Public Health Assessment for

MONTICELLO MILL TAILINGS (DOE) AND
MONTICELLO RADIOACTIVELY CONTAMINATED PROPERTIES
(a/k/a MONTICELLO VICINITY PROPERTIES)
MONTICELLO, SAN JUAN COUNTY, UTAH
CERCLIS NOS. UT3890090035 AND UTD980667208
SEPTEMBER 30, 1997

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

PUBLIC HEALTH ASSESSMENT

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Prepared by:

Energy Section
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.

In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. The revised document was released for a 30-day public comment period. Subsequent to the public comment period, ATSDR addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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FOREWORD

The Agency for Toxic Substances and Disease Registry, ATSDR, is an agency of the U.S. Public Health Service. It was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the *Superfund* law. This law set up a fund to identify and clean up our country's hazardous waste sites. The Environmental Protection Agency, EPA, and the individual states regulate the investigation and cleanup of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. (The legal definition of a health assessment is included on the inside front cover.) If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from the states with which ATSDR has cooperative agreements.

Exposure: As the first step in the evaluation, ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how might people come into contact with it. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by EPA, other government agencies, businesses, and the public. When there is not enough environmental information available, the report will indicate what further sampling data is needed.

Health Effects: If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists then evaluate whether or not there will be any harmful effects from these exposures. The report focuses on public health, or the health impact on the community as a whole, rather than on individual risks. Again, ATSDR generally makes use of existing scientific information, which can include the results of medical, toxicological, and epidemiologic studies and the data collected in disease registries. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain substances is not available. When this is so, the report will suggest what further research studies are needed.

Conclusions: The report presents conclusions about the level of health threat, if any, posed by a site and recommends ways to stop or reduce exposure in its public health action plan. ATSDR is primarily an advisory agency, so usually these reports identify what actions are appropriate to be undertaken by EPA, other responsible parties, or the research or education divisions of ATSDR. However, if there is an urgent health threat, ATSDR can issue a public health advisory warning people of the danger. ATSDR can also authorize health education or pilot studies of health effects, full-scale epidemiology studies, disease registries, surveillance studies, or research on specific hazardous substances.

Interactive Process: The health assessment is an interactive process. ATSDR solicits and evaluates information from numerous city, state, and federal agencies, the companies responsible for cleaning up the site, and the community. It then shares its conclusions with them. Agencies are asked to respond to an early version of the report to make sure that the data they have provided is accurate and current. When informed of ATSDR's conclusions and recommendations, sometimes the agencies will begin to act on them before the final release of the report.

Community: ATSDR also needs to learn what people in the area know about the site and what concerns they may have about its impact on their health. Consequently, throughout the evaluation process, ATSDR actively gathers information and comments from the people who live or work near a site, including residents of the area, civic leaders, health professionals, and community groups. To ensure that the report responds to the community's health concerns, an early version is also distributed to the public for their comments. All the comments received from the public are responded to in the final version of the report.

Comments: If, after reading this report, you have questions or comments, we encourage you to send them to us.

Letters should be addressed as follows:

Attention: Chief, Program Evaluation, Records, and Information Services Branch, Agency for Toxic Substances and Disease Registry, 1600 Clifton Road (E-56), Atlanta, Georgia 30333

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AEC	Atomic Energy Commission
ATSDR	Agency for Toxic Substances and Disease Registry
BDL	Below Detection Limit
BLM	Bureau of Land Management
BU	Boston University
BW	Body Weight
CDC	Center for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulation
CNS	Central Nervous System
cm	centimeter
Cr	Chromium
CREG	Cancer Risk Evaluation Guide
CSF	Cancer Slope Factor
DCG	Derived Concentration Guide
DHS	Division of Health Studies
dl	deciliter
DOE	Department of Energy
ED	Exposure Dose
EF	Exposure Factor
EMEG	Environmental Media Evaluation Guide
EPA	Environmental Protection Agency
FS	Feasibility Study
FY	Fiscal Year
GJPO	Grand Junction Projects Office
Gy	Gray
HARP	Health Activities Recommendation Panel
IARC	International Agency for Research on Cancer
IRIS	Integrated Risk Information System
kg	kilogram
L	Liters
m	meter
m^3	cubic meter
MAC	Maximum Allowable Concentration
MCL	Maximum Contaminant Level
mg	milligram
mg/kg	milligram per kilogram
μg	microgram
μg/dl	microgram per deciliter
μg/L	microgram per liter
MMTS	Monticello Mill Tailings Site

mrem	milliRoentgen equivalent man
MRL	Minimal Risk Level
MVP	Monticello Vicinity Properties
N/A	Not Applicable
NA	Not Available
NAREL	National Air and Radiation Environmental Laboratory
ND	No Data Were Collected
NIOSH	National Institute for Occupational Safety and Health
NOAEL	No-Observed-Adverse-Effects-Level
NORM	Naturally Occurring Radioactive Materials
NPL	National Priorities List
NTP	National Toxicology Program
OH&S	Occupational Health and Safety
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
pCi/g	picocuries per gram
pCi/L	picocuries per liter
pCi/m^3	picocuries per cubic meter
pCi/m^2s	picocuries per square meter second
PHAP	Public Health Action Plan
PMCL	Proposed Maximum Contaminant Level
ppb	parts per billion
ppm	parts per million
QA/QC	quality assurance quality control
RAC	Reasonably Assumed a Carcinogen
RCRA	Resource Conservation and Recovery Act
RfC	Reference Concentration
RfD	Reference Dose
RI	Remedial Investigation
RMEG	Reference Dose (or Concentration) Media Evaluation Guide
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SEER	Surveillance, Epidemiology, and End Results
SRU	Site Review and Update
SSAB	Site Specific Advisory Board
TAL	Target Analyte List (inorganic chemicals)
TCL	Target Compound List (organic chemicals)
TIC	tentatively identified compounds
TIGER	Topologically Integrated Geographic Encoding and Referencing
TRI	Toxic (Chemical) Release Inventory
UDEQ	Utah Department of Environmental Quality
WL	Working Level

SUMMARY

There are two National Priorities List (NPL) sites in Monticello, San Juan County, Utah: the Monticello Mill Tailings Site (MMTS) and the Monticello Vicinity Properties (MVP). Both sites are associated with the Monticello Uranium Mill.

The Monticello Mill Tailings Site is a former uranium and vanadium processing mill. It is divided into three distinct operable units: the mill site tailings and mill site property; the peripheral properties; and surface water, groundwater, and contaminated sediments in Montezuma Creek Canyon. The mill posed a public health hazard when it was operating. The tailings that remain on the mill site would be a public health hazard today if the public had access to the mill site. However, access is strictly controlled: the mill site, therefore, does not pose a threat to area residents.

The Monticello Vicinity Properties are off-site residential and commercial properties. Land use of most of these properties is residential housing. The community will continue to be exposed to low-level radiation until remediation is complete. The remedial actions will eventually remove most of the contaminated soils within the residential community, thereby eliminating concerns about long-term exposure.

For the purpose of this public health assessment, on site describes the actual mill site itself and off site describes all other areas (vicinity and peripheral properties).

There are several sources of contamination in soils and buildings throughout the city of Monticello: the mill tailings which, in the past, were windblown into the city, were prevalent throughout the southeastern quadrant, and were also taken from the mill site and used as fill for open lands; backfill around water, sewer, and electrical lines; and sand mix in concrete, plaster, and mortar. As a result, residents have been exposed to low levels of radium-226 and radon-222. Department of Energy (DOE) representatives have surveyed and recommended for clean-up inclusion a total of 449 vicinity and peripheral properties (420 vicinity and 29 peripheral). Three hundred eighty-nine vicinity properties and 11 peripheral properties have been remediated.

Agency for Toxic Substances and Disease Registry (ATSDR) staff members believe that exposures were greater in the past than they are today. Industrial hygiene surveys of the mill performed when the mill was operating reported that conditions were very dusty and that many workers were exposed to levels of radioactive dusts above allowable concentrations. Analysis of the available health outcome data show that San Juan County has the highest rate of renal failure among women in the state, and limited evidence suggests that there is an increased risk of dying of lung cancer in Monticello compared with the risk for the rest of the county. There is no supporting information connecting these incidences to the mill site.

The largest risk to the general public stems from exposure to direct gamma radiation from unremediated soils in Montezuma Creek Canyon. However, this risk is relatively low and direct gamma radiation exposure exists mostly at or near natural background levels. The

contamination of Montezuma Creek by surface runoff of tailings from the mill site creates a potential exposure pathway. The most likely exposure would occur if hunters consumed game animals that had entered the mill site or the Montezuma Creek floodplain and eaten vegetation or drunk water from either one of the areas. However, such exposures, if any, would have been intermittent and highly unlikely to have resulted in adverse health effects. In the fall of 1996 the Environmental Protection Agency (EPA) and Utah Department of Environmental Quality (UDEQ) staff conducted a study of the body burden of contaminants in tissues and organs of deer and cattle that consumed water and vegetation from the Montezuma Creek floodplain. Cattle and deer from a background reference area were also sampled. The meat, liver kidney, and ribs are being analyzed for radionuclides and nonradionuclide contaminants. Although the analyses have not yet been completed, preliminary results indicate little or no contaminant uptake in cattle or deer above the uptake in the reference area animals. Since 1993, drainage controls on-site have nearly eliminated surface water run-off contamination. Surface water run-on has been eliminated by a series of ditches that divert water around the mill site. Surface water on-site is collected and routed to a pond for treatment before release. The major contribution to surface water contamination is leachate in groundwater that enters Montezuma Creek downgradient from the mill site. Also, the shallow alluvial aquifer is contaminated with uranium-234 and uranium-238 at levels of public health concern, but there are no known private wells associated with the aquifer and currently in use. ATSDR representatives recommend that local ordinances be established to prevent future installation of wells into the contaminated alluvial aquifer.

Monticello is in the geographic center of San Juan County. San Juan County covers a very large and sparsely populated area of southeastern Utah. With a total area of more than 7,800 square miles, the county is slightly larger than New Jersey, but its 1990 population was only 12,621. At 2.74 square miles, Monticello is the largest town in the county in terms of its area. More than half the population of San Juan County is Native American. Monticello's 1990 population was slightly more than 1,800.

The off-site area, the vicinity and peripheral properties, is being considered for follow-up public health actions. Exposure to contaminants from past and current activities at the MMTS suggests the need for health studies and further education efforts. ATSDR staff will conduct a needs assessment as a basis for determining the appropriate preventative health education plan for the sites. We will identify the public health problems, community concerns, health professional and community-specific needs, and primary target populations for health education. Special needs groups, such as children, minorities, and the elderly, will be noted. ATSDR staff plan to collaborate with state and local health departments.

BACKGROUND

A. Site Description and History

The Monticello Mill Tailings Site is a 110-acre abandoned uranium and vanadium processing mill in the city of Monticello, San Juan County, in southeastern Utah. The Monticello Vicinity Properties are off site residential and commercial properties. Both of the sites are associated with the Monticello Uranium Mill. The United States Department of Energy (DOE) owns the mill site (see Appendix F, Figure 1). The City of Monticello, private residents, and the state of Utah Highway 191 right-of-way own the land that borders the mill site. No residences are within the mill site boundary, but residences are adjacent to the north and east edges of the mill site (1).

Operating History

The Vanadium Corporation of America opened a vanadium ore-buying station at Monticello in late 1940 and began mill construction in 1941. In 1943, Vanadium Corporation began producing a uranium-vanadium sludge for the Manhattan Engineer District (1).

Construction of the Monticello plant, in addition to the mill proper, included the development of an adequate water supply, installation of a power plant, and construction of two large housing projects for workers. The staff town site, on the hill opposite the mill, consisted of a staff house for 12 men, a manager's house, and 14 4-room family dwellings. The other housing project consisted of 32 2-room family houses and a bunkhouse and boardinghouse for 32 men (2).

Intermediate owners and operators of the Monticello Mill Tailings Site included the War Assets Office; the Atomic Energy Commission (AEC); American Smelting and Refining Company; Galigher Company; Lucius Pitkin, Inc.; National Lead Company; the Bureau of Land Management (BLM) (acquired the mill site by means of a land transfer, never operated the mill); and the DOE. Mill operations were terminated on January 1, 1960. The ore-buying station remained open until March 1962 . Remediation work on the site is still being done today (1).

Milling processes used at Monticello during the 11 years of AEC operation included raw ore carbonate leach, low-temperature roast/hot carbonate leach and salt roast/hot carbonate leach until 1955, acid leach resin-in-pulp and raw ore carbonate leach from 1955 to 1958, and a carbonate pressure leach resin-in-pulp process from 1958 until mill closure in 1960 (1).

The mill tailings were stabilized between 1961 and 1962, and the plant was dismantled in 1964. Removal of contaminated soils from the ore-buying stations occurred between May 1974 and August 1975 (1, 3).

Remediation Activities

In 1978, the United States Department of Energy (DOE), under the authority of the Atomic Energy Act, initiated the Surplus Facilities Management Program to assure safe caretaking and decommissioning of government facilities that had been retired from service but still had radioactive contamination. The Monticello Mill Tailings Site was accepted into the Surplus Facilities Management Program in 1980. The Monticello Remedial Action Project was then established to restore the government-owned mill site to safe levels of radioactivity, to dispose of or contain the tailings in an environmentally safe manner, and to perform remedial actions on off-site vicinity properties that had been contaminated by radioactive material from the mill operations.

In 1983, remedial activities for vicinity properties were separated from the Monticello Remedial Action Project with the establishment of the Monticello Vicinity Properties Project. The Grand Junction (Colorado) Projects Office of the Department of Energy conducts both the Monticello Remedial Action Project and the Monticello Vicinity Properties Project (1).

There are two National Priorities List (NPL) sites in Monticello, the Monticello Mill Tailings Site (MMTS) and the Monticello Vicinity Properties (MVP). Both sites are associated with the Monticello Uranium Mill. The Environmental Protection Agency (EPA) formally included the MVP and the MMTS on the NPL on June 10, 1986, (4) and November 16, 1989, respectively (3). The sites are being remediated in accordance with the Monticello Vicinity Properties Project November 1989 Record of Decision and the Monticello Mill Tailings Site August 1990 Record of Decision.

Mill tailings and associated contaminated material remain on the mill site as a result of milling ore to recover uranium and vanadium. Tailings particulate material has been blown by the wind and carried by surface water to off-site properties, over time. The tailings piles have been covered and vegetated to prevent further windblown dispersion of contaminants.

The MMTS is divided into three distinct operable units:

Operable Unit I	Mill Site Tailings and Mill Site Property
Operable Unit II	Peripheral Properties
Operable Unit III	Surface Water, Groundwater, and Contaminated Sediments in Montezuma Creek Canyon (4, 5)

The remedial actions planned for these operable units are interdependent.

The August 1990 Monticello Mill Tailings Site Record of Decision addresses the remedial actions for Operable Units I and II. A record of decision will be prepared for Operable Unit III after remedial actions for Operable Units I and II are initiated and additional monitoring data for groundwater and surface water are collected.

The mill site consists of the former locations of the mill and residential areas, covering 32 acres, the tailings-impoundment area, covering 68 acres, and the former BLM property, covering 10 acres. The land that the BLM occupied was originally part of the mill site, but that land was deeded back to DOE in 1992. An estimated 100,000 cubic yards of contaminated material has been identified in the mill area, and approximately 1.4 million cubic yards (2 million tons) of tailings, contaminated soil, by-product material, and contaminated building material is located in the tailings-impoundment area (4). Appendix F, Figure 2, depicts the mill site property, associated buildings, and tailings piles.

