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A SUMMARY OF THE ENGINEERING ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS

BELFIELD SITE
BELFIELD, NORTH DAKOTA

NOVEMBER 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

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New Project

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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, Belfield Site, Belfield, North Dakota." 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 present important engineering and environmental information gathered from many federal, state, and local sources. This information is essential to assess the impacts associated with the options suggested for remedial actions for the contaminated residues from the former ashing operations at the Belfield site. Although the reports may at times refer to uranium mill tailings, the information is also relevant to the contaminated materials on the Belfield site.

Ford, Bacon & Davis Utah Inc. has received excellent cooperation and assistance in obtaining the data necessary to prepare these reports. Special recognition is due Richard H. Campbell and Mark Matthews of DOE, as well as personnel of the Burlington Northern Railroad Company, the present owner of the Belfield site, and of the L.P. Anderson Construction Company.

ABSTRACT

Ford, Bacon & Davis Utah Inc. has evaluated the Belfield site in order to assess the problems resulting from the existence of radioactive ash at Belfield, South Dakota. This engineering assessment has included drilling of boreholes and radiometric measurements sufficient to determine areas and volumes of ash 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 55,600 tons of ash and contaminated material at the Belfield site constitutes a significant environmental impact, although external gamma radiation also is a factor. The four alternative actions presented in this engineering assessment range from millsite and off-site decontamination with the addition of 3 m of stabilization cover material (Option I), to removal of the ash and contaminated materials to remote disposal sites, and decontamination of the Belfield site (Options II through IV). Cost estimates for the four options range from about $1,500,000 for stabilization in-place, to about $2,500,000 for disposal at a distance of about 17 mi from the Belfield site.

Reprocessing the ash for uranium recovery is not feasible because of the extremely small amount of material available at the site and becvause of its low U_3O_8 content.

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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, and two sites in North Dakota (Belfield and Bowman), and deleted Ray Point, Texas, for a total of 24 sites. 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 24 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 Belfield site:

(a) Exhalation of radon gas from the ash

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

(c) Land contamination from windblown ash

(d) Hydrology and contamination by water pathways

(e) Potential health impact

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

Investigation of these and other factors has led to the evaluation of remedial action alternatives which are generally categorized as follows:

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

(b) Option II - Disposal at site 3, uranium pit about 8 mi from the Belfield site

(c) Option III - Disposal at site 7, scoria pit about 4.8 mi from the Belfield site

(d) Option IV - Disposal at site 8, uranium pit about 17 mi from the Belfield 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

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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.

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 that 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.

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 field work by FB&DU in support of this report was performed during the week of June 16, 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.

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 Belfield site.

1.2 SITE DESCRIPTION

1.2.1 Location and Topography

The Belfield site is located in southwestern North Dakota about 19 mi west of Dickinson, North Dakota, and 5 mi east of the Billings County-Stark County border. The site is located on a nearly level piece of land immediately south of the North Branch of the Heart River. While elevations within a few hundred feet of the site vary from just less than 2,550 to 2,570 ft above sea level, the site is at about 2,565 ft above sea level. The Heart River, an intermittent stream, flows generally west to east in a channel 10 to 15 ft below the general elevation of the site. The surrounding hills reach elevations of up to 2,700 ft. The original topography of the site may have been altered slightly by the addition of up to 2 to 3 ft of scoria as roadbed material.

1.2.2 Ownership and History of Milling Operations and Processing

The present owner of the Belfield site is the Burlington Northern Railroad Company, which was formed by merger with Northern Pacific Railroad in 1970. The site has been owned by Burlington Northern or its predecessor since 1888 when the land was obtained as a land grant to Northern Pacific by the U.S. Government. The site was leased to Union Carbide Corporation, which constructed and operated the ashing plant from 1964 to 1966. In August 1968, Dakota Industries leased the site and purchased the structures to be used in the calcination of clay for use as cat litter. In December 1971, the L.P. Anderson Construction Company of Miles City, Montana, purchased the structures on the site and executed a lease for the use of a portion of the property.

The Union Carbide plant in Belfield started ashing operations in July 1964. Lignite, which contained as much as 0.35% U_3O_8, was trucked to the site from several mines in the surrounding area. The wet lignite was burned in an 8-ft-dia by 125-ft-long rotary kiln rated at 100 tons/day capacity. Normal production rate was approximately 60 tons/day. The only process used involved the combustion of the organic material. No chemical, metallurgical, or nuclear processes were involved. The ash handling system was enclosed completely to control dust emissions. Dust was separated from the kiln off-gas stream by a cyclone and scrubber system and released to the atmosphere from a stack. The ash from the kiln was air-cooled in a rotary cooler and loaded into railroad cars which then were covered for shipment to Union Carbide's uranium ore processing plant in Rifle, Colorado.

Union Carbide suspended ashing operations at Belfield in October 1966. Before the plant was sold in 1968, the plant equipment, building, and yard were cleaned and decontaminated by Union Carbide, where necessary, to meet then-current AEC requirements.

1.2.3 Present Condition of the Site

Figure 2-3* is a descriptive map of the site as it now exists. The L.P. Anderson Construction Company has a maintenance shop and storage area at the site, with its main building about 100 ft east of the concrete remains of the original kiln. The area east of the L.P. Anderson Building is used by the construction company for equipment storage. Several old storage tanks, other equipment, and some new pipe are stored there, none of which appear to be contaminated. Also located on or adjacent to the site are a water well and the LP gas storage area of the Cenex Company, an agricultural cooperative.

The site has barbed-wire fencing on the north and east sides, but none on the south or west sides. There are no radiation warning signs posted at the site. Access is generally unrestricted.

1.2.4 Contamination and Soil Characteristics

No mill tailings pond or pile is present at the site because the ash from the kiln was collected and shipped to Rifle, Colorado, for further processing. However, radiation measurements showed that most of the surrounding soil at the site is contaminated to depths of 6 to 12 in. The soil just east of the L.P. Anderson Building is contaminated to depths of 4 ft. The estimated amount of contaminated material, including material from cleanup of off-site areas, is 71,500 tons, as shown in Table 2-1.

1.2.5 Geology, Hydrology, and Meteorology

The soils present on the site are classified as Savage silty clay loams. The surface soil and the subsoil are generally from 2 to 3 ft thick. Well logs in the area indicate that clays and silty clays are generally continuous to about a 6-ft depth on these terraces.

The site is located on alluvial deposits of the Heart River which are largely silt and clay with a few beds of sand and gravel. The depth of the alluvial deposits in the site area is difficult to determine since the underlying bedrock is poorly consolidated. It is definitely not more than 50 ft, where a lignite bed is located, and may be less than 20 ft. In many

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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.

localities scoria beds are present. These are reddish masses of baked and fused clay, shale, and sandstone, which have been formed where seams of lignite have burned.

The site is located on the south side of the north branch of the Heart River. In the vicinity of the site, the river is an intermittent stream since it drains only a small area. During summer months there may be areas of stagnant water in the streambed.

The Heart River in the vicinity of the site flows in a channel which is from 10 to 15 ft deep. The railroad bed south of the site protects the site from surface flows from the south. Therefore, surface flows arise only from rainfall directly on the site. Precipitation on the site drains either to the Heart River or to ponds on the site.

As shown in Figure 2-6, there are at least 16 wells within 1 mi of the site, including four Belfield municipal supply wells in Section 5, and at least 35 wells within 2 mi. At least four of these wells, all in Section 4, are not in use. They appear to be test wells drilled by the city and are from 44 to 81 ft deep. One of these, shown in Figure 2-6, is the well directly north and downgradient of the site. The two wells just east and the one south of the site are the other unused city wells. There are undoubtedly more wells than these in the area which are not registered with the State. Most of these are west of the site and not downgradient of the site. Therefore, water in the aquifers would not move from the site toward these wells, unless high pumping in the area should cause a cone of depression affecting the general hydrology of the site.

Wells to the north or downgradient of the site can be affected by water flowing under the site. Any wells downstream and along the Heart River can be recharged by water flowing past the site, since the Heart River is an influent stream in this area.

At Dickinson, the nearest weather reporting station, the mean annual precipitation is 15.9 in. Prevailing winds are from the west. Wind speeds measured at the Dickinson Municipal Airport are usually moderate, with 70% of the observations less than 16 mi/hr, and about 95% less than 22 mi/hr. Wind information for the area is presented in Table 2-2.

