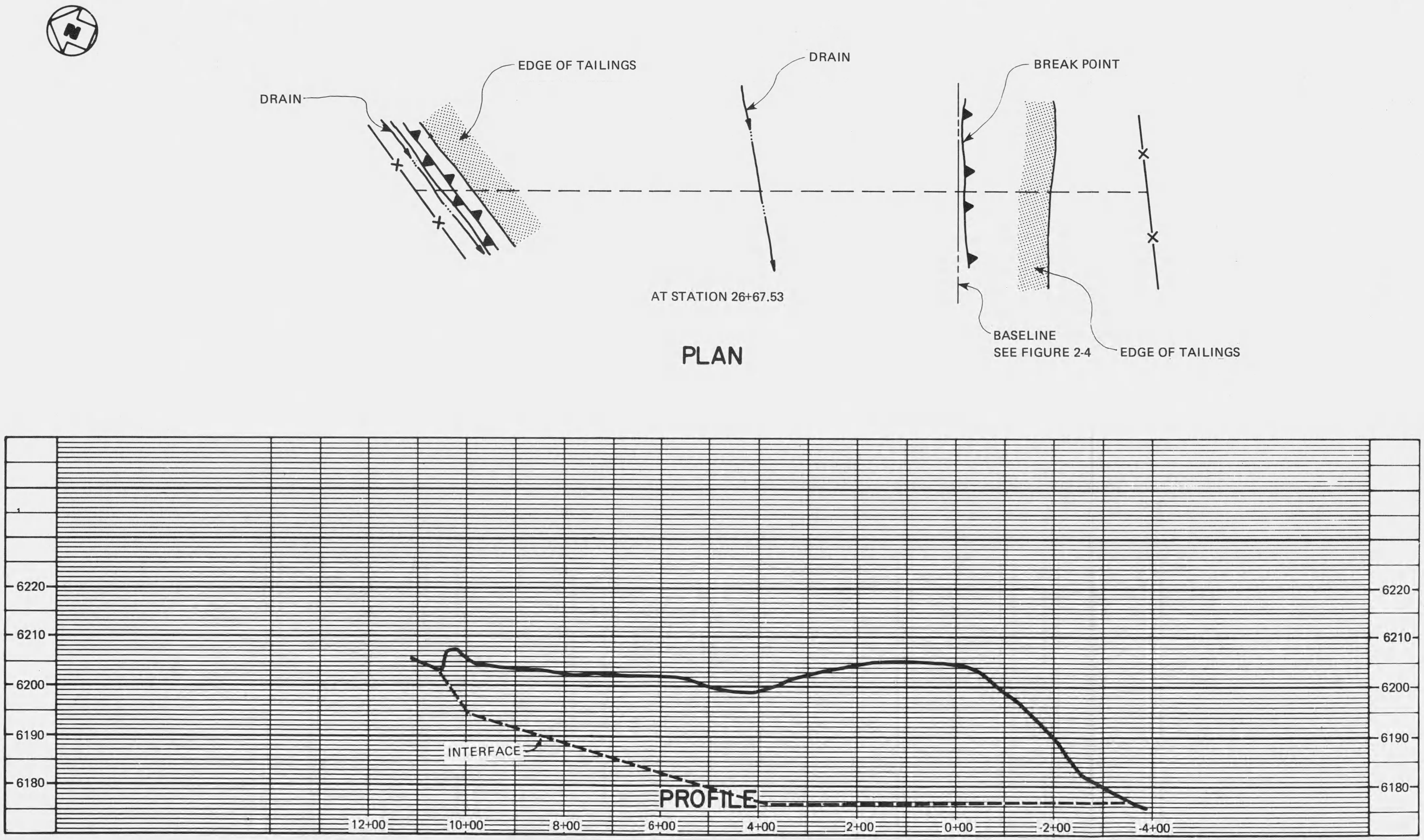

FIGURE 2-5B. CROSS-SECTION AT STATION 26+67.53

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SYSTEM	FORMATION	THICK-NESS (FT)	CHARACTER	POSITION OF TAILINGS
TERTIARY (MIOCENE)	BROWNS PARK FORMATION	500 - 1500	SANDSTONES WITH SOME SILTSTONE AND BASAL CONGLOMERATE; FORMS VALLEYS, AND HILLS; AQUIFER	← MAYBELL TAILINGS
			MAJOR UNCONFORMITY	
CRETACEOUS	MANCOS SHALE	2000 - 5000	GREY SHALE; FORMS VALLEYS AND SLOPES; AQUICLUDE	
	DAKOTA SANDSTONE	0- 200	GREY AND BROWN SANDSTONE, SHALE AND CONGLOMERATE; CAPS MESAS AND FORMS CLIFFS; LOW QUALITY, LOW QUANTITY, AQUIFER	
			OLDER SEDIMENTARY ROCKS	

FIGURE 2-6. SIMPLIFIED STRATIGRAPHIC COLUMN 360-11 10/77

SITE NO.	24 HR OUTDOOR (pCi/l)	AVG WIND SPEED (KNOTS)	AVG WIND DIRECTION	LOCATION
1	14.6	2	NE	ON PILE
2	9.6	2	SE	0.5 MI E OF PILE
3	3.5	2	S	2.6 MI E OF PILE
4	2.5	2	SW	2.4 MI SW OF PILE