The tailings are stored in four piles:

1. Carbonate Tailings Pile (oldest of the tailings piles),
2. Vanadium Tailings Pile,
3. Acid Tailings Pile (received tailings from 1955 to 1956), and
4. East Tailings Pile (received tailings from 1956 to 1960) (1).

The peripheral properties are adjacent to the DOE property but are owned by other individuals or entities. During the period of mill operation, mill operators leased private land north and south of the existing mill site to stockpile ore. The former ore-stockpile areas and other adjacent areas contaminated by windblown and water-borne tailings cover approximately 300 acres around the mill site and contain most of the estimated 300,000 cubic yards of peripheral property material to be remediated. Peripheral properties also include the bed and banks of a 3.3-mile reach of Montezuma Creek between the city of Monticello and Vega Creek (4).

The Monticello Vicinity Properties (MVP), also referred to as the Monticello Radioactively Contaminated Properties, are off-site residential and commercial properties. Land use of most of these properties is residential housing. Adjacent land usage includes heavy and light commercial use and a "controlled" zoning district that allows a mix of agricultural, residential, industrial, and commercial use (3).

Throughout the operating period of the Monticello Uranium Mill, mill tailings from the mill site were windblown into the city of Monticello or used in construction in the city of Monticello. Windblown tailings contamination is prevalent throughout the southeastern quadrant of the city. The tailings were used as fill for open lands; backfill around water, sewer, and electrical lines; sub-base for driveways, sidewalks, and concrete slabs; backfill against basement foundations; and sand mix in concrete, plaster, and mortar. The total tonnage of uranium mill tailings removed from the mill site for construction purposes was never documented. However, contaminated material from the vicinity properties is estimated at 156,000 cubic yards. The removal of contaminated tailings from the mill site was restricted in August 1975, when a fence was erected around the mill site to prevent unauthorized access and the ore-buying stations were cleaned up. Appendix F, Figure 3, outlines the MVP project area and shows the adjacent mill site location (3).

Remediation began in 1984, and Appendix F, Figure 4, depicts the status of the Monticello Vicinity Properties as of February 1995.

According to the EPA Region VIII Hazardous Waste Management Division Five-Year Review (Type Ia) document, 420 individual properties were included in the Monticello Vicinity Properties (MVP) Site as of December 1996. This document covers the first 5-year review period from 1991 through 1996. DOE is the responsible party for remediating the MVP and is further responsible for certifying that the remediation is completed at each of the properties. These 420 individual properties are grouped into eight operable units, designated A through H. These operable units are defined for administrative convenience and, except for Operable Unit E, do not imply geographic proximity of individual properties to each other. For fiscal year 1996, 14 remedial actions were completed and by the end of 1996, 389 properties were remediated on the MVP Site. There are an additional 29 peripheral properties. As of May 1997, 11 peripheral properties were remediated (5, 6).

The MVP is divided into 8 distinct operable units (OU):

Operable Unit A. OU A consists of 104 properties. As of May 15, 1996, remedial construction for this OU was complete. A draft-final Remedial Action Report was submitted November 8, 1996. The report was approved by EPA, with the concurrence of the state, on January 13, 1997.

Operable Unit B. OU B consists of 243 properties. As of December 13, 1996, construction was complete at 237 properties; 3 properties were under construction; and 3 properties did not require remedial action.

Operable Unit C. OU C consists of 34 properties. Contamination is traceable to uranium milling at Dry Valley, Utah, or to other sources not associated with the Monticello Uranium Mill. As of December 13, 1996, construction was complete at 32 properties; 1 property was scheduled to be remediated; and 1 property did not require remedial action.

Operable Unit D. OU D consists of six properties. These are properties on which nonradiological hazardous substances are known or suspected to exist. As of December 13, 1996, construction was complete on three properties and three properties were under construction.

Operable Unit E. OU E consists of eight properties. These properties are crossed by Halls' Ditch, an irrigation ditch that passes through the mill site. As of December 13, 1996, remedial action was in progress on these properties.

Operable Unit F. OU F consists of ten properties. As of December 13, 1996, construction was completed on 4 properties. Owner negotiations are complete on 3 of the properties. The remaining 3 properties are still in negotiation.

Operable Unit G. OU G consists of ten properties. As of December 13, 1996, construction was completed on 3 properties. Remediation will not be required on one property because contamination does not exceed standards. The remaining 6 properties are either in design or scheduled for construction.

Operable Unit H. There are five properties being considered for supplemental standards within the MVP site. One of the properties is privately owned and the owner has requested DOE not to proceed with the remedial action due to the environmental degradation that will result from the cleanup work. Four of the properties are associated with the Highway 191 embankment where the cost of remediation may be excessive compared to the reduction in risk achieved by remediation. Supplemental standards are also being considered for city streets and utilities within the MVP site boundary. On December 23, 1996, EPA and Utah Department of Environmental (UDEQ) concurred, with comment, on the use of supplemental standards at the proposed properties. Negotiations on specific issues are under way (5, 6, 7).

In January 1996, DOE proposed to the regulators to remediate soils in the upper part of Montezuma Creek Canyon, and to perform risk assessments to determine the need for remediation in the middle and lower parts of the canyon. These actions will remove the primary source of risk to human health in the canyon. DOE, EPA, and UDEQ decided to defer the decision for remedial action of the upper canyon until the risk assessments are finalized.

All surface contaminants posing an unacceptable risk to human health and the environment will be placed in the permanent repository immediately south of Monticello. In late May, 1997, DOE began placement of approximately 2.3 million cubic yards of mill tailings and other contaminated materials in the recently completed repository. Excavation has begun on the Carbonate Tailings Pile on the north side of the former mill site. The excavation and transportation of the tailings should be in full swing by June 20, 1997. The excavation and hauling will be conducted 7 days per week, 12 hours per day. The excavation activities will be completed by November 1998.

The Agency for Toxic Substances and Disease Registry (ATSDR) released the Monticello Mill Tailings and Monticello Radioactively Contaminated Properties (aka Monticello Vicinity Properties) Public Health Assessment for public comment on December 20, 1996. The official comment period ended on February 21, 1997. Several new DOE documents have been released and become available during the finalization of this public health assessment. ATSDR scientists requested, received, and reviewed these documents. These documents did contain in-depth valuable information. ATSDR updated the conclusions and recommendations of this document to reflect this more recent information.

Following is a synopsis of the newly released documents:

Operable Unit III Baseline Human Health Risk Assessment, March 1997--This document illustrates that when the risk is characterized in terms of the potential numbers of persons exposed, added cancer mortality associated with exposure to Operable Unit III contaminants is unlikely and would be indistinguishable from the background cancer mortality rate (8).

Operable Unit III Alternatives Analysis, Draft, May 1997--The purpose of this alternatives analysis is to identify and evaluate remediation alternatives for soil and sediment in the vicinity of Montezuma Creek, which is part of Operable Unit III of the Monticello Mill Tailings Site. This report is being prepared to support a non-time-critical removal action. A removal action is being pursued so an expedited remediation decision can be made for soil and sediment. Recommended removal actions for each reach of Montezuma Creek (Upper, Middle, and Lower) will be included in the future draft final and final versions of the document. The state will review the draft Alternatives Analysis Report and provide input on the alternatives. Input from the state will be incorporated under "State Acceptance" in the Draft Final Alternatives Analysis Report. DOE staff will then hold a landowner briefing to get input on the alternatives from the property owners. After input from the state and the landowners is incorporated into the Alternatives Analysis Report, the risk managers (i.e., DOE, EPA, and the state of Utah) will select recommended removal actions for soil and sediment in Upper, Middle, and Lower Montezuma Creek and present the information at a public meeting (9).

Operable Unit III Ecological Risk Assessment, Draft, June 1997--Only the aquatic community may be of "possible concern," although actual risks may be of "no concern." There is little likelihood that the Operable Unit III contaminants of concern are harming the other receptors. This conclusion is substantiated by the tissue sampling done for the cliff swallows (surrogate for the southwestern will flycatcher) and mule deer, which indicated that concentrations of contaminants of concern concentration in these tissues are not elevated. These findings need to be contrasted to short-term and long-term impacts to these receptors and their ecosystems that would occur during remediation. The potential impacts from remediation will be discussed in the alternative analysis for Operable Unit III soil and sediment (10).

ATSDR scientists will continue to review any future documents that become available. Should additional information become available that alters the findings of this public health assessment or addresses issues described herein, this public health assessment will be modified as needed.

ATSDR Activities

The Agency for Toxic Substances and Disease Registry (ATSDR) released a preliminary public health assessment for the Monticello Radioactively Contaminated Properties National Priorities List Site, more commonly referred to as the Monticello Vicinity Properties (MVP), in July 1988. The preliminary public health assessment concluded that the MVP site was of public health concern because of the risk to human health from exposure to hazardous substances. Assessors determined that people could be exposed during domestic uses of contaminated groundwater and by eating garden vegetables grown in contaminated soil. The document recommended that future environmental investigations be designed to address environmental and human exposure pathways.

ATSDR also released a site review and update (SRU) for the MVP in September 1992. The SRU concluded that although the community will continue to be exposed to low-level radiation until remediation is complete, the remedial actions will eventually remove most of the contaminated soils within the residential community, thereby eliminating concerns about long-term exposure from outside sources. However, there are properties in the community that may not be addressed by the current remedial actions for various reasons (i.e., properties whose owners have refused remediation, areas outside the 8-mile radius clean-up boundary, properties that contain naturally occurring radioactive materials (NORM), or properties where the brick veneer was left behind and, as a result, small sections of the community may continue to be exposed to low levels of radiation. The original clean-up boundary (6-mile radius) of the MVPs were those properties within the city limits. Peripheral properties generally lie outside the Monticello city limits. The new clean-up boundary extends to an 8-mile radius. DOE representatives, at the insistence of EPA and UDEQ, sent letters to all property owners within the 8-mile radius of the mill site. If owners suspected that tailings or materials from the mill site were on their property, they were requested to notify DOE. If contacted, DOE staff conducted radiological surveys of the property. Five additional properties have been included as a result of the surveys. Unless supplemental standards are approved, properties will be cleaned up to the 40 Code of Federal Regulation (CFR) 192.12 standard. EPA and UDEQ will consider supplemental standards (alternative clean-up levels including institutional controls) only if they are protective of human health and the environment. In November 1996, DOE released a draft final General Radiological Risk Assessment Methods document. The methods described in this document are intended for assessing exposure, dose, and risk for candidate supplemental standards properties. A risk assessment will be developed for each property using site-specific data, and these methods will be used to derive supplemental standards for evaluating response alternatives. If remedial actions are considered as a response alternative, the supplemental standards will serve as target performance goals. These methods provide supplemental standards that ensure overall protection of human health and the environment and compliance with applicable or relevant and appropriate requirements (11). EPA and UDEQ have no statutory requirement to clean up NORM. Property owners with such materials will be contacted and given the opportunity to have NORM disposed of in a repository.

The 1988 preliminary public health assessment discussed possible contamination of off-site groundwater and possible contamination of vegetables from home gardens as a concern at the MVP. The SRU concluded that groundwater contamination does not appear to be a problem at the MVP site, but does appear to be a concern at the MMTS. The Operable Unit III investigation addresses groundwater and surface water issues at the MMTS, and remediation of the soil should eliminate the possibility of contaminated vegetables. Currently, produce are not being grown within Operable Unit III or in the Montezuma Creek Canyon. The document recommended a health consultation to evaluate data on the disputed properties (disputed properties are no longer an issue, DOE representatives have agreed to remediate all properties inside the cleanup boundary), removal of tailings from the Monticello area, and naturally occurring radioactive materials such as rock collections. The document also recommended that workers for the City of Monticello use radiation detectors while conducting municipal improvements that require excavation of soils in areas where the soils have not been characterized for radioactivity (12).

B. Site Visits

ATSDR headquarters staff members and the ATSDR Region VIII representative conducted the first MMTS and MVP site visit July 20-24, 1992. They met with representatives of DOE; Chem-Nuclear Geotech; EPA Region VIII; other federal, state, and local environmental and health officials; and Monticello city officials. DOE and Chem-Nuclear Geotech staff members provided an overview and tour of the MMTS and the MVP.

Site visitors observed that small gardens are common in the community. Also, soils on and around the MMTS generally appeared to have some form of vegetation. The MVP locations were under remediation. The remediation debris from these off-site properties was being trucked to and then temporarily stored on top of the East Tailings Pile. Remediation workers were practicing dust-control measures to minimize redistribution of the contaminated material. City workers were improving the water system, and piles of soil marked areas where improvements were being installed throughout the community.

Staff members from the EPA's National Air and Radiation Environmental Laboratory (NAREL) and from Boston University (BU) accompanied ATSDR representatives on a second site visit, which took place from October 4 to 8, 1993. NAREL staff members helped ATSDR with radiation evaluation, and BU staff members helped to evaluate community health concerns and health outcome data. They met with representatives of DOE, RUST Geotech (formerly Chem-Nuclear Geotech), EPA Region VIII, and the UDEQ. ATSDR staff members also met with Monticello community members and city officials to gather community health concerns. ATSDR representatives performed an introductory orientation at two DOE-hosted public meetings. There were no significant observations other than those already mentioned in the background and history portions of this document.

ATSDR representatives conducted public availability sessions in Monticello and Blanding from December 7 to 8, 1993. ATSDR staff members met informally with individuals or small groups of community members during the trip and the public availability sessions, which helped to gather health information and collect community concerns. They interviewed approximately 160 community residents and concerned residents. A variety of questions and concerns were collected. Community members indicated that a group of concerned residents existed in the northwest quadrant of Monticello. These residents filed a lawsuit against the National Lead Company, the contractor that operated the Monticello Uranium Mill before the mill closed in 1960, for the multiple deaths of children from leukemia (13).

ATSDR and NAREL staff members provided information on radiation and health issues during community information sharing sessions from April 24 to 27, 1995. They discussed what radioactive materials, radiation, and contamination are; how we locate radioactive materials and measure radiation; how we are exposed to radiation in our environment and from naturally occurring radioactive materials inside the human body; the possible health effects of exposure to radiation; and how we protect ourselves from radiation sources. They conducted 13 community radiation and health information-sharing sessions in Monticello and Blanding. The audience included community members, groups of students, Blue Mountain Dineh (Navajo), and White Mesa Utes. Attendance at each session was as follows:

Sessions 1 & 2	Blanding Elementary School = 650 students
Session 3	San Juan High School = 35 students
Session 4	Blanding Middle School = 140 students
Session 5	Blanding Community = 4 people
Session 6	Monticello High School = 40 students
Session 7	Monticello Community (Session A) = 4 people
Session 8	Monticello Community (Session B) = 6 people
Sessions 9 & 10	Monticello Elementary School = 325 students
Session 11	San Juan High School = 12 students
Session 12	Blue Mountain Dineh = 10 people
Session 13	White Mesa Utes = 2 people.

C. Demographics, Land Use, and Natural Resource Use

Appendix A, Tables A1-A3, and Appendix F, Figures 5-9, present demographic information.

C.1 Demographics

Monticello is in the geographic center of San Juan County, Utah. The city of Monticello was established in 1888 and was named for Thomas Jefferson's home in Virginia because of similarities in geography.

Data used in Appendix A, Tables A1-A3 and the following text are approximations from the 1990 Census of Population and Housing for San Juan County and Monticello (14). Figures 5-9 in Appendix F present demographic data extracted from the United States Bureau of the Census Topologically Integrated Geographic Encoding and Referencing (TIGER) system (15). The TIGER system was launched in 1983 to automate the mapping and other geographic activities required to support the bureau's censuses and surveys.