1.3 RADIOACTIVITY AND POLLUTANT IMPACTS ON THE ENVIRONMENT

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 residues. Although these radionuclides occur in nature, their concentrations in uranium ore and lignite ash are several orders of magnitude greater than their average concentrations in the earth's crust.

1.3.1 Radiation Exposure Pathways, Contamination Mechanisms, and Background Levels

The major potential environmental routes of exposure to man are:

(a) Inhalation of ^{222}Rn and its daughter products, resulting from the continuous radioactive decay of ^{226}Ra in the ash. Radon is a gas that diffuses from the site. 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 at the site.

(c) Inhalation and ingestion of windblown ash. 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

No measurements of atmospheric radon concentrations in the Belfield area were made since calibrated instrumentation was not available at the time of the field work. The background radon concentration was estimated to be 1 pCi/l.

Measurements of the radon exhalation flux from the tailings using the charcoal canister technique[3] ranged from less than 1 to about 63 pCi/m^2-s on and adjacent to the ash site. The area-weighted average radon flux was estimated to be about 20 pCi/m^2-s. Radon flux depends principally on radium content of tailings or ash; however, it also varies considerably because of moisture, soil characteristics, and climatological conditions.

1.3.1.2 Direct Gamma Radiation

The external gamma radiation (EGR) levels measured on and adjacent to the site are shown in Figure 3-4. These measurements were made with a scintillation detector. The highest uncorrected EGR rate (800 μR/hr) was measured between grid points (about 650 ft east of the L.P. Anderson Building) in the area where there is no scoria cover. The lowest uncorrected EGR level on site was about 35 μR/hr. The uncorrected EGR levels along the boundary adjacent to the railroad were generally higher than in other areas of the site.

The background EGR levels in the vicinity of Belfield range between 8 and 15 μR/hr, with an average of about 10 μR/hr.

1.3.1.3 Windblown Contaminants

The estimated 5-pCi/g contour around the site is indicated in Figure 3-5. The maximum extent of windblown contamination is about 400 ft north of the site boundary and about 100 ft north of the Cenex boundary, while the minimum extent is about 200 ft south of the site.

Measurements of ^{226}Ra concentrations in three soil samples from the vicinity ranged from 1.5 to 2.5 pCi/g, with an average of about 2.0 pCi/g.

1.3.1.4 Surface and Ground Water Contamination

Three surface water samples and two samples from wells were taken in the site vicinity and analyzed. The locations of these samples are shown in Figure 3-6.

These water samples showed the gross alpha content to be less than 2 pCi/l, while the ^{226}Ra content was less than 0.6 pCi/l. The ^{238}U concentration ranged from 0.03 to 0.08 pCi/l for the surface water samples and less than 0.01 pCi/l for the ground water samples. Arsenic concentrations did not exceed 0.041 ppm. In all cases, the concentrations of those elements measured did not exceed Interim Primary Drinking Water Regulations.(4)

1.3.1.5 Soil Contamination

Contamination of soil below the existing grade at the site was determined both by gamma logging of drill holes and by radiometric analysis of soil samples taken from drill holes. In most cases, radium activity was greatest in the first 2 ft below existing grade, and in no case was activity above background levels detected at depths greater than 4 ft.

1.3.2 Remedial Action Criteria

In the following paragraphs, where reference is made to tailings, the statement should be interpreted as being directly applicable to residual radioactive materials at the Belfield site.

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 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.

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 Belfield site and the subsequent inhalation of radon daughters account for most of the total dose to the population from the site under present conditions. The gamma radiation exposure from the site is very small since there are very few persons who live or work within 0.2 mi of the site, where gamma radiation is above background. However, external gamma radiation exposure on the site is comparable to that at other inactive uranium millsites.

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 ash, 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 ash. If the diffusion path 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 contaminated material 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 under present conditions the average lung cancer risk attributable to radon released from the ash residues in the vicinity within 2 mi of the Belfield site is less than 1.6×10^{-7} per person per year, or less than 0.1% of the average lung cancer risk due to all causes for North Dakota residents (2.3×10^{-4}).(9)

The 25-yr health effects were estimated on the basis of present site conditions for three population projections using the present population of 1,650 in the 0- to 2-mi area, and are presented below. These calculations assume that no habitable structures will be built on the radioactive residues shown in Figure 3-5.

25-Year Cumulative Health Effects Within 2 Miles of Edge of Site

Projected Population Growth	Site-Induced RDC	Background RDC
0.6% constant growth rate	0.006	1.6
2.3% declining growth rate*	0.008	1.8
4% declining growth rate*	0.008	2.1

The site-induced radon daughter health effects are less than 1% of the background radon daughter health effects for the 0- to 2-mi area, based on the estimated background radon concentration of 1 pCi/l. This exposure and consequent risk will continue as long as the radiation source remains in its present location and condition.

1.3.4 Nonradioactive Pollutants

Soil and water samples taken in the vicinity of the Belfield site indicate unusually high concentrations of arsenic. The data are insufficient to implicate or dismiss the ashing site as the source of this contamination.

1.4 SOCIOECONOMIC AND LAND USE IMPACTS

The land in the area near the Belfield site is used primarily for agricultural purposes, although being located adjacent to a railroad, there is potential for commercial or light industrial applications.

The presence of the contaminants on site does not appear to have any significant influence on property values or land usage. The current market value of the Belfield site is estimated at the rate of $10,000/acre, whereas the adjacent agricultural land has an estimated market value of $150 to $400/acre.

1.5 RECOVERY OF RESIDUAL VALUES

There is no appreciable mineral value in the contamination at the Belfield site. Therefore, no consideration was given to the possibility of reprocessing residual ash.

1.6 MILL TAILINGS STABILIZATION

Although little ash remains at the Belfield site, contamination from the cleanup of off- and on-site areas must be disposed of properly. Since remedial action for this contaminated material must satisfy the same requirements as uranium mill tailings, the following discussion of stabilization methods for uranium mill tailings is presented.

---

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

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

Since the ash from the process was the valued and only product from the Belfield ashing operation, it was assumed that there has been no intentional removal of contaminated material for use in off-site applications. The responsibility to search for such possible off-site locations was beyond the scope of this assessment.

The extent of windblown contamination was assessed and is shown in Figure 3-5. About 21 acres of land adjacent to the Belfield site are estimated to require cleanup in order to meet current requirements.

1.8 DISPOSAL SITE SELECTION

In this report, three of the alternative remedial action options include moving the contaminated material at the Belfield site to a disposal site. The corresponding three potential disposal sites were selected after consultation with local agencies, concerned individuals, and industry personnel. Each 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 sites evaluated in this work must be considered only as tentative.

The locations of sites listed in Table 1-2 as Options II through IV are shown in Figure 8-1. In each of these options, 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 a 3-m depth of soil. The surface would 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 residual radioactive material at the Belfield site in its present location, and removal of all radioactive materials to an area where these materials could be isolated from the public.

The four remedial action options for which cost estimates were made include stabilization on the present site with 3 m of cover material and the removal of contaminated material to one of three possible locations. 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 ash more completely in its present location with the addition of 3 m of cover. Erosion would be controlled more completely and radon exhalation would be reduced to less than 2 pCi/m^2-s above background. The site would have limited future use.

Options II through IV would require moving the contaminated material to specific disposal sites, as described in Chapter 8.

The relative total cost differences between these options are small and reflect variances in the haul distance, the haul route, and site preparation. The site that offers the most direct and easiest access is located 4.8 road miles east of the Belfield site. The scoria pits, only one of which is presently active, are located at this site. An inactive uranium pit located about 17 mi southwest of the Belfield site is considered attractive because of its remoteness from significant development and the easy access for transportation during disposal activities.