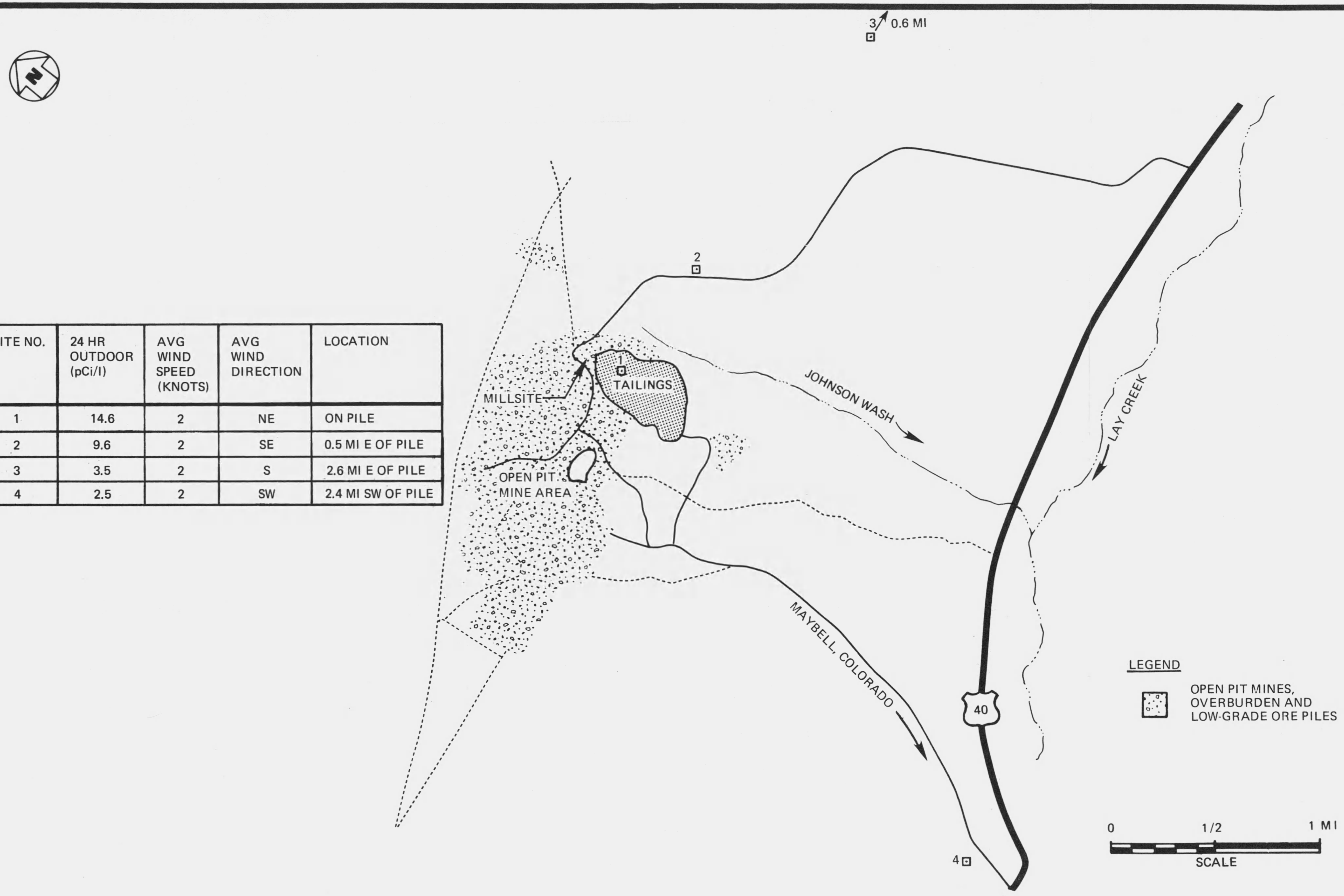

FIGURE 3-5. RADON CONCENTRATION IN VICINITY OF PILE