San Juan County covers a very large and sparsely populated area of southeastern Utah. With a total area of more than 7,800 square miles, the county is slightly larger than New Jersey, but its 1990 population was only 12,621. More than half the population of San Juan County is Native American. At 2.74 square miles, Monticello is the largest town in the county in terms of its area. Monticello's 1990 population was slightly more than 1,800. In contrast to the population of the county as a whole, more than 87% of Monticello's residents are white; 12.3% are of Hispanic origin. Persons of Hispanic origin may be of any race. Extraordinarily high percentages of the population for both the city, 41.4%, and the county, 43.3%, are under age 18.

There were 3.26 persons per household in Monticello in 1990, which is well above the national average of about 2.6 but is consistent with the town's large percentage of persons under age 18. (A household is an occupied housing unit, but the definition does not include such group quarters as military barracks, prisons, and college dormitories.) Nearly 80% of Monticello's households are owner-occupied, which suggests a stable, nontransient population. Homeowners tend not to move as often as do renters. The cost of housing in isolated rural areas is typically much lower than in metropolitan areas. What appears to be relatively low mean value of owner-occupied housing ($55,300) and rent paid for renter-occupied housing ($199 per month) in Monticello is consistent with that fact.

The median household income is $25,787, and the per capita income is $8,615 for Monticello. San Juan is one of the nation's poorest counties, with 36.4% of the population below the poverty level. Monticello has a poverty rate of 12.6%. More than three-fourths of Monticello residents aged 25 and older have a high school equivalency or higher educational background, which indicates a relatively well-educated community.

C.2 Land Use

San Juan County, the largest county in Utah, comprises 5,045,760 acres, most of which is sparsely populated rangeland and forest. Most county land is managed by either the federal government or the Navajo Indian Nation. The U.S. Forest Service (Manti-La Sal National Forest), the Bureau of Land Management (San Juan District Office), and the National Park Service manage approximately 61% of the land in the county, and the Navajo Indian Reservation encompasses another 25% along the county's southern border. The state of Utah administers 6%, and less than 1% of that 6% is owned by cities and the county. The remaining 8% is privately owned land, located primarily in Monticello and Blanding (1).

Historically, the primary uses of county lands have been mining, farming/ranching, and recreation (e.g., camping, hiking, and hunting). Mining in Utah, as in other western states, is subject to supply and demand, and thus has been cyclical. Oil, gas, and uranium are the primary mineral resources of interest in the county. Utah is the fourth largest U.S. producer of oil and gas, although no major oil or gas fields are located in the immediate vicinity of Monticello (1).

Uranium ores have been found locally in approximately half of the county, including areas close to Monticello. However, the uranium market has been depressed since 1982, and White Mesa Mill is the only active uranium processing facility in the county (1). Since 1995, White Mesa Mill has been the only active mill in the United States.

Farming and ranching, the latter primarily cattle and sheep grazing, are common throughout the county. A total of 213 farms and ranches use approximately 8% of county land (411,693 acres) for agricultural purposes (1).

Most recreational use occurs in the many parks, forests, and proposed wilderness areas, a number of which are relatively close to Monticello. The largest of the parks is Canyonlands National Park. The South Unit entrance of Canyonlands is 15 miles north of Monticello. Lake Powell is approximately 100 miles southwest, with approximately 1,000 miles of its coastline in San Juan County (1).

Five zoning districts have been established within San Juan County: multiple-use, agricultural, rural residential, controlled, and Indian reservation. Within the city limits of Monticello, areas have been zoned for heavy and light commercial use and for residential use. Commercial zoning along the major thoroughfares of Monticello, U.S. Highway 191 and U.S. Highway 666, has established a central business district. Commercial growth has occurred to the north and east, radiating from the center of town along those routes. Heavy commercial (formerly industrial) zoning exists in the southeastern corner of the city. The mill site and tailings piles lie south of this area, within a controlled district that permits a mix of agricultural, residential, industrial, and commercial use. Several residences have been built east and immediately north of the mill site, but otherwise most of the land is nonresidential. Alfalfa for livestock feeding is grown immediately east of the mill site. Land to the south is marginal for grazing (1).

C.3 Natural Resource Use

a. Surface Water

All domestic surface water resources for the Monticello area are upgradient from the mill site. The City of Monticello public water system draws from two sources: the springs located on the flanks of the Abajo Mountains and the Monticello Reservoir on South Creek 1 mile southwest of the mill site. The raw water from those sources is treated, stored, and used as the public drinking-water supply, with the current treatment capacity of the public water system at 1.2 million gallons per day. The municipal distribution system has 650 residential and commercial connections, serving 2,000 people (16).

Blue Mountain Irrigation District has a permit to irrigate approximately 1,000 acres with surface water diverted from South Creek. A ditch originating at South Creek upgradient of the mill site diverts water to irrigation sites east of Monticello. The irrigation season begins April 1 and ends around mid-July, when surface water ceases to flow in South Creek. Montezuma Creek runs through the mill site, and return flow of irrigation water to Montezuma Creek occurs downstream from the tailings area. Additional water rights permit downstream landowners to draw agricultural irrigation water from Montezuma Creek. The creek provides drinking water for livestock (1).

b. Groundwater

The source of potable water (water used for drinking, cooking, showering, etc.) for those people living outside the city of Monticello is predominantly groundwater. Private groundwater wells penetrate the Dakota Sandstone Aquitard (a geological formation that impedes groundwater flow from one aquifer to another) and draw water from the lower Burro Canyon Aquifer. The shallow (upper) alluvial aquifer is currently not used as a potable water source (16).

Groundwater is also used for irrigation in the Montezuma Creek area, which encompasses the entire Montezuma Creek drainage area as far as the creek's confluence with the San Juan River. Existing water rights permit irrigation of some 299 acres with groundwater as the sole supply and another 1,718 acres with groundwater as a supplemental supply. Groundwater is not currently being used for irrigation in the area immediately downgradient from the mill site (1).

D. Health Outcome Data Sources

Health outcome data for Utah and the vicinity of the Monticello Mill Tailings Site and the Monticello Vicinity Properties are available from a variety of sources. The sources reviewed for this public health assessment are described below.

1. The Utah Cancer Registry was started in 1966 and is supported by the National Cancer Institute and contracted with the Utah Department of Health. Utah cancer mortality rates were calculated from death certificates provided by the Utah Bureau of Vital Statistics. The publication *Cancer in Utah 1966-1990*, compiled by the Utah Cancer Registry, was reviewed.

2. The National Cancer Institute and the EPA have produced the Riggan's Mortality Tapes, a database that provides a comparison of the number of deaths resulting from a

specific cancer type in a specified county (San Juan) and state (Utah) with the numbers of deaths from the same type of cancer for the entire United States over a period of 30 years in 10-year increments.

3. The Utah Department of Health Bureau of Vital Records and Health Statistics provided a diskette containing information on all Utah deaths from 1956 to 1992. These data were coded to reflect cause of death, age at death, year of death, residence (both town and county), and other case-specific information. These data allowed us to analyze causes of death in Monticello and Blanding during different periods and compare them with the rates for rest of San Juan County and for Utah as a whole.

4. A residents' survey of health problems in residents of Monticello from the 1940s through the 1960s was conducted during the last few years. Survey information was available on approximately 250 such individuals, some of whom had moved away from Monticello since the early 1970s and some of whom are still residents. Information from the survey was put on a computer database, without personal identifiers, and provided to Boston University staff members for analysis. Although this survey was conducted by volunteers and is not a complete sample of all the residents of the town during the years of interest, it nevertheless has value in identifying issues that might be addressed in future studies.

5. *Cancer Cases for Monticello*, prepared by the Utah Cancer Registry, lists the number of adult and childhood cancer cases in Monticello by primary site and year of diagnosis, 1967 to 1992. The report does not list the cases by sex.

6. *WONDER: Wide-Ranging ONline Data for Epidemiologic Research* is a computer database designed by the Information Resources Management Office, Centers for Disease Control and Prevention (CDC). The mortality section of the database provided information for comparing the rates of the county with rates for the state and the rest of the country.

7. The state of Utah does not have a birth defects registry. However, a summary report, *Congenital Malformations in Utah*, by Seegmiller and Hansen, in *Teratology* Volume 22, 1980 for the years 1968 to 1972 was available.

8. *Interim Report of a Health Study of the Uranium Mines and Mills* by the Federal Security Agency Public Health Service, Division of Occupational Health, and the Colorado State Department of Public Health, May 1952, contains information about uranium millers.

9. "Cancer Mortality Patterns Among U.S. Uranium Miners and Millers, 1950 through 1962," *Journal of the National Cancer Institute*, is a journal article containing information about cancer mortality patterns among uranium miners and millers for the cohort study that lasted 12 years.

10. "Cancer Mortality Among Uranium Mill Workers," *Journal of Occupational Medicine*, January 1973, is a continuing study and follow-up to the previous journal article (number 9).

11. ATSDR scientists reviewed "Health Concerns in Uranium Mining and Milling," *Journal of Occupational Medicine*, July 1981, which is a compilation of health concerns gathered from uranium miners and millers.

12. *Mortality Patterns Among a Retrospective Cohort of Uranium Mill Workers*, National Institute for Occupational Safety and Health, Division of Surveillance, Hazard Evaluations and Field Studies, November 1983, is an article containing an analysis of the mortality patterns of uranium mill workers for the retrospective cohort study performed between 1940 and 1977.

COMMUNITY HEALTH CONCERNS

We consolidated concerns collected from site visits, public meetings, public availability sessions, letters and phone calls to ATSDR, and site-related documents. When several people expressed the same or similar concerns, we consolidated those concerns but took care to maintain the integrity of the original concerns as expressed. Numbers in parentheses represent the number of times a given concern was reported.

Boston University staff members assembled a list of 66 individuals and organizations familiar with the Monticello sites; we contacted most of them during site visits or follow-up telephone calls. In addition, Boston University staff representatives reviewed 94 documents, scientific articles, or print media articles related to community concerns at the Monticello sites. We categorized concerns as follows:

- A. Concerns about past site-related exposures
- B. Concerns about continuing site-related exposures
- C. General health outcome concerns
- D. Specific health outcome concerns

A. Past Site-Related Exposures

1. **People who visited the mill site** (23):
Residents reported having played on the mill site as children and that their own children played at the mill site. Some said they helped unload the trucks and shoveled off the ore. Others reported having climbed on the ore and tailings piles, swum in the tailings pond, waded in the creek on the mill site, ridden dirt bikes on the mill site, ridden sleighs on the mill site, taken rocks home from the mill site, and engaged in Boy Scout training activities on the mill site. Some of the children who played on the mill site got sick. Some died. Were they exposed to radiation? Were their childhood illnesses caused by exposure to radiation and other toxic substances? Could the childhood exposures cause illnesses later as adults?

2. **Mill workers exposed to hazardous materials** (13):
Workers at the mill were exposed to hazardous substances, including yellow cake (uranium oxides), black cake (vanadium oxides), uranium, vanadium, and chlorine gas. The ventilation was very poor and there was a lot of dust. Workers ate lunch on the tailings piles. Mill workers did not use safety masks and were not informed of the hazards during the time of operating the mill. Urine samples were taken, but workers were not given the results. What are the dangers? What is going to happen to these workers?

3. **Releases from the mill to the environment** (13):
   a. When the plant was operating, yellow dust was everywhere. Chrome was eaten off cars. Clothes on the clotheslines would turn yellow and fall apart. Screen doors would disintegrate. The air smelled like sulfur. What was the yellow dust? What was the smell? What are the health effects?
   b. Yellow cake powder settled on the hay that our dairy cows ate. We drank the milk. The cows died.
   c. Up to 2 tons a day of ammonium nitrate was used in the precipitation process to extract uranium. The solution then went in the waste stream to the tailings piles. What are the possible harmful effects?
   d. Wind blew the dust out of uncovered ore trucks on Main Street going from the mines to the mill. How would this affect people who lived there?
   e. Mill tailings got into the creek. We used the water for irrigation and our crops and animals died.
   f. When the plant was in operation, all the vegetation died on our land which was near the mill site. Why?

4. **Contamination from the work site going home with workers** (6):
   Workers wore contaminated work clothes home (there was yellow dust on their clothes and shoes), and the clothes were washed with the family wash. Could the families of workers have been exposed to radiation and other hazards?

5. **Housing at the mill site** (5):
   Several people reported having lived in government housing on the mill site while the mill was in operation. Tailings were used as fill around these houses. The residents are concerned about harmful exposures from living so close to the mill.

6. **Contaminated soil** (3):
   For many years, residents ate vegetables from gardens located where soil is now being remediated.

7. **Clean-up worker being exposed to hazardous materials** :
   A resident was concerned about exposure to radiation 15 years ago when he was removing fire hydrants from the mill site and there were very warm Geiger counter readings.

B. Continuing Exposure Concerns Related to the Sites

1. **Exposures resulting from the cleanup** (19):
   a. Many residents feel the tailings piles and contaminated soils should be kept on the mill site. They are worried about stirring things up and generating dust that might recontaminate previously remediated properties.
   b. People who live next to the mill site want to know what will happen to them

during the cleanup.

c. Residents are concerned about radon gases being emitted from a permanent tailings repository.

2. **Transfer of hazardous waste from the mill site to the community** (10):

a. One resident was concerned about having taken asbestos from the mill site (along with other residents) and used it in fireplaces and around stoves. Asbestos from the mill site was disposed of in a local sanitary landfill.

b. Materials from dismantled on-site storage buildings were used in construction off site. Construction materials from several buildings were sent to the state prison. Could buildings built from these materials be contaminated and exposing people to harmful substances?

c. Tanks were removed from the mill site and used to store grain on local farms.

d. Radon gas migrates through the tailings into the atmosphere. Radon progeny--decay products or radium--can attach themselves to smoke or dust particles and can damage sensitive lung tissue if inhaled over a long period of time, potentially resulting in lung cancer. The tailings emit gamma radiation. Gamma radiation can also penetrate the entire body, damaging cells and potentially resulting in other types of cancer. What are the risks to the community around the Monticello area?

e. It is believed that approximately 135,000 tons of tailings were used in the community (e.g., as fill around utilities and basements, as a sub-base for sidewalks, driveways, and concrete slabs, and as sand mix for concrete, plaster, and mortar). Residents are concerned about exposure to radiation in and around their homes and businesses.

f. Is the golf course in Monticello contaminated?

g. Is the cemetery contaminated? What about exposure to workers digging graves and doing maintenance? Are there plans to remediate the cemetery?

3. **Dangers from contaminated properties in the community** (9):

a. A residential property immediately adjacent to the mill site was previously an ore-testing area. What are possible health effects?

b. A resident expressed concern about radioactive mortar in the bricks of her son's home; she wants to know what will be done and what, if any, dangers there are?

c. Several people are concerned about contaminated soil in their gardens. (3)

d. A granary where people now work was previously used as an ore-buying station; ore was weighed and dumped there. Three-fourths of this site is contaminated; there are major hot spots (at the warehouse, under the grain cleaner, and under six silos; a large silo has a radiation-contaminated rebar in its concrete floor).

e. Tailings were used around houses. Are people still at risk?