1.9.2 Cost-Benefit Analyses

As summarized in Table 9-1, the total costs for the four remedial action options vary from about $1,500,000 to about $2,500,000. 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 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	1,500	Existing structures not in use would be demolished and the debris buried on site; structures in use would be decontaminated as necessary; the contaminated material would be placed in a pit excavated on site and stabilized with 3 m of local earth cover. Natural vegetation would be established or a riprap cover provided. Off-site contaminated soil would be cleaned up.	A,B,C,F	X,Y,Z
II	2,200	The ash, contaminated soil, and rubble would be removed by truck to site 3, uranium pit located about 8 mi north of the Belfield site. The Belfield site would be decontaminated as in Option I and released for unlimited use.	A-F	--
III	2,200	Same as Option II, except contaminated material removed to site 7, scoria pit located about 4.8 mi east of the Belfield site.	A-F	--
IV	2,500	Same as Option II, except contaminated material removed to site 8, uranium pit located about 7 mi south of the Belfield site.	A-F	--

TABLE 1-2 (Cont)

Notes

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

2. For Options II through IV, costs include removal of up to 5 ft of contaminated earth at the ashing site.

Definition of Benefits

A. On-site windblown contamination cleaned up
B. Wind and water erosion controlled
C. Portions of the site not used for tailings available for other uses
D. The source of gamma radiation and radon gas removed from site
E. Total Belfield site available for unrestricted usage
F. Radon exhalation flux reduced to less than 2 pCi/m^2-s

Definition of Adverse Effects

X. Some security and maintenance required
Y. Tailings remain in the center of a growing area
Z. Restricted use of Belfield site

CHAPTER 1 REFERENCES

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

2. S.D. Shearer, Jr., and C.W. Sill; "Evaluation of Radon-222 Near Uranium Tailings Piles"; Department of Health, Education and Welfare, DER 69-1; Mar 1969.

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

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

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-218-1); 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

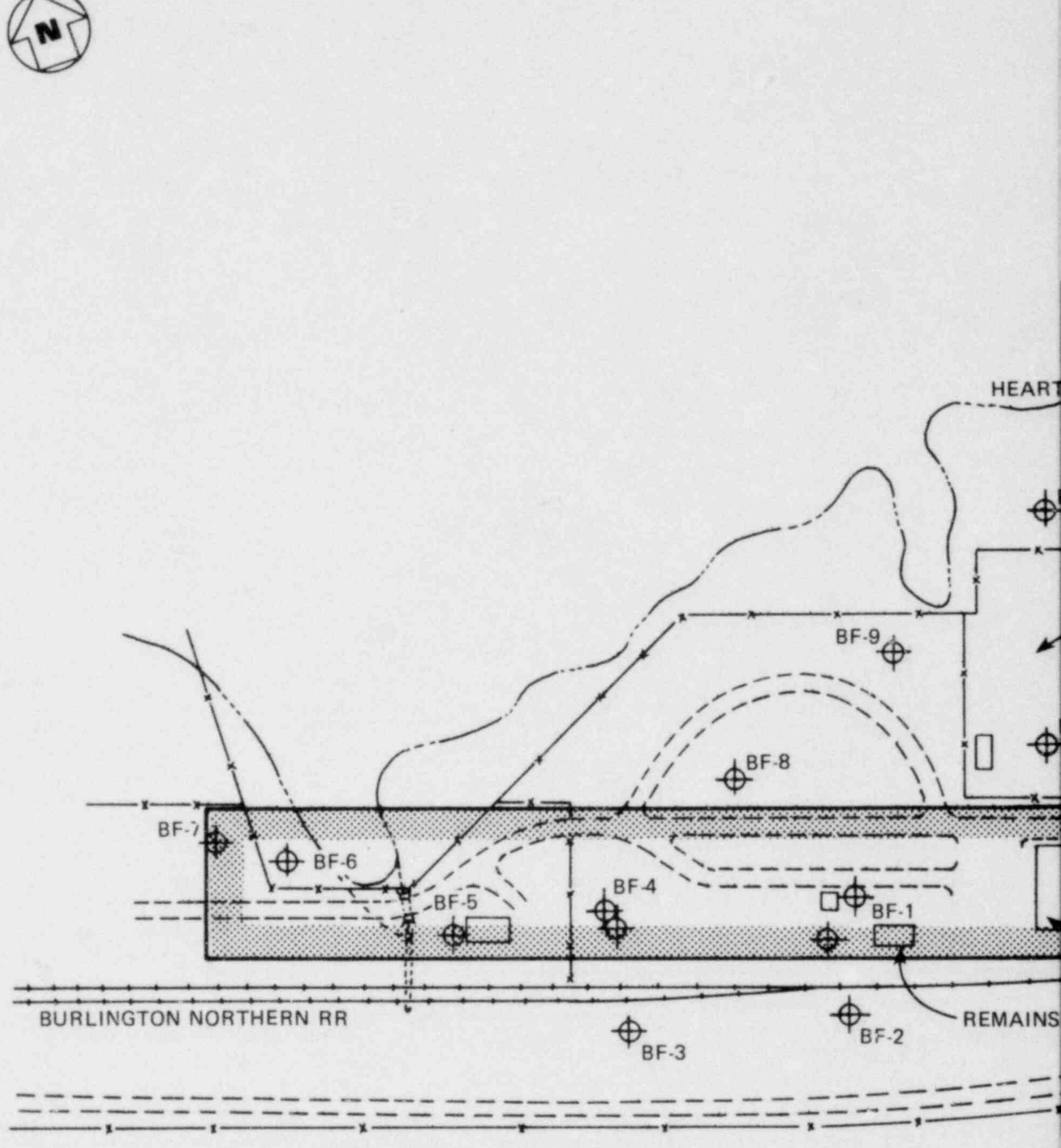
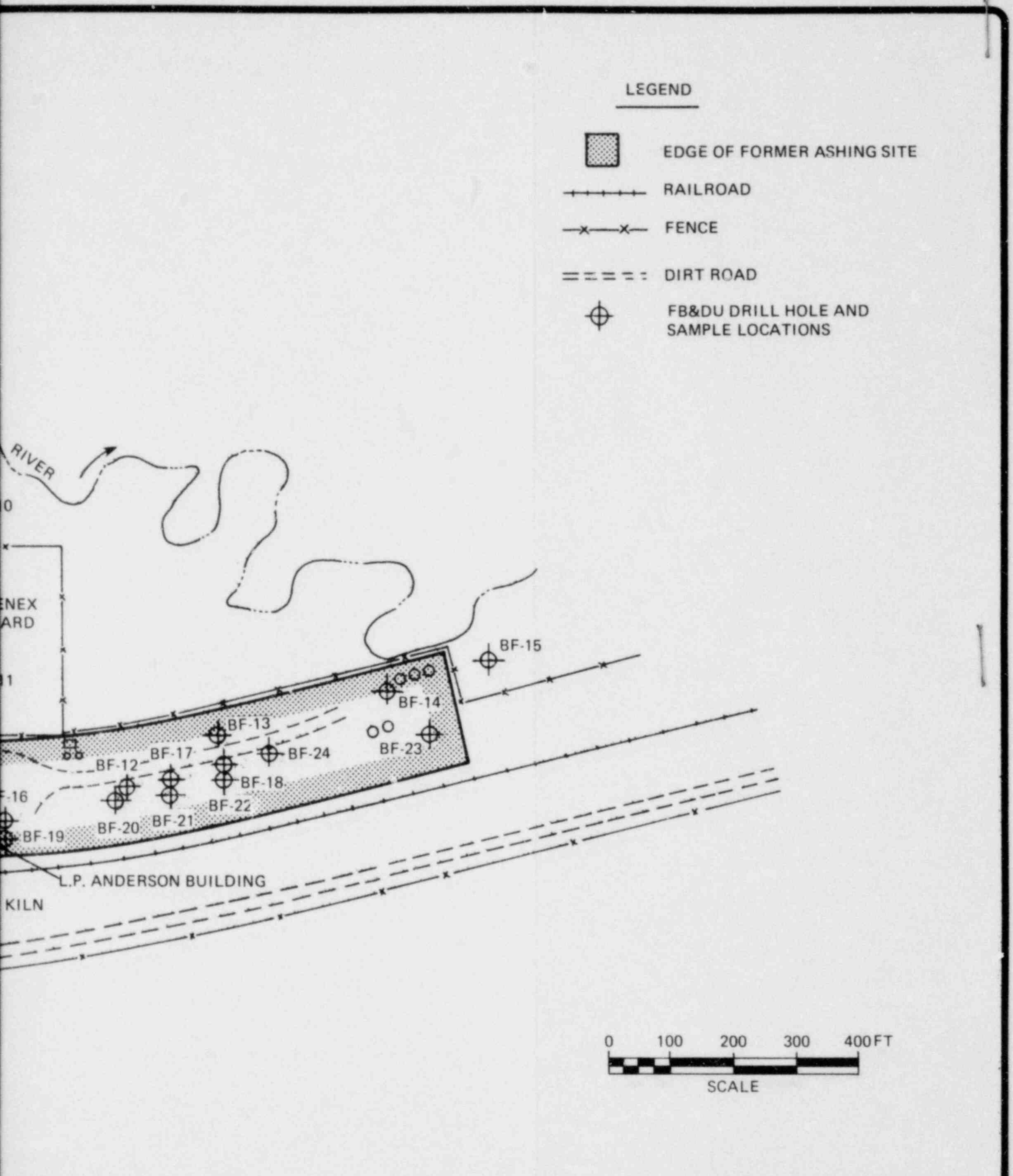