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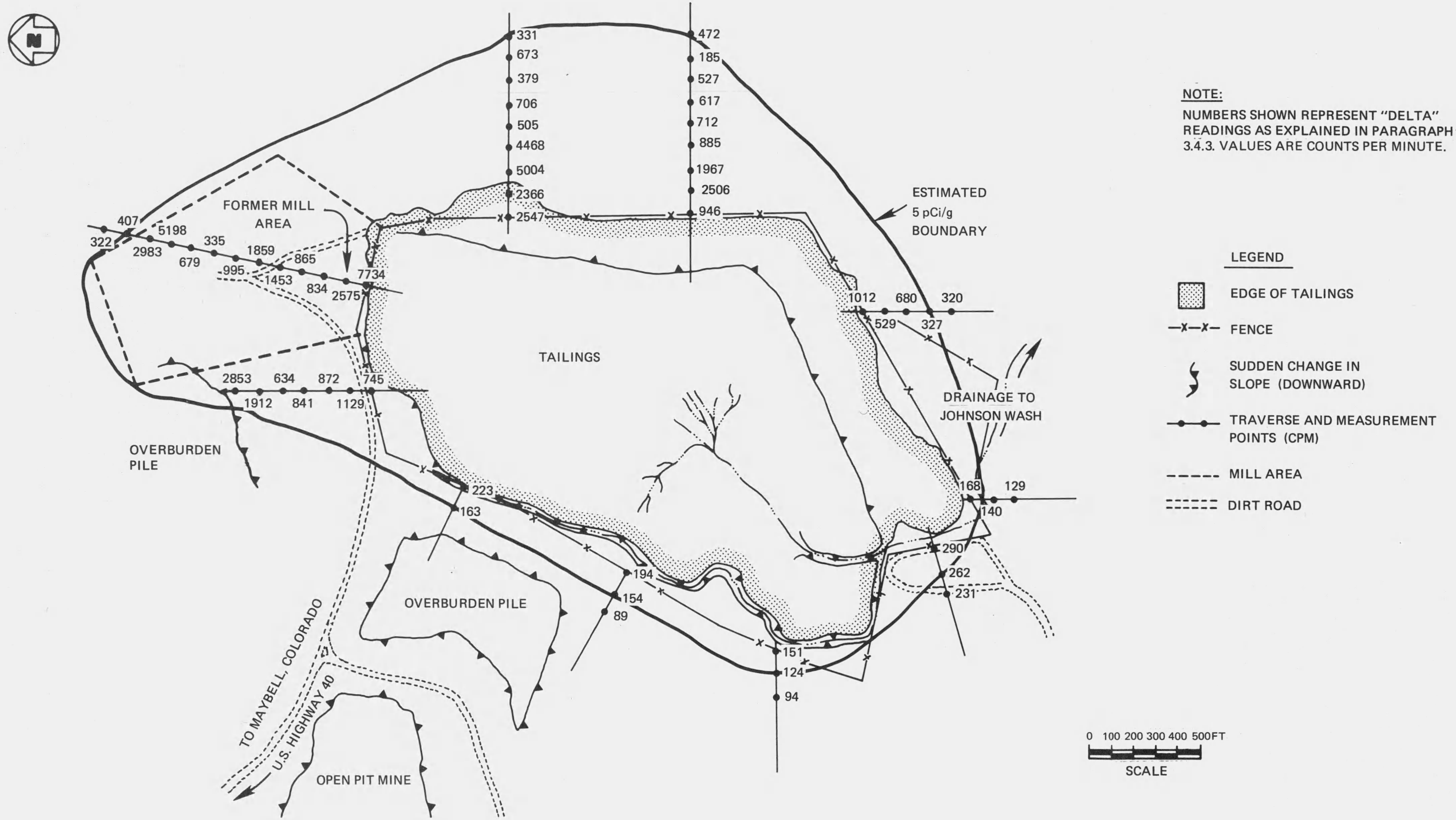