4. **Contamination of groundwater/surface water** (5):
   a. During the 1970s, when there was a water shortage, attempts were made to clean and use wells on and near the mill site. Some could not be cleaned up, but some were cleaned and put into use and are probably still being used today. Could these wells be contaminated?
   b. Several people expressed concern that leachate from the mill tailings is still contaminating surface and groundwater. Does this represent a long-term health hazard? People are concerned about being exposed.
   c. Representatives of the Southeastern Utah District Health Department expressed concern that present and future downstream uses of Montezuma Creek water had not been fully taken into consideration and proposed that the final clean-up plan incorporate a suitable measure of health protection for all present and potential future users.
   d. The groundwater plume extends further downstream than the location where remediation and testing are taking place. Has this problem been studied adequately? Will people be exposed to contaminants in the 60 years or so that passive restoration of groundwater is expected to take?

C. General Health Outcome Concerns

1. **Community health data/monitoring:**
Many people are concerned about the long-term health effects of living near and/or working at the mill site. They would like to see comparisons of disease rates with rates for other towns and states with national data. They would also like to see long-term monitoring.

2. **Radiation health effects:**
People are concerned about the health effects of uranium, vanadium, and radon. Specifically, what are the likely health effects from drilling for ore and drilling to clean out wells at the mill site?

3. **Smoking/uranium synergism:**
What are the synergistic effects of smoking and uranium exposure leading to cancer?

D. Specific Health Outcome Concerns

1. Cancer:

Many people expressed concern about the numbers of people in the area with cancer and want to know if it is related to exposure to contaminants from the mill site, either while it was operating or after it closed. They were concerned about the following specific cancers, either because the respondent, a friend, or a family member had been diagnosed with the cancer or because there was a concern about the number of people in the community with the condition. The number enclosed in brackets indicates the number of persons expressing the concern.

a. breast cancer [16]
b. leukemia [13]
c. stomach/intestinal/colon/bowel cancers (A specific concern was the high rate of intestinal cancer in the area of town populated primarily by Spanish-speaking people.) [11]
d. skin cancer (including melanoma) [10]
e. liver cancer [6]
f. lymphoma [6]
g. lung cancer [5]
h. pancreatic cancer [4]
i. uterine/endometrial cancer [4]
j. Hodgkin disease [3]
k. mouth/throat cancer [2]
l. cancer of the cervix [2]
m. prostate cancer [2]
n. testicular cancer [2]
o. brain cancer
p. multiple myeloma
q. kidney cancer
r. thyroid cancer
s. mesothelioma (a person who worked at the mill and in the mines)
t. retinoblastoma
u. bone cancer

There was also concern about a perception of elevated rates of cancers, particularly leukemia, in Blanding.

2. **Other illnesses:**
Residents reported a range of noncarcinogenic conditions they suspect may be caused by living on or near the mill site, working at the mill site either when it was operating or during the cleanup, or playing on the mill site as children. Could the following illnesses be related to the mill site? The number enclosed in brackets indicates the number of persons expressing the concern.

a. respiratory problems (including bronchitis, pleurisy, pneumonia, asthma, frequent coughs, and sinusitis) [21] (A specific question: Could severe sinusitis experienced by a number of clean-up workers be related to exposure to mill tailings?)
b. heart disease (including mitral valve prolapse and high blood pressure) [9]
c. headaches (severe, chronic, migraine) [7]
d. kidney disease [6]
e. allergies [5]
f. eye disease/vision problems [5]
g. lumps/growths/moles [4]
h. birth defects [4]
i. dental problems (poor teeth, many cavities, soft teeth) [4]
j. loss of coordination/tremors/dizziness/blackouts [3]
k. emphysema [3]
l. miscarriages [3]
m. stillbirths [2]
n. mental retardation [2]
o. bone problems (including spinal curvature and brittle bone disease) [2]
p. arthritis [2]
q. digestive tract problems [2]
r. chronic fatigue syndrome [2]
s. pneumoconiosis (a former worker at the mill who had also worked in the mines)
t. anemia
u. high hematocrit
v. nosebleeds
w. slow healing of cuts
x. frequent infections
y. diabetes
z. muscle spasms
aa. thyroid disease
bb. neurofibromatosis
cc. Parkinson disease
dd. Crohn disease

Appendix D contains information on community concerns categorized as procedural concerns and community health concerns not related to the mill site.

OVERVIEW OF RADIATION

This section provides an historical perspective on radiation and discusses its effects on human health. In the 1890s, scientists learned how to produce a type of radiation they called x-rays, and they also found that certain naturally occurring elements emit particles and rays which they called radiation. Soon, radiation and radioactive materials were being used for medical purposes, both externally as well as internally, to diagnose and treat a host of medical conditions like ankylosing spondylitis, acne, and cancer. Commercial use of radioactive materials evolved and included making electron tubes, static eliminators, smoke alarms, and glow-in-the-dark watches. Radiation has been used for many purposes since its discovery but, like a double-edged sword, it has produced both good and bad effects as an historical review of its destructive side proves.

The effects of radiation were found to vary from one individual to the next, and with such factors as dose, dose rate, nonuniformity of dose distribution, type of radiation, gender, age, health status, portion of the body or organ involved, cell oxygen concentration, rate of cell division, density of ionization, and presence of carcinogenic promoting and radiation protective chemicals. In general, the effect increases with higher dose, higher dose rate, delivery of the dose in a shorter exposure period, larger portion of the body being exposed, the younger the individual (especially the embryo/fetus), and the higher the internal oxygen concentrations. To provide statistically useful information, it was necessary to select several large groups of individuals that had been exposed to large doses of radiation. Some of these groups included ankylosing spondylitis patients, radium dial painters, atomic bomb survivors, cancer therapy patients, and laboratory animal studies. Another group is the uranium miners where it was found that the ability of radon gas to produce lung cancer was enhanced by smoking and breathing silica dust and diesel fumes that were present inside the mines. The result is an understanding of the average and range of effects at high doses.

The reasons that individuals respond differently to radiation is complicated, but the reasons that radiation can affect an individual has been intensely studied. DNA is a two-stranded, twisted molecule inside cells that directs the formation on the proteins for human life. Radiation exposure can break one or both stands of the DNA molecule, break a bond that connects the two strands, or alter the sequence of the DNA building blocks. These processes can kill the cell, or allow it to produce nonfunctional tumor tissue or chromosomal abnormalities. The rate of these mutations would be higher than actually observed if it were not for repair mechanisms. A repair mechanism for broken strands cuts out the damaged section and reportedly regenerates it slowly and faithfully.

It would be useful to know the actual effects of radiation at the relatively low doses and low dose rates seen around Monticello. The effects at environmental levels, however, are too small to be seen directly, or perhaps, indirectly. Scientists calculate the effect from high dose studies and interpolate or estimate the effect at low environmental doses, or rely on epidemiologic studies that relate health incidence rates of a potentially exposed population with a control population. The extrapolation of effects from high doses to low has been considered by many to be linear with no threshold. This means that cutting the dose in half would reduce the effect by two, and there would be no dose below which there is no effect. Other possible dose-response charts have been suggested, but the linear-no-threshold model provides the basis for the most radiation protection practice. An example to the contrary is cataract formation, which clearly has a threshold and which is regulated with that in mind. Even though a threshold may exist for cancer production in humans, the production rate is so small at low doses that it is unlikely that the presence or absence of a threshold can be demonstrated.

Radiation protection recommendations and regulations have grown out of the need to protect patients, occupational workers, and the public from the potentially harmful effects of radiation, while allowing its beneficial use. Some beneficial uses include consumer products, various industries, and medical diagnosis and therapy. Even now, many people may just be starting to understand that the coal, natural gas, fertilizer, and other industries with no obvious relationship to radioactive material actually use and distribute large quantities of radioactive material. The doses of radiation in medical settings can be extreme, even when compared with either environmental or bomb survivor levels. The medical community recognizes that the potential harmful effects of radiation can be outweighed by the positive benefits of increased cancer cure rates, less need for surgery, and more effective diagnoses.

Radiological effects are usually classified in two groups (nondeterministic and deterministic) based on the statistical probability or determined certainty that they are due to radiation. The nature of how human biological quantities are changed distinguishes these. A short definition of each group, followed by an example, is provided below for explanation.

A. Nondeterministic Effects

A nondeterministic effect is one that occurs at random, or purely by chance, and cannot be related 100% to any particular case. Most diseases associated with smoking are considered a nondeterministic effect. For example, a person might develop lung cancer from smoking cigarettes. If the same person had not smoked, that person could have developed lung cancer anyway. There is no way to determine whether a particular person's lung cancer resulted from smoking cigarettes; i.e., there is no proof of a cause-effect relationship. Similarly, exposure to radiation does not guarantee that an individual will develop a certain medical condition, but it does increase the likelihood. Cancer is a main somatic effect that may be caused by radiation exposure, and includes such types as thyroid, skin, bone, breast, liver, lung, and leukemia.

Many scientists use the "linear no-threshold" assumptions to determine nondeterministic effects from radiation exposure. "No threshold" means that any exposure, no matter how small, may be harmful. "Linear" means that the probability of the development of an effect doubles as the exposure doubles.

Our present knowledge of science, radiation, and human anatomy suggests that a single change in just one of our body's cells can produce cancer or genetic defects. The body's cells are divided into two classes: somatic cells and germ cells. The majority of cells that make up our tissue, organs, and other parts of our body structure are somatic. The germ cells (sperm or ovum) are used for reproduction. Damage to the chromosomes (a small part of the cell), whether it comes from a single radiation particle such as an alpha or beta particle, an x-ray, or a gamma photon, can initiate the process. It is very important to realize that when considering nondeterministic effects even the smallest amount of exposure to radiation may carry an associated risk, and exposure to more radiation does produce a higher probability of a person acquiring certain medical conditions than no exposure at all.

Nondeterministic effects can be cumulative in a way that is additive, synergistic, or antagonistic. Additive effects are those where the total risk of acquiring cancer is the sum of the risks from all insults, such as receiving two doses of radiation in a short time period. Synergistic effects are those where the total cancer risk is greater than the sum of the individual risks, such as with smoking and breathing radon gas. In this case, the risk from doing both is more than the risk from smoking plus the risk from breathing radon. Antagonistic effects are those where the total risk is less than the individual risks. An example would be receiving two doses of radiation separated by a long period of time, during which the body's defense mechanisms provide partial repair before the second exposure is received.

B. Deterministic Effects

Deterministic effects do not occur at random but have a direct cause and effect relationship. Intoxication from drinking alcohol is considered a deterministic effect. For example, a person consuming alcohol might appear normal. After too many drinks, the person will appear a little woozy. If the person had not consumed alcohol he or she should not show signs of intoxication. So there appears to be proof of a cause-effect relationship between drinking and showing signs of intoxication.

Some radiation effects, including cataract formation, embryonic malformations, and radiation sickness, are deterministic. They have time and quantity thresholds, just as do the deterministic effects for alcohol. Individuals exposed to *very high* radiation doses in a short period of time do show a response. Normally, the more radiation exposure the individual experiences and the faster the exposure occurs, the more pronounced the biological effects will be and the sooner they will become evident. However, at low exposure rates, adverse health effects may not be noticed. At this point the radiation dose is below the threshold level. Exposures to uranium mill workers and populations surrounding mill tailings sites would have been well below the threshold level for deterministic effects.

C. Radioactive Health Effects

The amount of exposure, or dose, primarily determines whether radiation effects are nondeterministic or deterministic. Very high levels of radiation exposure, which are far above environmental levels, cause *acute* health effects, such as radiation sickness. Initial symptoms and the median acute dose that cause them include anorexia (97 rads), nausea (140 rads), fatigue (150 rads), vomiting (180 rads), and diarrhea (230 rads) (17, 18). The rad is the traditional measurement unit for radiation absorbed dose. The larger the dose, the quicker the symptoms and signs develop. Blood syndrome occurs rapidly at 100 to 250 rads, gastrointestinal tract syndrome at more than 1,200 rads, and central nervous system syndrome at more than 3,000 rads. The clinical symptoms of blood syndrome are bleeding in various organs and decreased blood pressure, of gastrointestinal tract syndrome are nausea and vomiting, and of central nervous system syndrome are convulsions and disorientation. Other clinical symptoms related to high levels of radiation exposure are loss of hair (2,000 to 3,000 rads), skin reddening (850 rads), skin damage (2,000 rads), and sterility as discussed later (18). These dose estimates can vary widely among individuals. At higher doses, the symptoms can indicate the onset of disease; for example, a highly upset stomach can indicate total destruction of cells lining the gastrointestinal tract. These types of health effects are readily noticeable--the radiation effects are deterministic, i.e., the effect is proportional to the dose. Immediate and continuing low-level exposures may produce later health effects. These are known as *chronic* or *delayed* health effects.

We have identified six areas of concern: cancer, mutations, infertility, degenerative effects, life shortening, and cataracts.

A large amount of data concerning cases in which humans experienced exposure to high levels of radiation has been collected (19). For those cases, it is not the acute health effects discussed earlier that are important, but the delayed health effects. Several questions are relevant. For instance, if a person were exposed, did the person develop cancer, how long after exposure, was the source of radiation inside or outside the body, what type of cancer, and how old was the person at the time of exposure? There is normally a latent period of about 10 to 15 years before any clinical signs or symptoms of carcinogenic effects appear. A lengthy plateau period, during which the risk of acquiring a late or delayed health effect exists, follows latency. However, leukemia caused by high radiation doses like those at Hiroshima and Nagasaki, Japan, is an exception. Its effects have been observed much earlier than with other forms of cancer, within a few years after exposure (20, 21).

A plateau period may last about 20 to 30 years. The risk of developing cancer is constant during the entire plateau period. Also, the higher the risk coefficient, the greater the probability that a person will develop cancer. The person's age at irradiation is also important. Evidence from human studies shows that a person's age at time of exposure can be a major determinant of radiation-induced cancer risk; the younger an adult is, the lower the risk of developing cancer becomes. However, unborn babies and children have a higher risk of developing cancer related to radiation exposure than exposed adults have.

Although cancer is probably the most important somatic radiation hazard, three of the other concerns merit brief discussion: degenerative effects, life shortening, and cataracts. Degenerative effects are failures of body organs to function properly. This does not necessarily imply complete failure, but it does indicate some amount of permanent impairment of the organ. Life shortening is believed to occur because of radiation-induced malignancies (cancer, tumors, etc.)--not because of any acceleration of the aging process. Cataracts, or vision-impairment of the eyes' lenses, normally occur after a long latent period. The threshold for lens opacity is 200 rads, and doses of 10 rads per year over many years should not affect the vision (18).

Effects discussed to this point have involved high radiation doses and the resulting damage to cell systems, i.e., injury to several cells or groups. Radiation exposure to a single cell may also produce damaging health effects. High doses of radiation to a single germ cell could lead to a variety of genetic defects in humans if the defect was passed on to the next generation. If the dose is received during pregnancy, defects could be observed in the developing fetus. Although the relationship between radiation exposure and probability of mutations is unclear, some clinically observable human defects, not necessarily related to radiation exposure, are point mutations (a single gene disorder), multiple point mutations (many gene disorders), chromosomal aberrations (e.g., Down syndrome), and spontaneous abortions.

Infertility is normally attributed to gamma-ray radiation of the human gonads. The amount of exposure, or dose, determines the probable effect. For males, a dose of 10 rads received within a short time period (hours to days), may cause a brief period of sterility, and 500 to 950 rads causes permanent sterility. For females, it takes 150 to 640 rads for temporary and 200 to 1,000 rads for permanent sterility depending on age (18). These values are thousands of times greater than the doses around Monticello (22).