FIGURE 2-3. SITE DESCRIPTIVE MAP


LEGEND
EDGE OF FORMER ASHING SITE
RAILROAD
FENCE
DIRT ROAD
FB&DU DRILL HOLE AND SAMPLE LOCATIONS
RIVER
NEX
ARD
BF-12
BF-13
BF-14
BF-15
-16
BF-17
BF-18
BF-19
BF-20
BF-21
BF-22
BF-23
BF-24
L.P. ANDERSON BUILDING
KILN
0
100
200
300
400 FT
SCALE
360-21 10/81

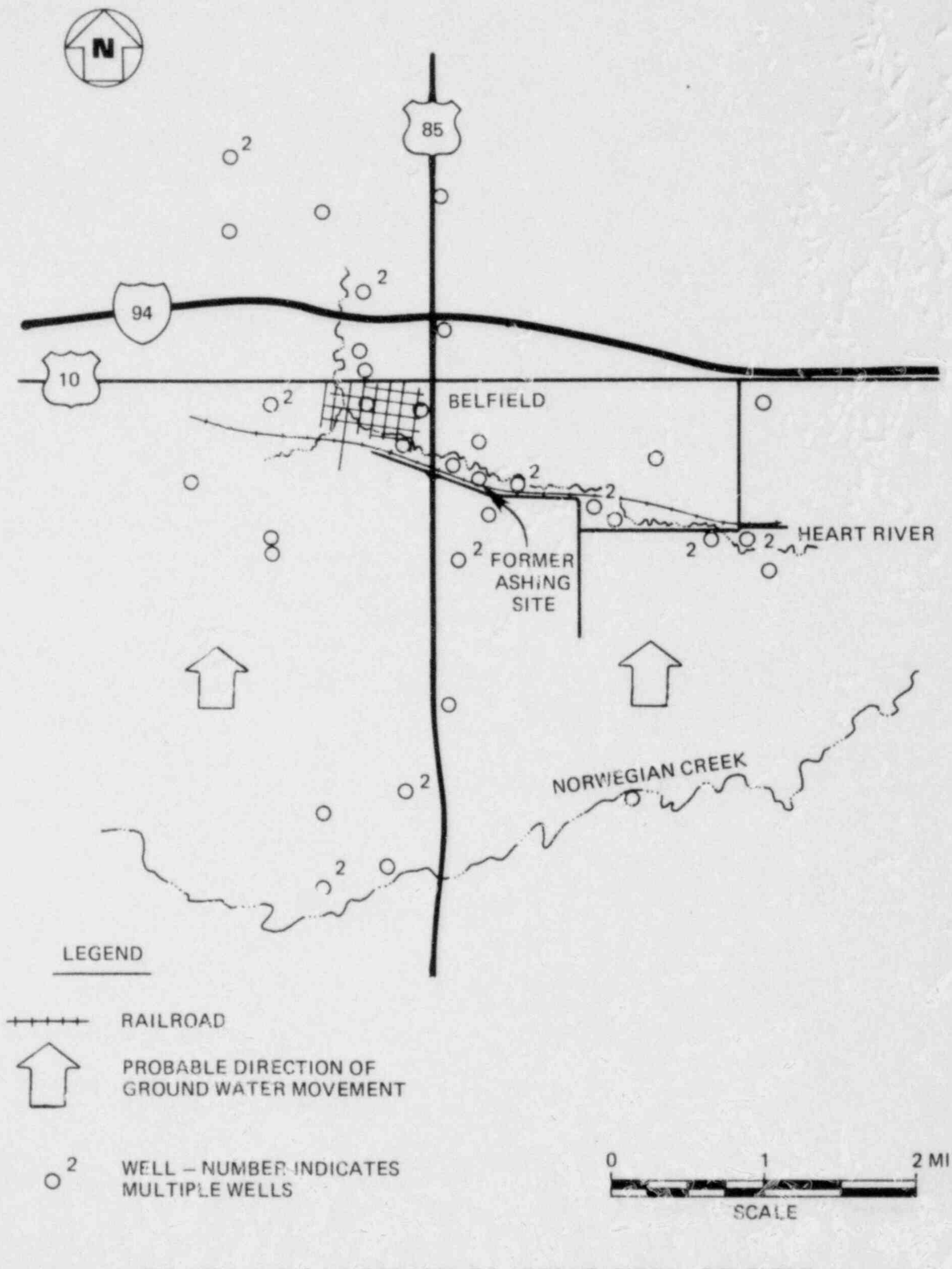


FIGURE 2-6. LOCATION OF WELLS NEAR BELFIELD