FIGURE 3-13. WINDBLOWN CONTAMINATION SURVEY

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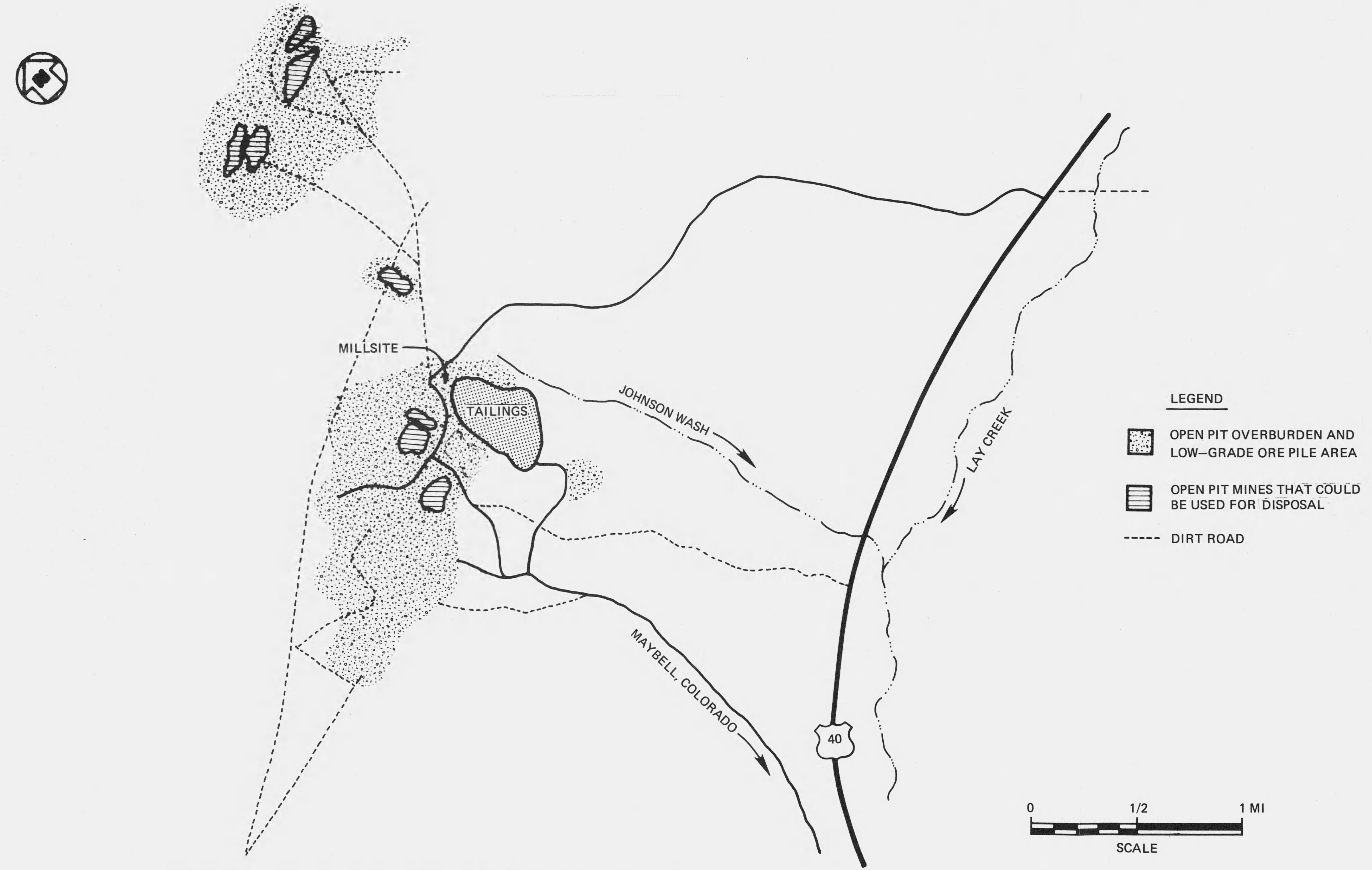