These effects occur at doses resulting from higher exposures or doses than existed around Monticello. At doses below 10 rem, delivered over many years, epidemiologic studies do not appear to show any adverse health effects. This may be the result of the body's own defense and repair mechanisms at work, or because the effects are too small to detect. The health effects from acute radiation doses are summarized in Table 1.

Table 1. Summary of Radiation Health Effects From Acute Doses

Radiation Dose		Effect (Varies with factors like age, gender, and physical condition)
Gray (Gy)	Rads	
0.1-0.5 Gy to unborn child	10-50 rads	May cause leukemia
0.1 Gy to the testes	10 rads	Brief period of sterility
0.25-0.5 Gy	25-50 rads	Appearance of blood changes
1 Gy	100 rads	Lowest dose observed to cause leukemia in Nagasaki atom bomb survivors
1-2.5 Gy	100-250 rads	Blood syndrome occurs starting in this range. Includes nausea and vomiting within hours, loss of appetite, fatigue, temporary loss of hair in 2-3 weeks, and possible death in 1-2 months
2 Gy to the lens of eye	200 rads	Lens opacity threshold for total dose (not dependent on exposure time)
1.5-6.4 Gy to the ovaries	150-640 rads	Temporary female sterility
2-10 Gy to the ovaries	200-1,000 rads	Permanent female sterility
5-9.5 Gy to the testes	500-950 rads	Permanent male sterility
8.5 Gy to the skin	850 rads	Skin reddening
12 Gy or more	1200 rads	Gastrointestinal syndrome occurs at this dose from desquamation of the intestinal epithelium. The symptoms are severe nausea, vomiting, and diarrhea almost immediately after exposure, and death within 1-2 weeks.
20-30 Gy	2,000-3,000 rads	Permanent hair loss
30 Gy or more	3,000 rads	Central nervous system syndrome occurs due to damage of the central nervous system. Disorientation and unconsciousness occur within minutes and death within hours to several days.

NOTE: Table 1 includes the following definitions:

Gray (Gy) = International unit of measurement for radiation absorbed dose (1 Gy = 100 rads)
Rads = Traditional unit of measurement for radiation absorbed dose. One rad is defined as the absorption of 100 ergs per gram of material.

D. Discussion

Possible adverse health effects of radiation exposure (whether internal or external) are numerous and quite complicated. Such factors as a radionuclide's toxicity, its decay scheme, the pathway into the human body, and the amount of dose play an important role. Cosmic rays and natural terrestrial radioactivity from uranium, thorium, and their decay products also potentially affect one's health. Because of the city's high altitude, residents of Denver, Colorado, receive around 100 milliRoentgen equivalent man (mrem) a year more than residents of such sea-level cities as Miami, Florida (18). For comparison, a typical chest x-ray can deliver a dose of 20 mrem. Using the linear-no-threshold model in ICRP 60 and NCRP 91, one would conclude that in geographical areas with high radiation exposure rates, the health risk from radiation to the general public is greater than in areas where radiation exposure rates are lower. However, the health risk at such doses does not correlate well with the observed effect, possibly because other insults to the body can be more significant (23, 24).

SOURCES OF CONTAMINATION

There are three principal ways for radioactive materials to leave a mill site during processing of uranium or ore: airborne radioactive dust and radon-222 gas, water-soluble radionuclides, and mill tailings (both fine and coarse) (25). All of the radionuclides leaving the mill site are naturally occurring.

A radioactive series originates with a long-lived heavy element, eventually decaying by a number of emissions to a stable element marking the end of the series. Four series of naturally occurring radioactive elements exist in nature: the thorium series, neptunium series, uranium series, and actinium series. The uranium series (uranium-238 to lead-206) and the thorium series (thorium-232 to lead-208) are most likely to present biological hazards to people (26). The isotopes of both the uranium and thorium series--particularly radium-226 (radium), radon-222 (radon), thorium-234, and thorium-230 from the uranium decay series, and radium-228 (mesothorium), radium-224, radon-220 (thoron), thorium-232, and thorium-228 (radiothorium) from the thorium series--are of most concern to human health. Because the radionuclides in these series are naturally occurring, they are present throughout the environment. These radionuclides, along with other sources of radiation, such as cosmic radiation, all contribute to radiation levels that exist naturally. This natural radioactivity level is called the background radiation level.

A. Uranium Milling in General

Uranium-bearing ores removed from the earth contain between 0.1-0.2% uranium (28). The uranium in the Colorado Plateau ores is primarily in the form of hydrated oxide uranium minerals. These include carnotite ($K_2O \bullet 2UO_3 \bullet V_2O_5 \bullet 3H_2O$) and tyuyamunite ($CaO \bullet 2UO_2 \bullet V_2O_5 \bullet 8H_2O$). Mined ores are shipped to a uranium mill, where the uranium is separated from the rock. There, the uranium is purified into yellow cake. Yellow cake is the name conventionally used for uranium ore concentrates. Depending on the separation process, carbonate or acid leaching, the yellow cake contains 85% or more of uranium oxide (U_3O_8), a small percentage of red cake (vanadium pentoxide [V_2O_5]), and other compounds (25, 29). The acid process, in particular, tended to release gaseous reaction products such as CO_2 (carbon dioxide), H_2 (hydrogen), and H_2S (hydrogen sulfide). The process would have also released unreclaimed sulfuric and hydrochloric processing acids. However, these are chemical effluents and are not radioactive.

B. Uranium and Vanadium Production Methods at Monticello

The Monticello Uranium Mill used three extraction processes: salt roast, carbonate leach, and acid leach-resin pulp. The first operation in all three processes was crushing, grinding, and screening to produce fine sand. The salt roast process produced red cake (vanadium pentoxide [V_2O_5]) by mixing the sand with a sodium salt, roasting, washing out with water, precipitation, and heating under pressure. The other two processes took the fine sand and added liquid and chemicals to suspend the particles in the liquid. This leached or washed the uranium and vanadium out of the particles, and the useful liquid was then filtered. The carbonate leach process began next. Chemicals were added to the liquid, and the uranium compounds were precipitated. These uranium solids were filtered and steamed to make hard yellow cake (uranium oxides). Finally, in the acid leach process, chemicals were added to the remaining liquid to precipitate the vanadium compounds. These vanadium oxide solids were removed on filters, pressed to form red cake, and heated to make black cake (29, 30).

C. Wastes Produced

The Monticello Uranium Mill, like all chemical plants, produced several wastes. The first was residual ore material left along the roadways and at the ore-buying station. This material came from trucking the ore to the station, segregating it, and moving it to the mill. Other wastes produced at the mill site were in the form of dusts, fumes, gases, liquids, and solids.

Dust. The second waste produced was dust from the crusher and grinder. The crusher took the ore rock and made 1-inch gravel, and then the ball mill turned the gravel into fine mesh sand. The ball mill was the dustiest operation at Monticello. The coarse dust settled out near the grinder and was a breathing hazard to the operators. Uranium concentrates in the fine dust particles, which can be carried farther than coarse materials by the wind. A large portion of the dust particles were 1 to 10 microns (0.001 - 0.01 millimeters) in diameter (31). This size is respirable, meaning it can enter and lodge in the deep, air-exchange regions of the respiratory tract. Once there, it has the potential to cause biological damage from the radiation it emits or the chemicals it contains. If the particles are insoluble, they are partitioned so that some remain in place and produce damage by exposing the surrounding tissue to radiation; most others are coughed up and swallowed, exposing the stomach and intestines to radiation as they pass out of the body; and a small fraction may even pass directly into the bloodstream. If the particles are soluble, some will enter the bloodstream; others are coughed up and can enter the bloodstream via the intestines.

Fumes. The next waste was fumes released from the roaster stack at the end of the production cycle. For the purpose of this public health assessment, a fume is considered a process chemical that is added or formed during plant operation and released into the discharge air. This waste stream included chlorine and hydrogen chloride gas and an estimated 1,182 kilograms (2,600 pounds) of fine particles each day. These particles contained 0.363% uranium oxide and 1.52% vanadium pentoxide (32). Although the size distribution of particles was not reported, they were likely small enough to be carried far by the wind and would penetrate deeply into the lungs of people who inhaled them. Even after such particles settle out, they can later be resuspended by the wind and vehicles and be inhaled.

Gases. In this public health assessment, a gas is considered to be any item in the process that is normally a gas. Radon gas is considered to be the primary gaseous waste, and it came from all parts of the operation. This inert gas is formed during the natural radioactive decay of uranium and thorium, and produces human exposure primarily through inhalation. Radon was released from essentially all parts of the milling operation, and is still being released from the tailings piles and locations where tailings are still present. Measurements taken in 1983 and 1984 showed that the concentrations of radon gas on site, at the boundary, and at various locations off site exceeded the administrative limit of 0.90 picocuries per liter (pCi/L). Remediation efforts appear to be successfully reducing the levels off site.

Liquids. Liquid tailings were the leftover processing liquids. The waste resulted from milling and leaching the ore, and from washing the filtered oxides. The main chemicals it contained were chlorides, sulfates, carbonates, and bicarbonates of sodium and other metals. Nitrates were added to this list late in the plant's operating history when ammonium nitrate was added as a process chemical. The liquid effluents flowed into a tailings pond and finally into Montezuma Creek, which runs through the mill site. The water with dissolved and suspended pollutants then became available for watering livestock and for irrigating crops and pasture grass.

Solids. Solid tailings were the leftover solid process wastes. They contain the original ore and the chemicals added during extraction, less most of the uranium and vanadium. The tailings were placed into four separate piles: the Carbonate Pile, Vanadium Pile, Acid Pile, and East Tailings Pile. The damp material normally stayed in place, but as it dried, the wind blew it off the mill site, contaminating some of the nearby land. By 1962, Atomic Energy Commission (AEC) representatives had covered the piles with earth and seeded them to reduce the public health risk. Rain and creek water, however, continue to wash some tailings downstream. Currently, the rate at which radon gas is being released from the tailings piles exceeds the EPA recommended limit of 20 picocuries per square meter second (pCi/m^2s). Radon gas consists of both Rn-220 and Rn-222, but the short 51.6 second half-life of Rn-220 makes Rn-222 the isotope of concern in health evaluations. Therefore, exposures to Rn-220 would not be of health concern. Radon gas also is released from the piles at elevated levels, but the levels are lower than levels present when the piles were uncovered.

The radioactive materials in the gas, liquid, and solid waste streams were mainly thorium and daughters of thorium and uranium. Radionuclides created when uranium or thorium decays toward a stable element and emits radiation are called "daughter" products. Tables 2 and 3 show the decay series for the uranium series and thorium series, respectively. Note that radium and radon gas are in those decay chains. Because the mill had removed most of the uranium, the tailings are less radioactive than the original ore.

Each table has 4 columns: element number, isotope, half-life, and energy. The element number is the atomic number of the atom as listed in the Periodic Table of the Elements. Each element may have many radioactive isotopes--same atomic number but different mass numbers (left superscript). The half-life is the time it takes for one-half of the atoms of an isotope to decay. Longer half-lives indicate a more stable radionuclide. Column 4 indicates the energy of the decay particle. Usually the higher the particle or photon energy, the more ionizing power it has.

Radioactivity involves the spontaneous decay of an unstable atomic nucleus accompanied by the emission of a particle or photon or both. There are basically three different types of decay products of interest: alpha (α), beta (β), and gamma (γ) rays. An alpha particle is a positively charged helium atom. Alpha radiation is the least penetrating of the three, subject to being stopped by a mere sheet of paper or a few centimeters of air. It is not normally considered dangerous, except when the alpha-emitting substance has been ingested or inhaled (33). Beta particles are electrons, either positively or negatively charged. Beta particles are easily stopped by a thin sheet of metal or a few feet of air. Beta radiation may cause skin burns, and a beta emitter is harmful inside the body. Gamma rays are high-energy photons, somewhat higher in energy than x-rays. Gamma radiation frequently accompanies alpha or beta emission and is the most penetrating of all three.

D. Uranium and Thorium Decay Schemes

Table 2. Uranium Series (34)

Element Number	Isotope and Types of Emission*	Half-Life	Energy (MeV) (Most Prominent) *
92	uranium-238 α, γ	4.5 x 10^9 years	4.19 α; 0.05 γ
90	thorium-234 β, γ	24.1 days	0.19 β; 0.06 γ
91	protactinium-234m ** protactinium-234 β, γ	1.14 minutes 6.7 hours	2.3 β; 1.0 γ 0.48 β; 0.17 γ
92	uranium-234 α, γ	250,000 years	4.7 α; 0.05 γ
90	thorium-230 α, γ	75,400 years	4.68 α; 0.07 γ
88	radium-226 α, γ	1,622 years	4.78 α; 0.19 γ
86	radon-222 α, γ	3.8 days	5.49 α; 0.58 γ
84	polonium-218 α	3.1 minutes	6.0 α; 0.5 γ
82	lead-214 β, γ	26.8 minutes	0.67 β; 0.35 γ
83	bismuth-214 β, γ	19.9 minutes	3.3 β; 0.61 γ
84	polonium-214 α	0.000164 seconds	7.68 α; 0.8 γ
82	lead-210 β, γ	22.3 years	0.02 β; 0.047 γ
83	bismuth-210 β	5.0 days	1.16 β
84	polonium-210 α, γ	138.4 days	5.3 α; 0.8 γ
82	lead-206	stable	-

* α = alpha particle, β = beta particle, and γ = gamma ray
** m = The m on 234m means this is an excited or metastable state of protactinium-234

Table 3. Thorium Series (34)			
Element Number	Isotope and Types of Emission*	Half-Life	Energy (MeV) (Most Prominent)*
90	thorium-232 α, γ	1.4×10^{10} years	4.00 α; 0.059 γ
88	radium-228 β, γ	5.8 years	0.039 β; 0.014 γ
89	actinium-228 β, γ	6.1 hours	1.2 β; 0.9 γ
90	thorium-228 α, γ	1.9 years	5.42 α; 0.08 γ
88	radium-224 α, γ	3.6 days	5.68 α; 0.24 γ
86	radon-220 α, γ	55.6 seconds	6.28 α; .055 γ
84	polonium-216 α	0.15 seconds	6.77 α; 0.8 γ
82	lead-212 β, γ	10.6 hours	0.33 β; 0.24 γ
83	bismuth-212 α, β, γ	60 minutes	6.08 α; 2.2 β; 0.7 γ
84	polonium-212 α	2.98×10^{-7} seconds	8.78 α
81	thallium-208 β, γ	3.1 minutes	1.79 β; 2.6 γ
82	lead-208	stable	-
* α = alpha particle, β = beta particle, and γ = gamma ray			

ENVIRONMENTAL CONTAMINATION AND OTHER HAZARDS

Contaminants discussed in later sections of this public health assessment are evaluated to determine whether exposure to them has public health significance. ATSDR staff members select and discuss contaminants based on several factors: sample design, field and laboratory data quality, and comparison of chemical concentrations to levels that could cause cancer or other health effects. We also consider community health concerns.

Evaluating the sample design involved reviewing Department of Energy Remediation Program regulations and the approach to locating contamination. ATSDR scientists consider spatial distribution of sampling locations, sampling frequency, concentration changes over time, medium-to-medium differences, and correlation between the selected list of analytical parameters and suspected environmental contaminants when determining the contaminants to which humans could be exposed.

Review of sampling field quality control procedures included interpreting data on background (or regional) concentrations of chemicals and checking the adequacy and number of replicate, spiked, and blank samples to verify detection of contaminants. We reviewed procedures used to verify instrument reliability to assess laboratory quality control.