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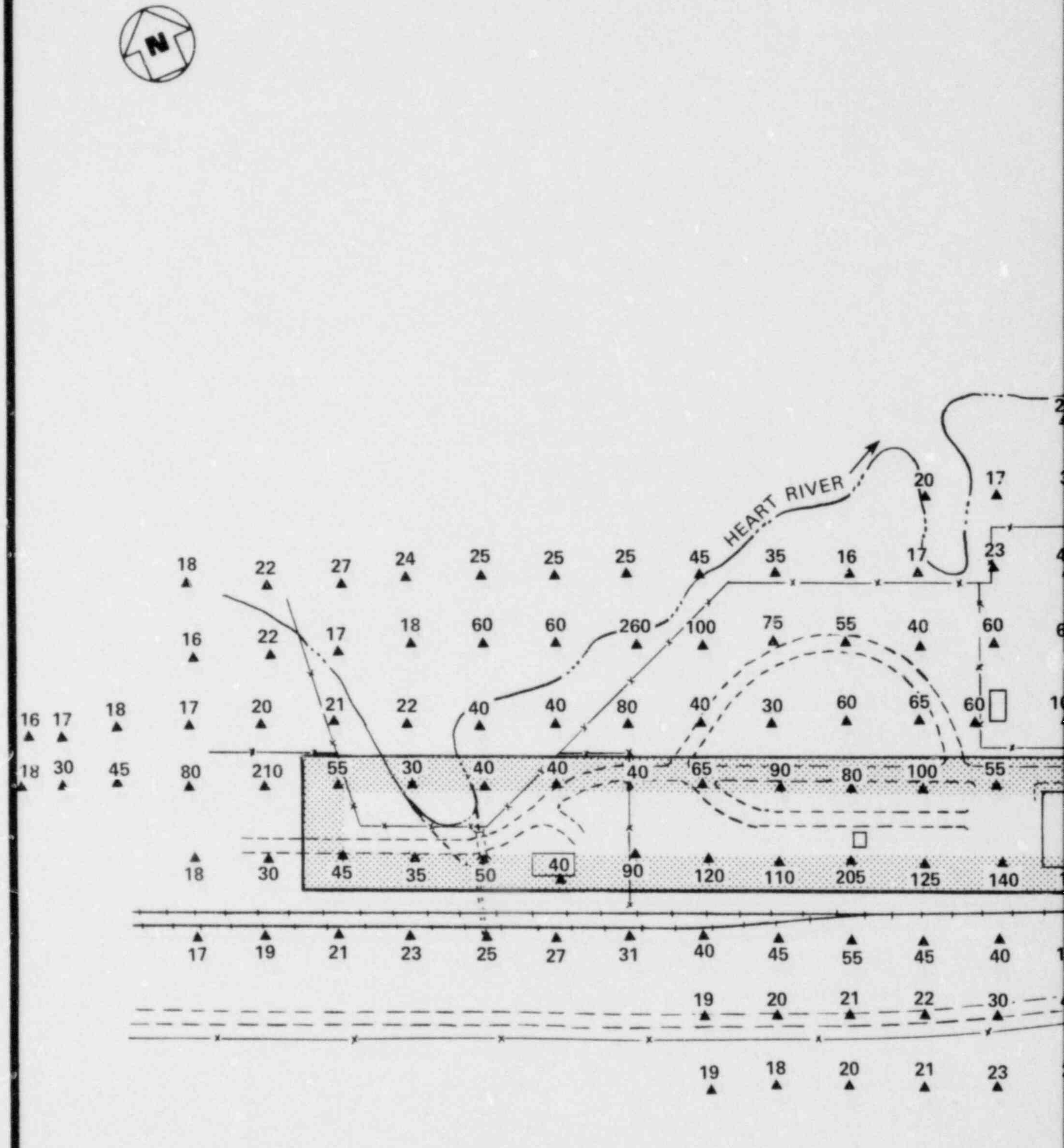
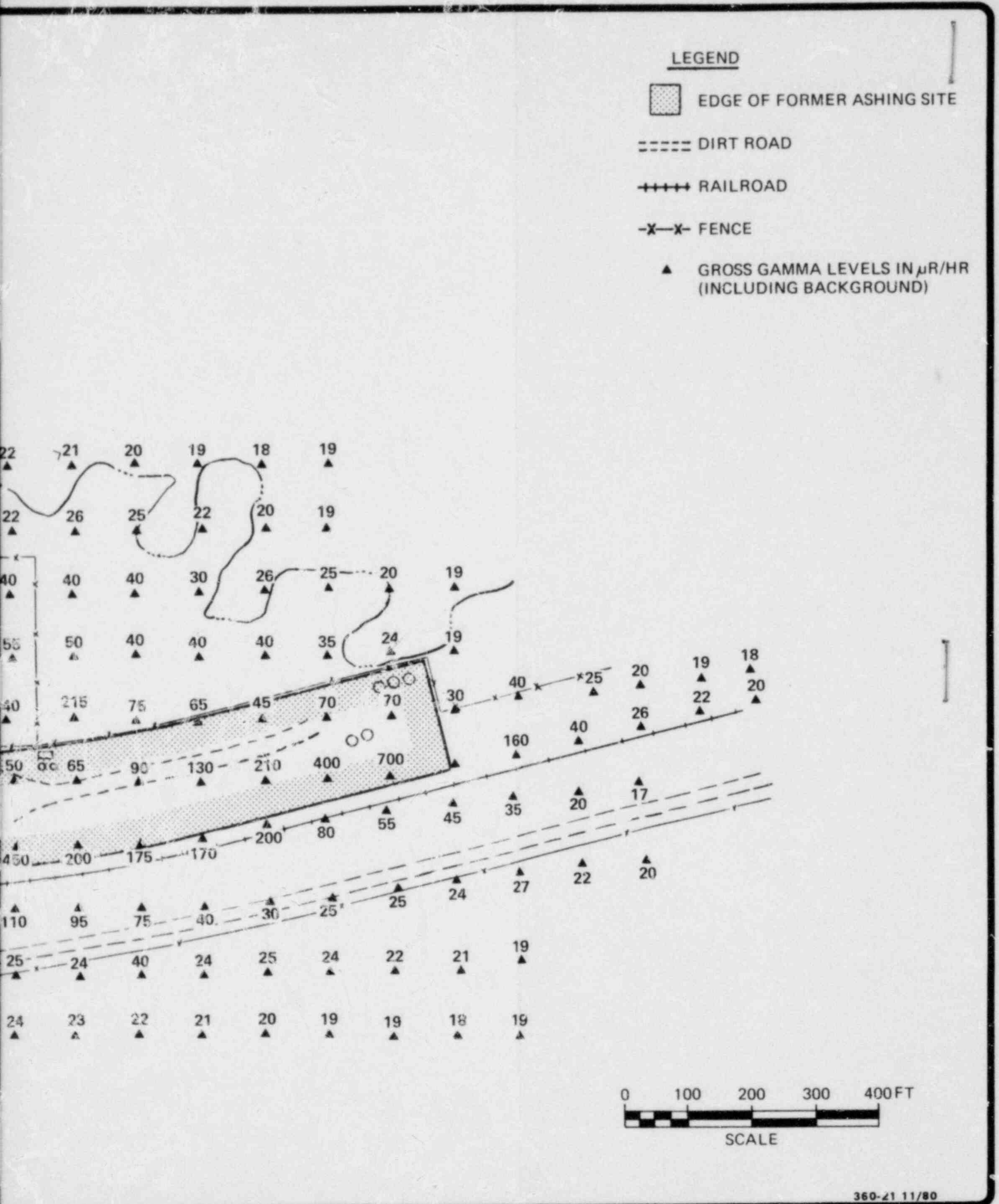


FIGURE 3-4. GAMMA LEVELS AT SITE 3 FT ABOVE GROUND


LEGEND
EDGE OF FORMER ASHING SITE
DIRT ROAD
RAILROAD
FENCE
GROSS GAMMA LEVELS IN μR/HR (INCLUDING BACKGROUND)
0 100 200 300 400 FT
SCALE
360-21 11/80