FIGURE 8-1. OPEN PIT MINES THAT COULD BE USED AS DISPOSAL SITES

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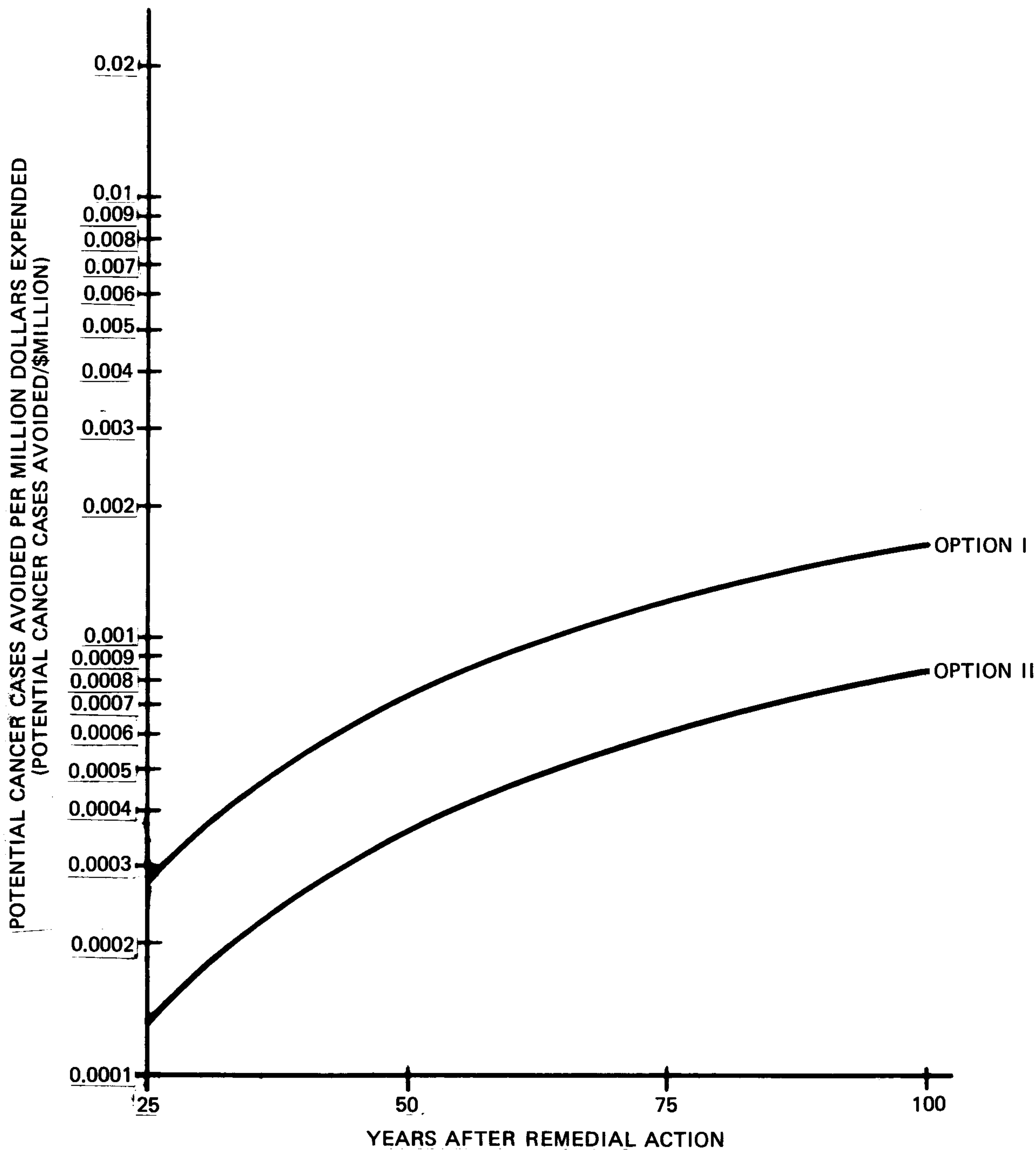