Contaminant concentrations detected on and off site are compared with comparison values, contaminant concentrations in specific media that are considered protective of public health (values that are believed to be without adverse health effects upon exposure). ATSDR and other agencies have developed the comparison values to provide guidelines for estimating contaminant concentrations in media at which adverse health effects are not expected to occur. A standard daily ingestion rate and body weight are assumed in deriving these values. These values, in many cases, have been derived from animal studies. Health effects are related not only to the exposure dose but also to the route of entry into the body and the amount of chemical absorbed by the body. For those reasons, comparison values used in public health assessments are contaminant concentrations in specific media and for specific exposure routes. Several comparison values may be available for a specific contaminant. ATSDR scientists use the most conservative assumptions (that is, we assume exposure to the maximum concentration) in order to protect the most sensitive segment of the population. The Public Health Implications section of this document contains a discussion of the potential for adverse health effects from exposure to contaminants.

The following paragraph is to provide additional clarification concerning comparison values. Comparison values are concentrations in environmental media, such as air, soil, or water, below which adverse health effects are not expected to occur as a result of likely exposures. Comparison values are used to determine which contaminants require additional evaluation concerning possible exposure scenarios and adverse health effects. These levels are derived using conservative assumptions about exposures. Because of their conservative nature, and because they are not derived using site-specific information, comparison values should never be used as clean-up levels. Their use should be limited to the initial screening of site contamination information.

The following abbreviations are used in Tables 4-12:

ATSDR Agency for Toxic Substances and Disease Registry.

EPA Environmental Protection Agency.

NTP National Toxicology Program.

BDL below detection limit. A chemical detected during chemical analysis is reported as BDL if the concentration detected is below the minimum concentration verifiable (can be duplicated through multiple analyses) by the analytical technique specified for that chemical. Analytical techniques have both a lower (minimum concentration detectable) and an upper (maximum concentration detectable) limit.

CREG cancer risk evaluation guide (ATSDR). Derived by ATSDR from the EPA cancer slope factor. It represents a concentration in water, soil, or air at or below which excess cancer risk is not likely to exceed one case of cancer in a million (10E-6) persons exposed over a lifetime.

EMEG environmental media evaluation guide (ATSDR). Derived by ATSDR from ATSDR's minimal risk level (MRL). It is the concentration in water, soil, or air at or below which daily human exposure is unlikely to result in adverse noncancerous effects.

RMEG reference dose (or concentration) media evaluation guide (EPA). Derived by ATSDR from the EPA oral reference dose. It is the concentration in water or soil at or below which daily human exposure is unlikely to result in adverse noncancerous effects.

MCL maximum contaminant level. Enforceable drinking water regulation established by EPA that is protective of human health to the "extent feasible" over a lifetime. MCLs represent contaminant concentrations that EPA scientists deem protective of public health over a lifetime (70 years) at an exposure rate of 2 liters of water per day. MCLs are also regulatory concentrations. MCLs take into account technological and economic feasibility.

mg/kg milligrams per kilogram (parts per million). The unit applied to express contaminant concentrations in soil.

N/A not applicable

NA not available

ND no data were collected.

pCi/g picocuries per gram of soil. The unit applied to express radioactive contaminant concentrations in soil.

pCi/L picocuries per liter of air or water. The unit applied to express radioactive contaminant concentrations in air or water.

μg/L micrograms per liter of water (parts per billion). The unit applied to express contaminant concentrations in water.

RAC reasonably anticipated to be a carcinogen (National Toxicology Program designation).

Class A Carcinogen human carcinogen (EPA designation).

Class B1 Carcinogen probable human carcinogen (EPA), based on limited human studies and sufficient animal studies.

Class B2 Carcinogen probable human carcinogen (EPA), based on inadequate human studies and sufficient animal studies.

EMEGs and CREGs are the first choice for comparison values. In addition, any contaminants will be contaminants of concern if they have no CREG, but have been designated as carcinogens or potential carcinogens by 1) the National Toxicology Program in the Department of Health and Human Services, 2) the EPA, or 3) the International Agency for Research on Cancer. If a contaminant is not a carcinogen, and has no EMEG, then the following values (in order of preference) will be chosen for the comparison value if available: the RMEG, the lifetime health advisory (derived by EPA, a drinking water concentration at or below which adverse, noncancerous adverse health effects would not be expected) or child longer-term health advisory (derived by EPA, a drinking water concentration at or below which adverse, noncancerous adverse health effects would not be expected in children after exposure up to 7 years in duration) (whichever is lowest), the maximum contaminant level goal (non-enforceable drinking water health goal recommended by EPA and set at a level at or below which no known or anticipated adverse human health effects are expected), the MCL, or the action level (derived by EPA for use in evaluating drinking water, the concentration in water at or below which daily human exposure is unlikely to result in adverse noncancerous effects).

We conducted a search of EPA's Toxic Chemical Release Inventory (TRI) for the San Juan County area to determine the extent of reported environmental contamination releases. The TRI, established through the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires the reporting of estimated annual releases of chemicals into the environment since 1987 (35). The database includes the annual quantity of toxic chemicals discharged into each environmental medium (air, water, and land) by manufacturing facilities that employ more than 10 people and are in Standard Classification Codes 20 through 39 (as in effect since July 1, 1985) (36). The Monticello Mill Tailings Site has not been in operation since 1960; therefore, no chemical releases were recorded on this database for the mill site. No local chemical releases were listed as originating from communities in San Juan County.

A. Surface Soil Contamination

A.1 On-Site Surface Soil

Surface soils (0-6 inches) have been contaminated in various ways, including storage of ore in open stockpiles, emissions from the roaster stack (heat process used to convert vanadium minerals to a soluble form), overflow of tailings ponds, and the erosion of tailings piles by wind and water. Results of a radiometric survey show that most of the mill site surface soil contains concentrations of radium-226 exceeding EPA Standard 40 Code of Federal Regulations (CFR) 192.12 for cleanup of land and buildings contaminated with residual radioactive materials from inactive uranium processing sites. EPA Standard 40 CFR 192.12 identifies areas as contaminated if their radium-226 concentrations in soils exceed 5 pCi/g above background in the top 15 centimeters (approximately 6 inches) of soil or 15 pCi/g above background in any 15-centimeter (cm) layer below the top 15 cm (1).

DOE representatives are conducting a background analysis and taking samples at selected peripheral properties. The result of the analysis would provide data to support whether or not there is a correlation between radioactive and nonradioactive materials. As of yet, there are no convincing analyses or evaluations to support this unproven assumption.

Analytical results of soil samples, together with results of in-situ spectrometer measurements, indicate an average natural background radium-226 concentration of 1.0 +/- 0.4 pCi/g. The average concentration of radium-226 in the surface soil layer (0-15 cm, or approximately 6 inches) is 20 pCi/g over the mill site. Contamination of cover material has been attributed to redistribution of tailings by burrowing animals (4).

The tailings generated by the mill site operations are in four piles referred to, in order of their construction, as the Carbonate Pile, Vanadium Pile, Acid Pile, and

East Pile (see Appendix F, Figure 10). Field investigations of the piles were conducted during the Remedial Investigation in 1990 and again as part of the Monticello Remedial Action Program in 1991. Nonradioactive composite samples were taken from borings and pits when radium-226 measurements were above 15 pCi/g. Borings were drilled to various depths to 50 feet or more; while the pits ranged from 9.5 to 21.5 feet deep. The samples were analyzed for the following nonradioactive contaminants:

- Antimony (Sb)
- Arsenic (As)
- Beryllium (Be)
- Cadmium (Cd)
- Chromium (Cr)
- Copper (Cu)
- Lead (Pb)
- Mercury (Hg)
- Molybdenum (Mo)
- Nickel (Ni)
- Selenium (Se)
- Silver (Ag)
- Thallium (Tl)
- Vanadium (V)
- Zinc (Zn) (1)

Maximum concentrations of each nonradioactive element found in the tailings piles were evaluated for potential health implications. Seven contaminants of concern were identified: arsenic, beryllium, chromium, copper, lead, nickel, and vanadium. Table 4 contains the concentration found and comparison values for each. The Pathways Analysis and Public Health Implications sections of this public health assessment contain further discussions of each contaminant of concern.

Table 4. Nonradioactive Contaminants of Concern in On-Site Tailings Piles (37)

Chemical	Maximum Concentration (ppm)	Comparison Value * (ppm)	Source
Arsenic	179	0.4 N/A	ATSDR CREG EPA-A
Beryllium	3.9	0.2 N/A	ATSDR CREG EPA-B2
Chromium	203	N/A	EPA-A
Copper	4,650	NA	NA
Lead	334	N/A	EPA-B2
Nickel	91	N/A	NTP-RAC
Vanadium	32,223	2,000	ATSDR Intermediate EMEG

N/A = not applicable
NA = not available
EPA-A = Environmental Protection Agency-human carcinogen
EPA-B2 = Environmental Protection Agency-probable human carcinogen
NTP-RAC = National Toxicology Program-reasonably anticipated to be a carcinogen
CREG = cancer risk evaluation guide
EMEG = environmental media evaluation guide
ppm = parts per million

* Value believed to be without adverse health effects upon exposure.

A.2 Off-Site Surface Soil

North and east off-site areas contaminated with radium-226 above EPA standard 40 CFR 192.12 (5 pCi/g above background in the top 15 centimeters (cm) of soil or 15 pCi/g above background in any 15 cm layer below the top 15-cm) are predominantly farming lands but include some residences. Windblown surface soil contamination is found as far as 0.5 mile north and 0.25 mile east of the mill site. Radium-226 concentrations above EPA standards ranged from 6 pCi/g to 494 pCi/g and averaged 27 pCi/g (1).

The major source of nonradioactive contaminants is confined to the tailings piles on site. A much smaller area with lower concentration of contamination occurs in stream sediments east of the mill site in an area used to pasture cattle and produce some crops. During milling operations, tailings, mixed with stream sediments, were deposited on the Montezuma Creek flood plain. Samples were taken in pasture soil south and east of the mill site in the flood plain, then were analyzed for tailings-related contaminants. Maximum concentrations of each contaminant were evaluated for potential health implications for any children who might play in the area. Additional sampling of sediments for nonradioactive contaminants were collected during the Operable Unit (OU) III study. The purpose of the OU III study was to collect sufficient information and data to characterize the nature and extent of environmental contamination in OU III, identify the sources of contamination, assess changes in contamination patterns over time once on-site sources (tailings piles) have been removed, and to calculate the levels of risk to human health and the environment from the contaminants associated with OU III. The OU III soil and sediment area, which is located entirely on private land, begins approximately 0.5 miles east of the eastern mill site boundary and extends downstream approximately 14,100 feet. The area is currently used for cattle grazing and recreational purposes; no residences are located within the OU III soil and sediment study area. Soil and sediment characterization began in 1994 and continued through September 1996. The primary source of soil and sediment contamination in the OU III soil and sediment study area is the mill site. Montezuma Creek, which flows through the tailings piles on the mill site, has been the primary transport mechanism for soils and sediments (38). Table 5 contains a list of contaminants of concern chosen for further consideration based upon sampling data collected during environmental monitoring program activities and the most recent OU III study. The Pathways Analyses section of this public health assessment addresses each contaminant of concern.

Table 5. Nonradioactive Contaminants of Concern in Off-Site Sediments(37)

Chemical	Maximum Concentration (ppm)	Comparison Value * (ppm)	Source
Arsenic	12	10	ATSDR EMEG
Beryllium	1	0.2	ATSDR CREG
Cadmium	<1	N/A	EPA-B1
Chromium	22	N/A	EPA-A
Lead	22	N/A	EPA-B2
Nickel	22	N/A	NTP-RAC
Thallium	<2	NA	NA
Uranium	237	200	ATSDR RMEG
Vanadium	545	200	ATSDR EMEG

ppm = parts per million
N/A = not applicable
NA = not available
EPA-A = Environmental Protection Agency-Human Carcinogen
EPA-B1 = Environmental Protection Agency-Probable Human Carcinogen
EPA-B2 = Environmental Protection Agency-Probable Human Carcinogen
NTP-RAC = National Toxicology Program
EMEG = environmental media evaluation guide
CREG = cancer risk evaluation guide
RMEG = reference dose media evaluation guide

* Value believed to be without adverse health effects upon exposure.

B. Surface Water Contamination

B.1 On-Site Surface Water Contamination

Surface water monitoring of Montezuma Creek has included collection of samples from upgradient (upstream), on site, and downgradient (downstream with respect to the mill site) locations. The creek, which flows through the mill site property, has frequently contained contaminants at levels exceeding comparison values as far as 3 miles downgradient of the property. Appendix F, Figure 11, depicts on-site surface water sampling locations, and Table 6 lists on-site surface water contaminants. Some contamination in the creek resulted from discharge of the contaminated alluvial aquifer beneath the mill site, although the primary source of contamination appeared to be past surface runoff from the tailings piles. Current controls in place collect and treat surface water before it is discharged. Alluvial groundwater is still providing base flow contaminants to Montezuma Creek. Montezuma Creek is used for both irrigation and livestock watering downgradient of the mill site.

To facilitate comparison of upgradient, on-site, and downgradient concentrations, the on-site and the off-site surface water contamination discussions of this public health assessment are combined.

B.2 Off-Site Surface Water Contamination

The two upgradient surface water sources used by the city of Monticello public water system are monitored in accordance with the Safe Drinking Water Act and Utah state requirements; those standards have not been exceeded for site-related contaminants. ATSDR representatives have used concentrations of chemicals detected during the monitoring program to depict naturally occurring concentrations for comparison with site-related data.

Montezuma Creek, the main surface water body in the project area, flows from west to east through the middle of the mill site property. Although flow is generally perennial, the creek can be quite low or dry during the late summer. Other surface water bodies on the mill site include ponds, seeps, and drainages. Surface water sampling at the mill site has had four primary goals: 1) compare upstream water quality conditions of Montezuma Creek with conditions on site and downstream from the mill site, 2) characterize the type and extent of contamination in surface water sources, 3) verify compliance with state surface water quality standards, and 4) detect changes in water quality resulting from remedial actions (39).

Montezuma Creek is one source for the city of Monticello municipal water supply about 1 mile upgradient of the mill site. Utah state regulations (Title 26, Chapter 11, Utah Code Annotated) place the segment of Montezuma Creek that flows through and downgradient from the mill site into four use classifications: 1) Domestic Source lC, 2) Recreation and Aesthetics 2B, 3) Agriculture, and 4) Aquatic Wildlife 3B. Downgradient surface water is used primarily for livestock watering and agricultural irrigation (1).

Appendix F, Figure 11, depicts upgradient and on-site surface water sampling locations. Two sampling locations (W-3 and W-5) have been the historic sources of upgradient water quality samples from Montezuma Creek. In November 1992, locations SW92-01, SW92-02, and SW92-10 replaced W-3 and W-5 as upgradient sampling locations (40).

Before November 1992, on-site sampling was limited to three locations: the drainage between the Carbonate and Vanadium Tailings Piles (W-2), the seep-fed pond adjacent to the Carbonate Tailings Pile (designated Carbonate Seep), and the low spot between the Carbonate and Vanadium Tailings Piles (designated North Drainage). In November 1992, on-site sampling was expanded to include two locations on Montezuma Creek, SW92-04 and SW92-05 (41).

Figures 12a and 12b, in Appendix F depict downgradient surface water sampling locations. In past years, downgradient water quality within Montezuma Creek was monitored at three locations: the W-4 site, approximately 325 feet downstream of the east boundary of the property; the Sorenson site, approximately 1.25 miles downstream of the mill site, and the Montezuma Canyon site, approximately 6 miles downstream of the mill site. In November 1992, four additional locations were sampled downstream of the property (SW92-06, SW92-07, SW92-08, and SW92-09) (41).