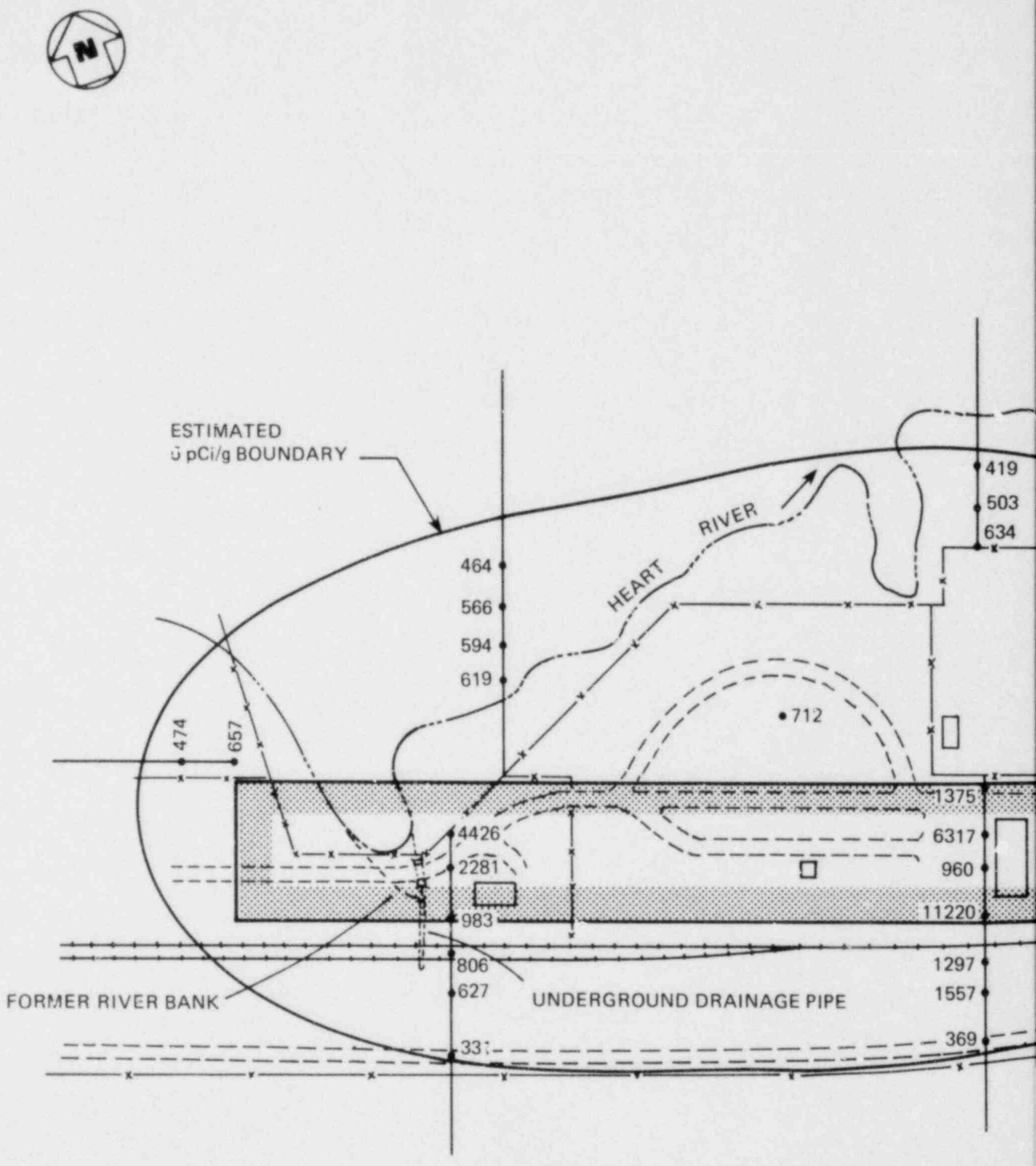
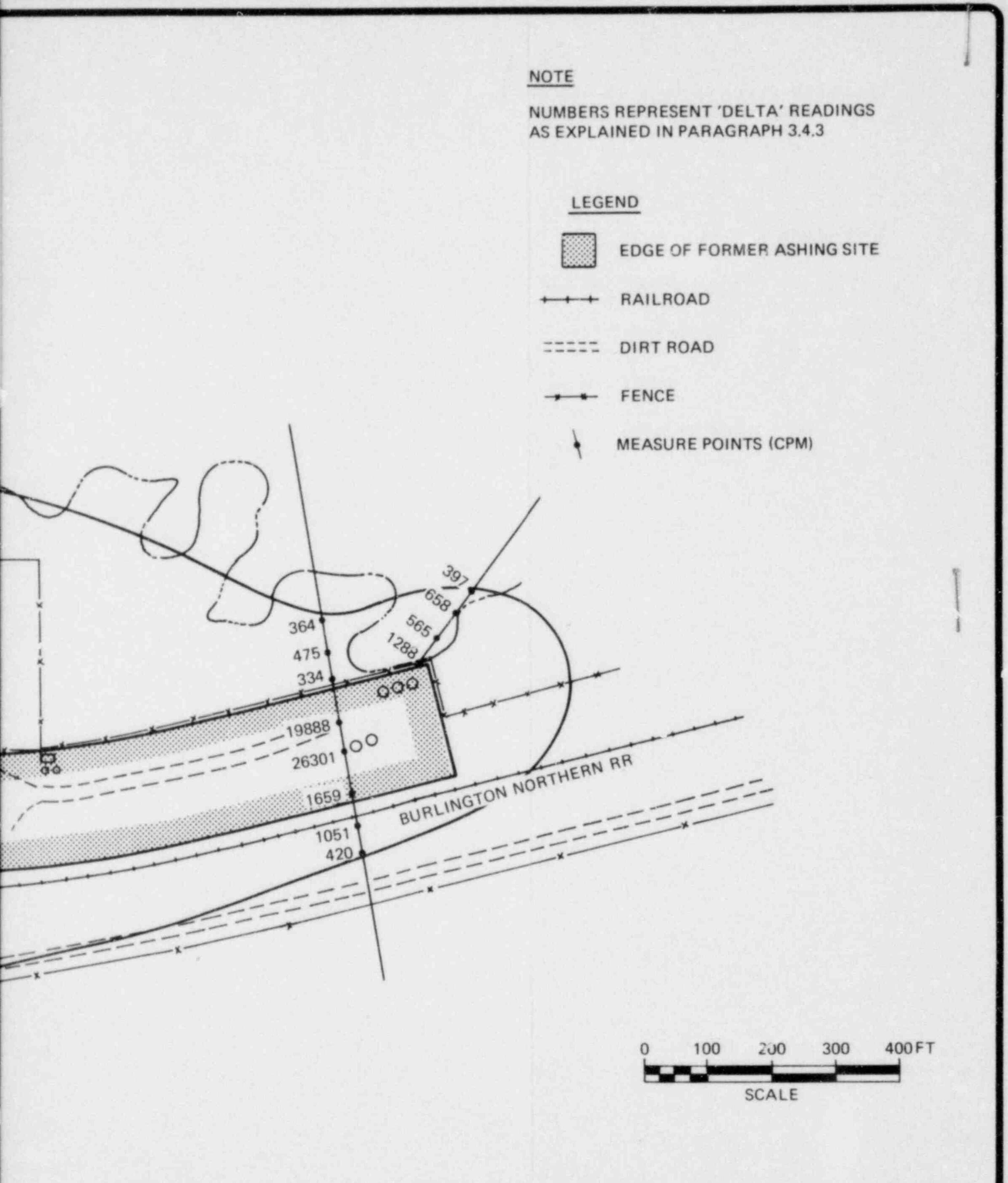


FIGURE 3-5. WINDBLOWN CONTAMINATION SURVEY


NOTE
NUMBERS REPRESENT 'DELTA' READINGS AS EXPLAINED IN PARAGRAPH 3.4.3
LEGEND
EDGE OF FORMER ASHING SITE
RAILROAD
DIRT ROAD
FENCE
MEASURE POINTS (CPM)
397
658
565
1288
364
475
334
19888
26301
1659
1051
420
BURLINGTON NORTHERN RR
0
100
200
300
400 FT
SCALE
360-21 11/80