FIGURE 9-2. POTENTIAL CANCER CASES AVOIDED PER MILLION DOLLARS EXPENDED

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LIST OF TABLES

TABLE 2-1

CONTAMINATED MATERIALS AT MAYBELL SITE

Material	Volume (yd^3)	Weight[a] (tons)
Uranium Tailings	1,900,000	2,600,000
Stabilization Cover	70,000	100,000
Contaminated Subsoil Beneath Tailings	580,000[b]	783,000[e]
Contaminated Soil in Mill Area	65,000[c]	88,000[e]
Windblown Contaminated Soil	40,000[d]	54,000[e]
TOTAL	2,655,000	3,625,000

[a] Weight based on average existing field densities, which include moisture, except in the case of tailings.

[b] Volume based on 90 acres contaminated to an average depth of 4 ft beneath tailings interface.

[c] Volume based on 20 acres contaminated to an average depth of 2 ft.

[d] Volume based on 50 acres contaminated to an average depth of 6 in.

[e] Weight based on 100 lb/ft^3 density.

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TABLE 9-1

SUMMARY OF STABILIZATION AND DISPOSAL COSTS[a]

		Options	
		I	II
1.	Tailings Site Costs	6.2	5.2
2.	Off-Site Other than Windblown	0.1	0.1
3.	Off-Site Windblown	0.7	0.7
4.	Transportation		
	a. Capital Costs	--	1.7
	b. Haul Costs	--	4.1
5.	Disposal Site	--	3.0
6.	Total Cleanup[b] (sum of lines 1 through 5)	6.9	14.8
7.	Engineering Design and Construction Management (30% of the difference between lines 6 and 4b)	2.1	2.7
8.	Total[b] (sum of lines 6 and 7)	9.0	17.5
9.	Contingency (30% of line 8)	2.7	5.2
10.	GRAND TOTAL[b] (sum of lines 8 and 9)	11.7	22.7

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

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

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TABLE 9-2

POTENTIAL CANCER CASES AVOIDED
AND COST PER POTENTIAL CASE AVOIDED

A. Number of Potential Cancer Cases Avoided

Options:	I	II
Option Cost (million $)	11.7	22.7
Years After Remedial Action		
25	<0.0033	0.0033
50	<0.0083	0.0083
75	<0.013	0.013
100	<0.019	0.019

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

Options:	I	II
Option Cost (million $)	11.7	22.7
Years After Remedial Action		
25	>3,500	6,900
50	>1,400	2,700
75	> 900	1,700
100	> 600	1,200

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