From 1987 through April 1992, surface water samples were analyzed for the following constituents: gross alpha, radium-226, radium-228, uranium-234, uranium-238, thorium-230, arsenic, molybdenum, nitrate, selenium, and vanadium. Tests in the field measured alkalinity, pH, and specific conductance. In November 1992, the list of surface water analytes was expanded to include aluminum, ammonia, antimony, boron, barium, beryllium, gross beta, calcium, cadmium, chlorine, cyanide, cobalt, chromium, copper, fluorine, iron, herbicides, lead, mercury, potassium, magnesium, manganese, nickel, nitrite, pesticides/polychlorinated biphenyls (PCBs), polonium-210, radon-222, semivolatile organic compounds, silver, sodium, sulfate, total dissolved solids, thorium-232, thallium, total uranium, volatile organic compounds, and zinc. During this same period, biological oxygen demand, chemical oxygen demand, and levels of fecal coliform, total coliform, total suspended solids, and total organic carbon were determined from samples collected at locations SW92-01, SW92-02, and SW92-10 (41).

The most recent sampling rounds (November/December 1992, March 1993, April/May 1993, July 1993, October 1993, May 1994, October 1994, April 1995, October 1995, February 1996, April 1996, and June 1996) furnished surface water contamination data for comparison with concentrations detected upgradient, on site, and downgradient from 1984 to 1992. Those concentrations exceeding comparison values are selected as contaminants of concern. Table 6 presents those surface water contaminants detected in concentrations exceeding comparison values during the most recent and historical sampling rounds. Listing the contaminants of concern maximum concentrations for the most recent surface water sampling rounds and the historical maximum concentrations for those contaminants of concern portrays the site's actual impact on downgradient water quality over time. In the case of nitrate contamination, although the site did contribute to contamination of downgradient surface water, screening values were exceeded upgradient. The Pathways Analyses section of this public health assessment contains further discussions of the contaminants.

Table 6. Contaminants of Concern in Surface Water (38, 42)

Constituent	Maximum Concentration[1]			Historical Maximum Concentration[2]			Comparison Value[3]	Source
	Upgradient	On-Site	Downgradient	Upgradient	On-Site	Downgradient		
Arsenic *	BDL (3 µg/L)	454 µg/L	15.1 µg/L	3.9 µg/L	3,600 µg/L	27 µg/L	0.02µg/L 50 µg/L	CREG MCL
Molybdenum	2.6 µg/L	321 µg/L	90.9 µg/L	178 µg/L	3,420 µg/L	340 µg/L	50 µg/L 100 µg/L	RMEG (CHILD) MCL
Nitrate	24,600 µg/L	18,500 µg/L	7,190 µg/L	3,000 µg/L	64,100 µg/L	10,007 µg/L	10,000 µg/L	MCL
Selenium	9.7 µg/L	41.4 µg/L	17.5 µg/L	6 µg/L	3,110 µg/L	42 µg/L	30 µg/L 50 µg/L	EMEG (CHILD) MCL
Vanadium	5.9 µg/L	7,830 µg/L	280 µg/L	142 µg/L	63,600 µg/L	750 µg/L	30 µg/L	EMEG (CHILD)
Gross Alpha *	BDL (1.0 pCi/L)	1,209 pCi/L	350 pCi/L	17 pCi/L	3,300 pCi/L	547 pCi/L	15 pCi/L	MCL
Radium-226 *	0.5 pCi/L	7.4 pCi/L	2.2 pCi/L	0.5 pCi/L	23.8 pCi/L	13 pCi/L	15 pCi/L	MCL
Uranium-234 and -238 *	5.5 pCi/L	1,638.5 pCi/L	350.7 pCi/L	9.7 pCi/L	2,336 pCi/L	399.8 pCi/L	15 pCi/L	MCL

NOTE: Table 6 includes the following abbreviations and footnotes:

BDL = below detection limit (analytical lower detection limit is in parentheses)
CREG = cancer risk evaluation guide
EMEG = environmental media evaluation guide
RMEG = reference dose media evaluation guide
MCL = maximum contaminant level from EPA Drinking Water Standards
NA = not available
pCi/L = picocuries per liter of water
µg/L = micrograms per liter of water (parts per billion)
* = Class A carcinogen

[1] Maximum concentration detected during the most recent surface water sampling rounds: November/December 1992, March 1993, April/May 1993, July 1993, October 1993, May 1994, October 1994, April 1995, October 1995, February 1996, April 1996, and June 1996.

[2] Maximum concentration detected for all surface water sampling rounds 1984 through 1992, excluding the November/December 1992 sampling round.

[3] Value believed to be without adverse health effects upon exposure.

Concentrations of arsenic, molybdenum, selenium, vanadium, gross alpha, radium-226, uranium-234, and uranium-238 increase within Montezuma Creek as the creek flows across the mill site and downgradient. Seeps from the shallow aquifer are visible along the creek downstream of the eastern mill site boundary, and creek discharge increases throughout this section for approximately 1.25 miles. Historical assessments of water quality data indicate that the highest downgradient concentrations of mill tailings-related constituents occur at either the W-4 site or at the Sorenson site. Both sampling sites are downgradient of the mill site (41).

Since 1985, selenium concentrations have consistently been below comparison values at the upgradient (W-5) location. Samples from the W-4 and Sorenson locations, which are 0.06 and 1.2 miles downstream of the mill site, respectively, have exceeded comparison values regularly. Selenium concentrations are also consistently below comparison values 6 miles downstream of the mill site at the Montezuma Canyon location. Selenium concentrations exceeded the comparison values at on-site locations during the recent sampling.

Since 1987, gross alpha levels have been below detection limits at the upgradient (W-5) location. Gross alpha concentrations have exceeded comparison values at the W-4, Sorenson, and Montezuma Canyon sampling locations. The trend continued through the 1995 sampling rounds (43).

Higher concentrations of mill tailings-related contaminants have been detected in the ponds and seeps on the mill site than in Montezuma Creek because the ponds and seeps are surface expressions of the groundwater (see On-Site Groundwater Contamination). Analyte concentrations in the seeps and ponds are similar to those in alluvial aquifer groundwater samples collected from wells near the Vanadium and East Tailings Piles. Levels of gross alpha (140 pCi/L), arsenic (245 μg/L), and selenium (26 μg/L) exceeded comparison values in at least one of the ponds or seeps.

Nitrate, although not totally a site-related contaminant, is a contaminant of concern in surface water because of historical and recent detection upgradient, on site, and downgradient at concentrations exceeding comparison values. Common agricultural activities around the mill site, such as the use of fertilizers, are known to cause nitrate contamination of surface water. Nitrate detected in upgradient surface water samples is not a site-related contaminant but is rather the result of those agricultural activities; however, nitrate detected in on site and downgradient surface water samples is, at least in part, site-related, resulting from former process operations at the mill. During the last 4 years of the mill site's active operations, ammonium nitrate and other miscellaneous oxidizers were added to a process for extracting and concentrating uranium from a liquid solution. A maximum of 2 tons per day of ammonium nitrate was used in the process, with the residual waste effluent from the process discharged to the Acid and East Tailings Piles (30). Nitrate was therefore selected as a contaminant of concern because both historical and recent concentrations in upgradient, on site, and downgradient surface water are elevated. The Public Health Implications (A. Toxicological Evaluation) section of this public health assessment contains further discussion of potential health effects of nitrate ingestion.

A wastewater treatment plant, designed to treat contaminated surface water runoff from the mill site and groundwater encountered during excavation to the tailings piles, began operation in May 1995. The wastewater treatment plant is designed to remove heavy metals and radionuclides from ground and surface wastewaters at an average flow rate of 60 gallons per minute. During operations, through August 21, 1995, influent and effluent samples were obtained and, with the exception of mercury and silver concentrations, effluent limits set by the Utah Department of Environmental Quality, Division of Water Quality, were not exceeded. A position paper was submitted to the Department of Water Quality in March 1996 to propose higher effluent limits for mercury and silver; approval was subsequently granted (44).

C. Groundwater Contamination

C.1 On-Site Groundwater Contamination

Two aquifers underlie the Monticello Mill Tailings Site (MMTS) and the surrounding area. Unconsolidated materials (such as loose sands and gravel) deposited by Montezuma Creek constitute an alluvial aquifer along the valley bottom. An underlying sandstone aquifer, the Burro Canyon Formation, is separated from the alluvial aquifer by the Mancos Shale Formation and by fine-grained units of the Dakota Sandstone Formation, both of which act as aquitards in the mill site area. Aquitards are low permeability geologic formations or groups of formations that impede groundwater flow from one aquifer to another (1).

The alluvial aquifer is approximately 16 feet thick near Montezuma Creek in the vicinity of the Carbonate Tailings Pile and thins gradually upgradient and downgradient from this location and toward the valley sides. Montezuma Creek is hydraulically connected (joined) with the alluvial aquifer on the upstream side of the East Tailings Pile. However, because of a realignment of the stream channel, the alluvial aquifer and Montezuma Creek are separated in the vicinity of the East Tailings Pile. The creek and the aquifer are reunited downstream of the East Tailings Pile (31).

The alluvial aquifer is recharged from infiltration of precipitation (rainfall and snow), surface water, and water that has percolated the Mancos Formation and the sediment gravel on the valley sides. Like the local surface waters, water levels within the aquifer fluctuate seasonally. The alluvial aquifer discharges into Montezuma Creek. Transmissivity values for the alluvial aquifer beneath the East Tailings Pile were determined from a pump test and ranged from 3.3×10^{-4} to 5.4×10^{-4} square meters per second. As the alluvial groundwater moves to the east and southeast across the mill site, it is degraded by contaminants leached from the mill tailings. Groundwater from the alluvial aquifer is not used in the vicinity of the mill site as a water source for human consumption, but it is used to irrigate crops and provide water for livestock (1).

The Burro Canyon Formation is a confined aquifer under the mill site, separated from the alluvial aquifer by an aquitard consisting of the Mancos Shale Formation and fine-grained units of the Dakota Sandstone Formation. Those geological units limit downward migration from the alluvial aquifer. The EPA and Utah Department of Environmental Quality (UDEQ) have challenged DOE's interpretation of the hydrologic conditions. Site-specific information indicates that there is a joint/fracture system possibly related to the uplift of the Abajo mountains. The Mancos Shale on the mill site is weathered and varies in thickness from 0 to less than 40 feet. Studies of the hydrologic heads of paired wells in the Mancos Shale, Dakota Sandstone, and Burro Canyon Formation in the vicinity of the mill site indicate that the movement is downward. Although EPA and UDEQ remain confident that contamination has not reached the Burro Canyon Formation, there is conflicting data as to whether radiological contamination from the mill site is present in the Dakota Sandstone.

The Burro Canyon Aquifer is recharged through the tilted, exposed area of the formation located along the margin of the Abajo Dome west of the mill site. Discharge from the aquifer occurs across the Great Sage Plain, along erosional margins, and in areas where canyons dissect the formation. Numerous stock ponds and marshy areas are created as a result of spring-fed discharge from the aquifer (1). Residences in the Monticello area not connected to the municipal water supply use the deep Burro Canyon Aquifer as a source of potable water (water used for drinking, cooking, showering, etc.).

Water quality data used to characterize groundwater chemistry in the mill site area come from sampling of selected monitoring wells that were installed beginning in 1982. Although some other wells were installed before 1982, the validity of samples collected from those wells is questionable because of poor well completion records. Data cited in this public health assessment are from those wells considered to yield reliable samples on the basis of satisfactory well completion records and relatively consistent well performance over several years. ATSDR staff members reviewed the DOE-validated groundwater sampling data from the March 1984 through the June 1996 sampling round (38, 42).

DOE's current groundwater monitoring strategy is to sample 6 upgradient wells (3 alluvial, 3 Burro Canyon), 10 on-site wells (7 alluvial, 3 Burro Canyon), and 8 downgradient wells (5 alluvial, and 3 Burro Canyon). The upgradient wells characterize groundwater quality before contact with mill site contamination, the on-site wells characterize the extent of groundwater contamination on site, and the downgradient wells characterize the impact of the mill site contamination on groundwater before the water leaves the mill site. Appendix F, Figure 13, depicts groundwater monitoring well locations upgradient and on site; Appendix F, Figure 14, depicts groundwater monitoring well locations downgradient (46, 47). Groundwater samples were analyzed for organic and inorganic chemicals, and radioactive parameters. Organic analytes included EPA's target compound list (TCL): volatile organic compounds, semivolatile organic compounds, herbicides, and pesticides/PCBs (see Appendix B). Inorganic analytes included major anions (chloride, cyanide, fluoride, nitrate, nitrite, and sulfate); major cations (ammonium, calcium, magnesium, potassium, and sodium); metals (aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, uranium, vanadium, and zinc); total dissolved solids; gross alpha; gross beta; and radionuclides (polonium-210, radium-226/228, thorium-230/232, uranium-234/238, and radon-222) (41).

Detected concentrations from the most recent sampling rounds (November/December 1992, March 1993, April/May 1993, July 1993, December 1993, May 1994, October 1994, April 1995, October 1995, February 1996, April 1996, and July 1996) provide data for comparing groundwater contamination that exceeds comparison values in the alluvial and Burro Canyon Aquifers, with concentrations detected upgradient, on site, and downgradient from 1984 to 1992. Table 7 presents groundwater contaminants detected in concentrations exceeding comparison values during the most recent and historical sampling rounds. The Exposure Pathways section of this public health assessment contains discussions of those contaminants.

Contaminant concentrations detected in samples from upgradient alluvial and Burro Canyon wells did not exceed comparison values during the most recent sampling rounds, with the exception of elevated nitrate concentrations detected in the alluvial aquifer. Nitrate detected in upgradient alluvial aquifer samples is not a site-related contaminant but is rather the result of agricultural activities; however, nitrate detected in on-site and downgradient samples from the same aquifer is, at least in part, site-related because of former process operations at the mill. During the last 4 years of the mill site's active operations, ammonium nitrate and other miscellaneous oxidizers were added to a process for extracting and concentrating uranium from a liquid solution. A maximum of 2 tons per day of ammonium nitrate was used in the process, with the residual waste effluent from the process discharged to the Acid and East Tailings Piles (30). Nitrate was therefore a contaminant of concern because of both historical and recent elevated concentrations in upgradient, on-site, and downgradient alluvial aquifer groundwater. The Public Health Implications (A. Toxicological Evaluation) section of this public health assessment contains further discussion of potential health effects of nitrate ingestion. Historical upgradient sampling (1984 to 1992) detected selenium and gross alpha contamination in excess of comparison values.

Groundwater sampled from the alluvial aquifer on site is contaminated by elements leached from the tailings piles. In general, the highest contaminant concentrations are found in the vicinity of the Vanadium and East Tailings Piles. Historically, levels of arsenic, molybdenum, selenium, vanadium, gross alpha, radium-226, radium-228, uranium-234, and uranium-238 have, at times, exceeded comparison values. During the 1993 sampling rounds, levels of those compounds continued to exceed comparison values in one or more on-site groundwater samples.

A sample collected during the November/December 1992 sampling round, from one on-site Burro Canyon well (84-77) had uranium (43.43 pCi/L) and gross alpha (46.67 pCi/L excluding uranium and radon) activities above the comparison value of 15 pCi/L. Subsequent sampling rounds, up to July 1996, did not detect concentrations above the comparison values. This well will continue to be sampled to determine whether the uranium and gross alpha activities measured in the July 1993 sample were anomalous or represented contamination in the aquifer. Other detected contaminant concentrations from on-site Burro Canyon wells were below comparison values.