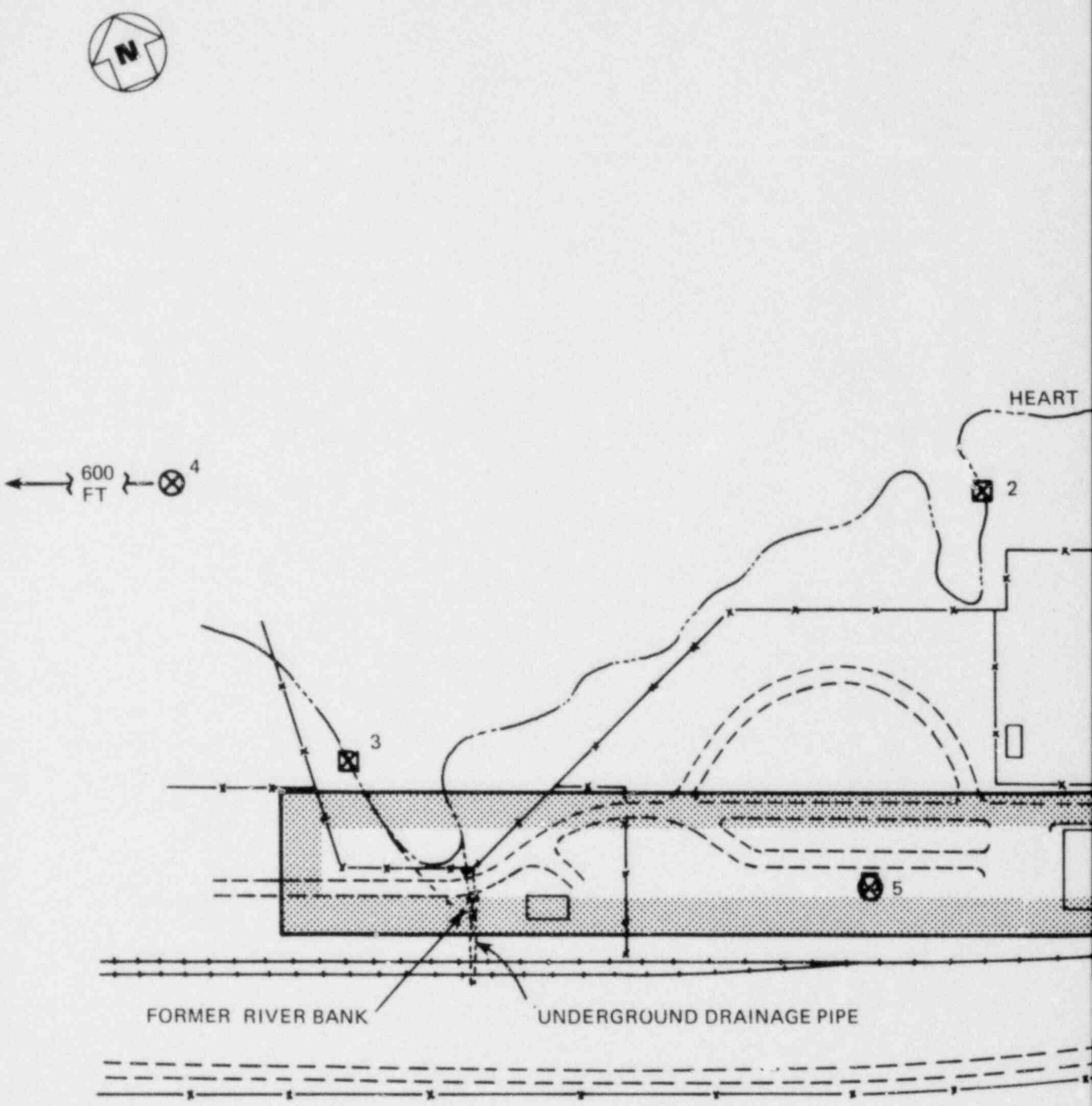
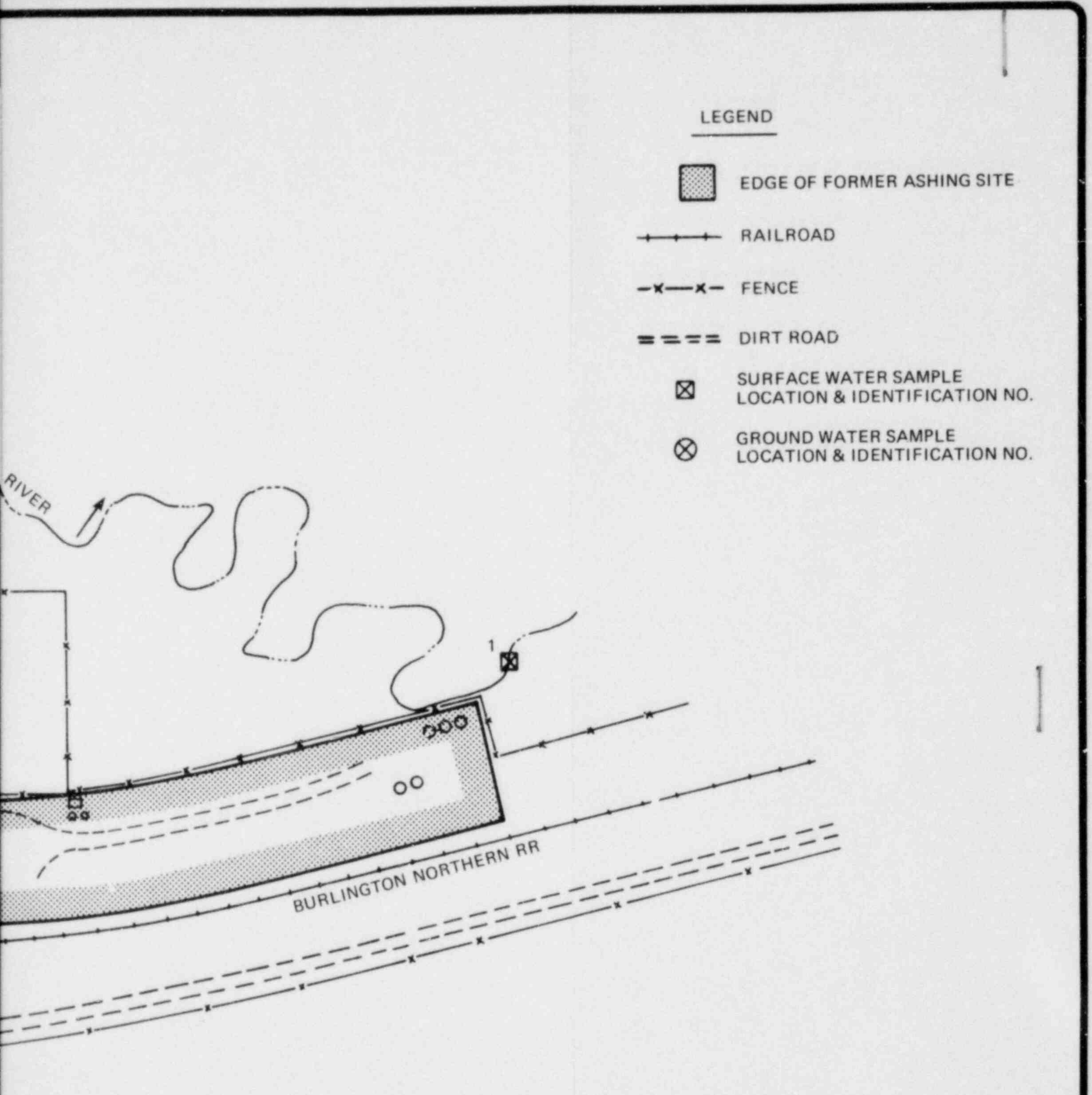
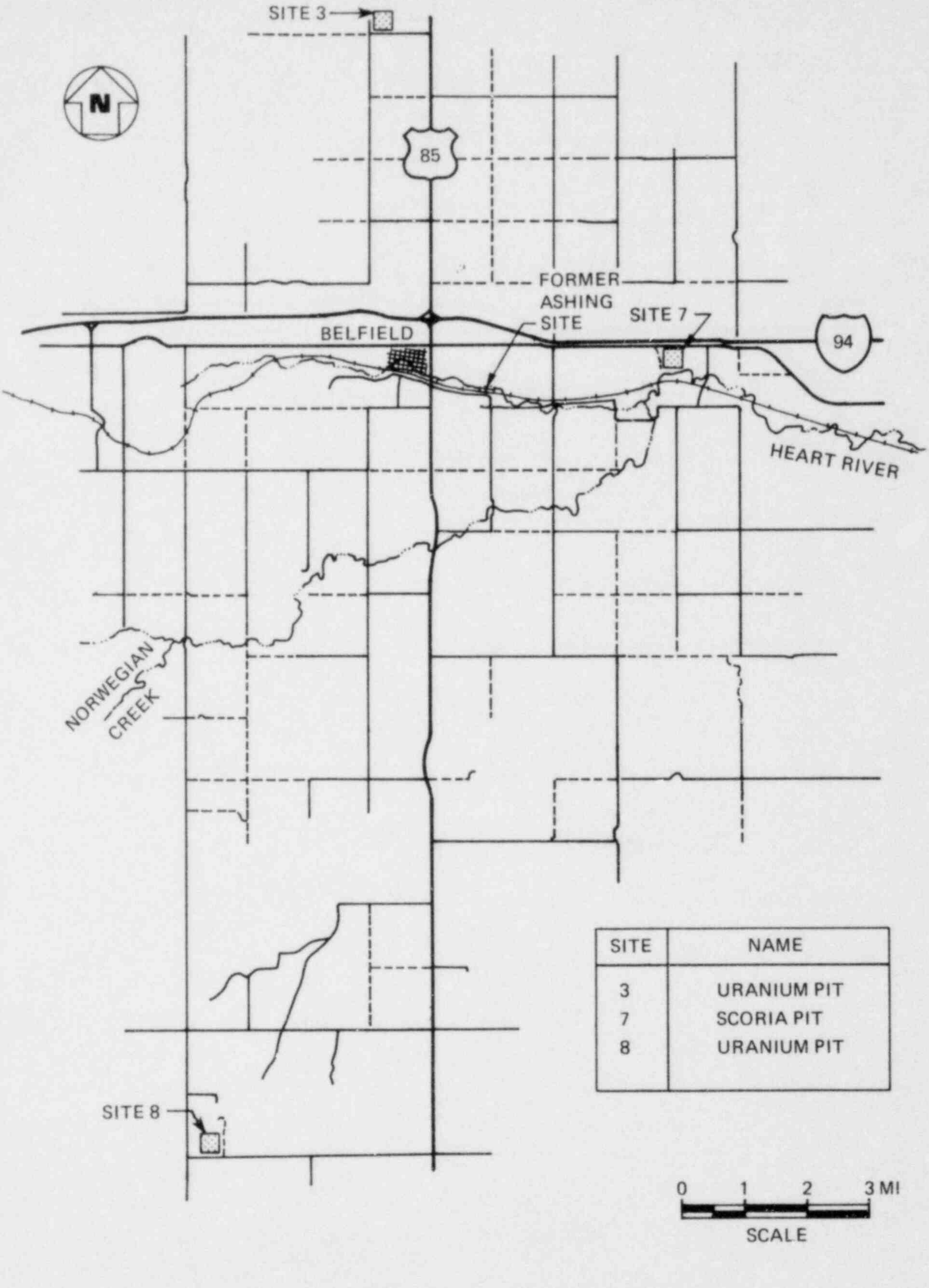


FIGURE 3-6. SURFACE AND GROUND WATER SAMPLE LOCATIONS


LEGEND
EDGE OF FORMER ASHING SITE
RAILROAD
FENCE
DIRT ROAD
SURFACE WATER SAMPLE LOCATION & IDENTIFICATION NO.
GROUND WATER SAMPLE LOCATION & IDENTIFICATION NO.
RIVER
1
BURLINGTON NORTHERN RR
0
100
200
300
400 FT
SCALE
360-21 11/80



SITE	NAME
3	URANIUM PIT
7	SCORIA PIT
8	URANIUM PIT

FIGURE 8-1. LOCATION OF PROPOSED DISPOSAL SITES

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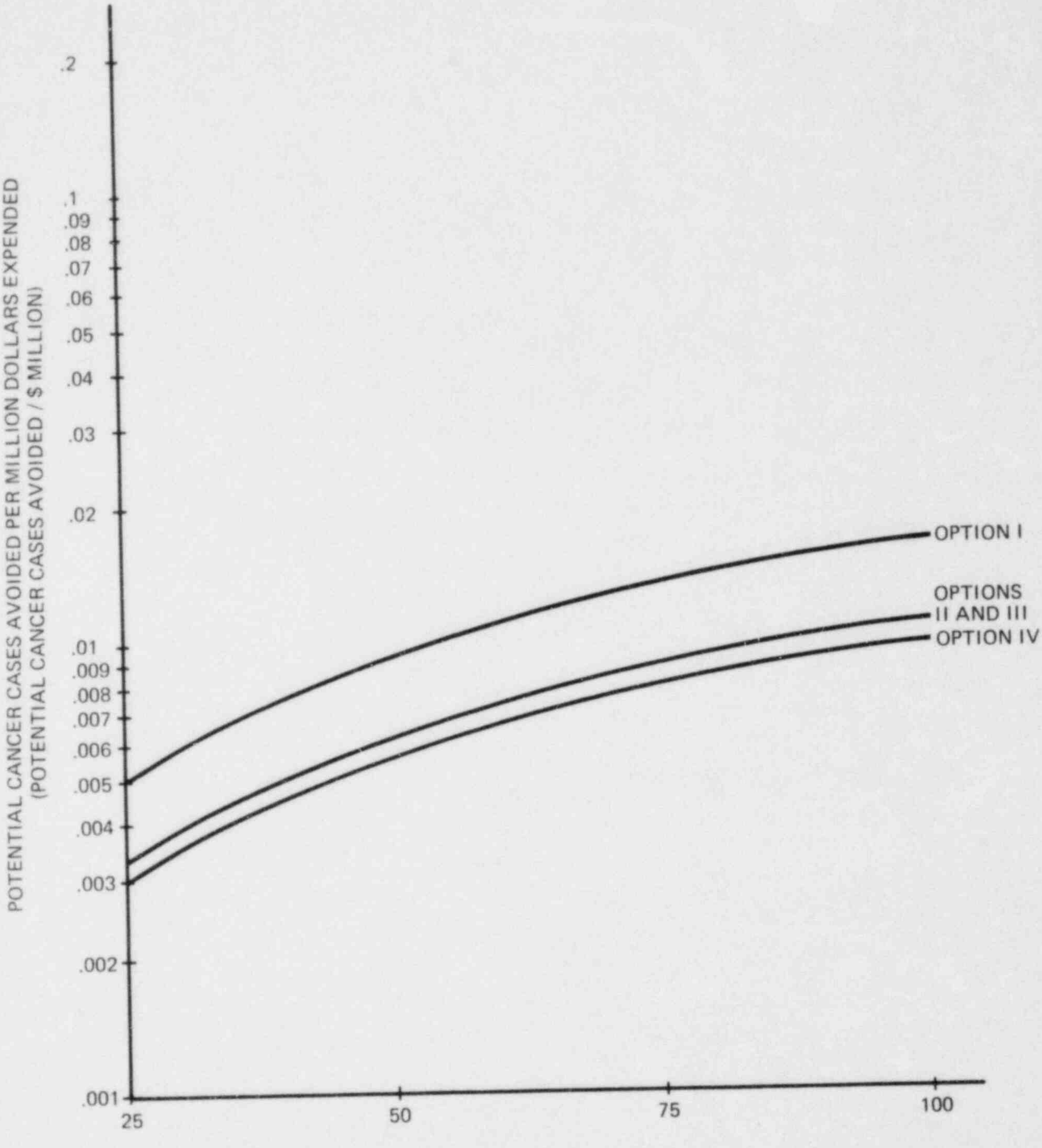

FIGURE 9-2. POTENTIAL CANCER CASES AVOIDED PER MILLION DOLLARS EXPENDED

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LIST OF TABLES

TABLE 2-1

ESTIMATED QUANTITIES OF CONTAMINATED MATERIALS

Material	Volume (yd^3)	Weight (tons)
Contaminated Soil, Gravel, Rubble, and Scoria within Site Boundaries[a]	39,600	50,000
Windblown Contaminated Soil[b]	17,000	21,500
Totals	56,600	71,500

[a]Based on an 8-acre site area and gamma logs of drill holes.

[b]Based on 21 acres contaminated to an average depth of 6 in.

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TABLE 2-2

FREQUENCY OF WIND DIRECTION AND SPEED
DICKINSON, N.D. MUNICIPAL AIRPORT (PERIOD: 1955-1967)[17]

	Wind Speed Range (mi/hr)					
Direction	0-5 (calm)	6-10	11-16	17-22	23	Total
N	--	1.37	1.19	0.53	0.06	3.15
NNE	--	0.96	0.98	0.52	0.06	2.52
NE	--	1.17	1.02	0.55	0.06	2.80
ENE	--	1.55	0.97	0.45	0.05	3.02
E	--	1.48	1.26	0.53	0.05	3.32
ESE	--	1.70	1.95	1.15	0.16	4.96
SE	--	1.61	2.57	2.01	0.42	6.61
SSE	--	1.98	3.05	2.42	0.54	7.99
S	--	3.40	3.19	1.42	0.17	8.18
SSW	--	1.59	1.36	0.52	0.04	3.51
SW	--	1.49	1.15	0.49	0.05	3.18
WSW	--	2.57	2.61	1.21	0.14	6.53
W	--	3.54	4.35	2.42	0.47	10.78
WNW	--	2.78	4.60	4.63	1.66	13.67
NW	--	1.52	2.42	3.05	1.25	8.24
NNW	--	1.31	1.70	1.33	0.27	4.61
Calm	6.92	--	--	--	--	6.92
Total	6.92	30.02	34.37	23.23	5.45	99.99

Average wind speed - 13 mi/hr

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TABLE 9-1

SUMMARY OF STABILIZATION AND DISPOSAL COSTS[a]

	Options			
	I	II	III	IV
1. Belfield Site Costs	0.6	0.4	0.4	0.4
2. Off-Site Remedial Action	--	--	--	--
3. Windblown Area Remedial Action	0.3	0.3	0.3	0.3
4. Transportation				
a. Capital Costs	--	0.1	0.1	0.2
b. Haul Costs	--	0.1	0.1	0.2
5. Disposal Site	--	0.4	0.4	0.4
6. Total Cleanup[b] (sum of lines 1 through 5)	0.9	1.4	1.3	1.5
7. Engineering, Design, and Construction Management (30% of the difference between lines 6 and 4b)	0.3	0.4	0.4	0.4
8. Total[b] (sum of lines 6 and 7)	1.2	1.7	1.7	1.9
9. Contingency (30% of line 8)	0.3	0.5	0.5	0.6
10. GRAND TOTAL[b] (sum of lines 8 and 9)	1.5	2.2	2.2	2.5

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

[b]Totals may differ from the sum of cost components 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	III	IV
Option Cost (million $)	1.5	2.2	2.2	2.5
Years After Remedial Action				
25	<0.0075	0.0075	0.0075	0.0075
50	<0.013	0.013	0.013	0.013
75	<0.019	0.019	0.019	0.019
100	<0.024	0.024	0.024	0.024

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

Options:	I	II	III	IV
Option Cost (million $)	1.5	2.2	2.2	2.5
Years After Remedial Action				
25	>200	290	290	330
50	>120	170	170	190
75	> 80	120	120	130
100	> 60	90	90	100

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