Table 7. **Contaminants of Concern in Groundwater for the Alluvial Aquifer (38, 42)**

Constituent	Maximum Concentration[1]			Historical Maximum Concentration[2]			Comparison Value[3]	Source
	Upgradient	On-Site	Downgradient	Upgradient	On-Site	Downgradient		
Arsenic *	12 μg/L	166 μg/L	131 μg/L	10 μg/L	190 μg/L	54 μg/L	0.02 μg/L 50 μg/L	CREG MCL
Molybdenum	BDL (50 μg/L)	812 μg/L	190 μg/L	60 μg/L	1,440 μg/L	213 μg/L	50 μg/L 100 μg/L	RMEG (CHILD) MCL
Nitrate	20,900 μg/L	198,000 μg/L	28,600 μg/L	19,600 μg/L	67,766 μg/L	33,308 μg/L	10,000 μg/L	MCL
Selenium	BDL (5 μg/L)	57 μg/L	51 μg/L	13 μg/L	160 μg/L	42 μg/L	30 μg/L 50 μg/L	EMEG (CHILD) MCL
Vanadium	BDL (50 μg/L)	2,920 μg/L	2,890 μg/L	NA	3,630 μg/L	90 μg/L	30 μg/L	EMEG (CHILD)
Gross Alpha *	BDL (1 pCi/L)	5,060 pCi/L	1,400 pCi/L	15 pCi/L	7,280 pCi/L	547 pCi/L	15 pCi/L	MCL
Radium-226 and -228 *	0.6 pCi/L	12 pCi/L	0.1 pCi/L	0.2 pCi/L	44 pCi/L	13 pCi/L	15 pCi/L	MCL
Uranium-234 and -238 *	6 pCi/L	4,440 pCi/L	2,870 pCi/L	13 pCi/L	8,525 pCi/L	533 pCi/L	15 pCi/L	MCL

NOTE: Table 7 includes the following abbreviations and footnotes:

BDL = below detection limit (analytical lower detection limit is in parentheses)
CREG = cancer risk evaluation guide
EMEG = environmental media evaluation guide
RMEG = reference dose media evaluation guide
MCL = maximum contaminant level
NA = not available
pCi/L = picocuries per liter of water
μg/L = micrograms per liter of water (parts per billion)
* = Class A carcinogen

[1] Maximum concentration detected during the most recent groundwater sampling rounds: November/December 1992, March 1993, April/May 1993, July 1993, October 1993, May 1994, October 1994, April 1995, October 1995, February 1996, April 1996, and July 1996.
[2] Maximum concentration detected for all groundwater sampling rounds 1984 through 1992, excluding the November/December 1992 sampling round.
[3] Value believed to be without adverse health effects upon exposure.

Downgradient alluvial aquifer monitoring wells on private property east of the mill site have provided evidence of contaminant migration. Previous and current groundwater sampling has detected levels of arsenic, molybdenum, selenium, gross alpha, radium-226, radium-228, uranium-234, and uranium-238 in concentrations exceeding comparison values. Limited historical sampling data did not indicate downgradient vanadium contamination in excess of comparison values; however, the more comprehensive recent sampling has detected vanadium at concentrations exceeding comparison values. Comparison values have not been exceeded in groundwater samples collected from downgradient off-site Burro Canyon Aquifer wells (84-74, 83-70, and 92-10) during either historical sampling or the recent sampling rounds (40).

Sampling for TCL (EPA's target compound list)--volatile organic compounds, semivolatile organic compounds, pesticides/PCBs, and herbicides--in the alluvial and Burro Canyon Aquifers has been conducted both historically and during the recent sampling rounds (see Appendix B). With the exception of a few semivolatile and volatile organic compounds detected and confirmed as common laboratory contaminants and introduced during the sampling and analysis process (acetone, bis[2-ethylhexyl] phthalate, chloroform, and methylene chloride), all concentrations of TCL volatile organic compounds, TCL semivolatile organic compounds, TCL pesticides/PCBs, and TCL herbicides have been below comparison values (40).

Semivolatile and volatile organic compounds that were not TCL analytes but were detected in groundwater samples were reported as tentatively identified compounds (TICs). A TIC is a chemical that is detected during analysis, but cannot be confirmed because the laboratory instrument utilized was not calibrated for that specific chemical. The result is an estimated concentration. Because of the low estimated concentrations detected (<58 μg/L), those chemicals are not considered potential contaminants of concern in groundwater (40).

A well abandonment project at the mill site was completed in September 1992. This project included DOE's abandonment of three wells that were used for water production during operation of the uranium mill, and four bedrock core holes that were installed for investigative purposes in 1982. In 1996 numerous wells on the mill site were abandoned. Abandonment was necessary because of the age, unknown construction information, and lack of use of the wells. Abandonment also eliminated a potential conduit for contaminant migration from the alluvial aquifer into the Burro Canyon Aquifer (41).

C.2 Off-Site Groundwater Contamination

There has been no off-site monitoring of private wells used as domestic water sources by people living outside the city of Monticello. However, those wells are screened in the lower Burro Canyon Aquifer, which has not shown evidence of site-related contaminant concentrations in excess of comparison values. A definitive well survey followed by initiation of private well monitoring should be considered if site-related contaminants begin to appear in downgradient Burro Canyon Aquifer samples.

D. Air Contamination

Air investigations have centered around two potential types of contaminants: 1) radon-222, a radioactive gas produced by the natural decay of radium-226, which is contained in the buried uranium mill tailings, and 2) airborne radioactive and nonradioactive particles associated with the tailings (1).

D.1 Radon in Air

Extensive measurements of radon concentrations were done at 19 sampling locations from November 2, 1983, to November 19, 1984. Duplicate samplers were placed 1 meter (3.3 feet) above ground level at each location. The 19 sample stations were divided among 3 different regions; 4 on site near the center of each tailings pile, 7 at the edge of the mill site boundary, and 8 at off-site locations. These locations are shown in Appendix F, Figure 15.

The measured value for background was determined to be 0.41 pCi/L based on an average of the data points. This background value was added to the allowable increase of 0.5 pCi/L to yield an administrative limit of 0.91 pCi/L. (The limit of 0.5 pCi/L comes from the 40 CFR 192 regulation for Inactive Uranium Processing Sites). Table 8 shows the maximum amount of radon-222 found at each sampling location from November 2, 1983, through November 19, 1984.

Table 8. Results of 1983-1984 Radon-222 Survey (1)

Sampling Location	Maximum Concentration (pCi/L)
On Pile	
ST-A	5.35
ST-E	9.80
ST-V	8.18
ST-C	9.61
Edge of Site	
ST-1	3.32
ST-2	4.94
ST-3	1.93
ST-5	2.21
ST-6	3.46
ST-7	4.19
ST-8	4.36
Off-Site	
ST-4	2.51
ST-9	0.82
ST-10	0.47
ST-11	1.10
ST-12	0.47
ST-13	0.58
ST-14	1.18
ST-15	0.58

All but five locations exceeded the administrative limit of 0.91 pCi/L. The 19 measurement locations used during this time were reduced to 8 thereafter. These 8 locations are shown in Appendix F, Figure 16 (31). In response to increased remediation activities, seven off-site locations were added during the third quarter of 1993. Annual surveys of these 15 stations show elevated radon concentrations at three points (2 on site and 1 off site about 0.5 kilometer east of the mill site boundary). The three points that exceed the administrative limit of 0.91 pCi/L range from 1.0 to 3.3 pCi/L (see Table 9).

Table 9. Atmospheric Radon-222 (pCi/L) (41,43)

Monitoring Station	1987	1988	1989	1990	1991	1992	1993	1994	1995
ST-4	1.1	1.3	1.8	1.39	1.5	1.5	1.1	1.2	1.0
ST-6	1.0	2.6	1.3	1.32	1.3	2.6	1.1	1.2	1.0
ST-7	1.7	1.4	3.3	1.94	3.0	1.3	2.8	1.7	1.9
ST-13 (background)	0.4	0.4	0.2	0.5	0.3	0.4	0.3	0.4	0.3

Note: DOE is using 0.91 pCi/L as the maximum allowable based on a limit of 0.50 pCi/L measured above a background of 0.41 pCi/L (40 CFR 192, Inactive Uranium Processing Sites).

Two new radon monitors were also installed adjacent to the mill site in 1992 to monitor the effect of increased construction activity at the mill site on ambient radon concentrations (see Appendix F, Figure 16). Average Monthly Real-Time Radon Monitoring Results are shown in Table 10. Station 1 exceeded the EPA standard during most of 1992, but concentrations at Station 2 were consistently below the EPA standard. During 1993 both stations were consistently below the EPA standard.

Table 10. **Average Monthly Real-Time Radon Monitoring Results for 1992-93** (31, 41)

Sampling Period	Station 1 (pCi/L)	Station 2 (pCi/L)	EPA Standard (40 CFR 192)
1992			
August	0.9	0.7	0.9
September	1.0	0.8	0.9
October	1.1	0.8	0.9
November	1.1	0.7	0.9
December	0.7	0.6	0.9
1993			
January	0.4	ND	0.9
February	0.5	ND	0.9
March	0.3	0.2	0.9
April	0.3	0.3	0.9
May	0.4	0.3	0.9
June	0.6	0.4	0.9
July	0.8	0.5	0.9
August	0.7	0.5	0.9
September	ND	ND	0.9
October	0.7	0.6	0.9
November	0.6	0.7	0.9
December	0.6	ND	0.9

NOTE: Table 10 includes the following abbreviations:

pCi/L = picocuries per liter
ND = no data were collected

Throughout the period of active operations, tailings from the mill site were used in the city of Monticello as fill for open lands; as backfill around water, sewer, and electrical lines; as sub-base for driveways, sidewalks, and concrete slabs; as backfill against basement foundations; and as sand mix in concrete, plaster, and mortar. The total tonnage of tailings removed from the mill site is estimated at approximately 135,000 tons (3). A potential health hazard exists from the radon-222 gas generated by the radioactive decay of radium-226 in those construction materials. The primary potential for exposure to radon-222 gas exists in confined spaces, without adequate ventilation, such as buildings where the gas can accumulate over time. Routine monitoring of buildings in Monticello has detected concentrations of radon in excess of comparison values. Therefore, the potential for exposure to radon-222 gas is further evaluated in the Pathways Analyses section, and the health effects resulting from exposure to radon-222 gas are presented in the Public Health Implications (A. Toxicological Evaluation) section of this public health assessment.

D.2 Nonradioactive Particulates

Air particulate measurements were begun at the mill site in August 1983. Sampling stations were located to the north and east in the path of prevailing wind patterns, with one background station placed west of the mill site. Sample station locations are pictured in Appendix F, Figure 17 (1). EPA has not accepted DOE's sampling locations for background air particulate measurements. An audit will be conducted to determine the appropriate locations for air monitoring. The samplers were placed 9 feet above ground level and operated for 24 hours every sixth day. Samples were not collected in winter months due to weather and snow cover on the tailings piles. Nonradioactive analytes that were detected included barium, copper, iron, lead, manganese, potassium, and vanadium. Maximum concentrations and the locations where they were detected are shown in Table 11. Detected concentrations were not significantly higher than ambient background concentrations; therefore, these analytes are not site-related contaminants (1).

Table 11. Nonradioactive Off-Site Air Contaminants of Concern 1984-1986 (1)

Chemical	Maximum Concentration ($\mu g/m^3$)	Sampling Station	Comparison Value * ($\mu g/m^3$)	Source
Barium	0.0135	5 North	0.52	EPA HEAST
Copper	0.0766	5 North	140	EPA HEAST
Lead	0.0490	5 North	1.5	NAAQS
Iron	2.0232	4 East	0.859	Background Measurement
Manganese	0.0392	4 East	0.3	EMEG/MRL
Potassium	1.2875	4 East	0.878	Background Measurement
Vanadium	0.1305	4 East	26.0	EPA HEAST

NOTE: Table 11 includes the following abbreviations:

$\mu g/m^3$ = micrograms per cubic meter (air)
EMEG = environmental media evaluation guide
EPA = Environmental Protection Agency
HEAST = health effects assessment summary tables
MRL = minimum risk level
NAAQS = national ambient air quality standard

* Value believed to be without adverse health effects upon exposure.

D.3 Radioactive Particulates

Radium-226, thorium-230, and uranium-238 particulates were sampled from 1984 through 1986 at locations near the mill site. Appendix F, Figure 17, shows the sampling locations. Sampling station 5 North had the highest concentration of radium-226 (0.0022 pCi/m^3) and the 4 East sampling station had the highest concentration of both thorium-230 (0.0011 pCi/m^3) and uranium-238 (0.0011 $\mu g/m^3$) (1). These concentrations are not at levels of public health concern.

D.4 Past Air Emissions

Earlier air emissions during plant operation consisted of end products, process chemicals, and reaction products. The end products were uranium oxide (U_3O_8) and vanadium pentoxide (V_2O_5) released during a salt roast process used to recover vanadium. Both are relatively nonreactive; however, vanadium pentoxide is an oxidation catalyst (45). The primary process chemicals added during different stages included sulfuric acid (a corrosive acid), sodium chlorate (a strong oxidizer), sodium carbonate (a base), and ammonium nitrate (a strong oxidizer with corrosive thermal decomposition fumes). The reaction products formed during the chemical reactions would have included a wide variety of compounds. This is because the ore contained a range of uranium and vanadium compounds, and the process chemicals would have encountered a large number of chemical valence states during the reactions. Emissions of these chemicals yielded about 1,200 kilogram per day of dust (46, 47). Increased corrosion of metal objects (fences, screen doors, and chrome automobile bumpers) presented evidence of these releases to the environment. Present atmospheric particulate concentrations are far below the EPA's National Primary Air Quality Standards defined in the Clean Air Act 1977, as amended. Uranium is typically measured three to four orders of magnitude below its respective Derived Concentration Guide (DCG), the concentration that would cause a member of the public to receive a dose of 100 millirem per year from inhalation of a specific radionuclide. Lead (Pb), the contaminant closest to its DCG, showed concentrations typically less than 1/10 of the standard of 1 $\mu g/m^3$. Consequently, lead measurements were discontinued in 1991 and, according to the data reports, will be "restarted at the time of tailings removal" (48).

E. Food Chain Contamination

E.1 On-Site Food Chain Contamination

Contamination in the soil and water represent a potential for contamination of game animals on the mill site. The security fence does not prevent large game animals from entering the mill site. Small game animals, such as rabbits, can also enter the mill site for grazing. Cattle are not presently pastured on the mill site, although cattle are pastured on lands immediately adjacent to the mill site.

E.2 Off-Site Food Chain Contamination

Contamination in the soil and water represent a potential for contamination of game animals, domestic cattle, and any food crops grown in the Montezuma Creek area. Several ranchers run cattle on the Montezuma Creek floodplain and canyon downgradient from the mill site.

EPA and UDEQ staff were equally concerned about food chain contamination. In the fall of 1996, EPA and UDEQ conducted a study of the body burden of contaminants in tissues and organs of deer and cattle that consumed water and vegetation from the Montezuma Creek floodplain. EPA sampled cattle that were fenced in the middle and lower canyon. The deer that were harvested and sampled were the resident herd in the Montezuma Creek floodplain and canyon east of the mill site. Cattle and deer from a background reference area were also sampled. The meat, liver kidney, and ribs are being analyzed for radionuclides and nonradionuclide contaminants. Although the analyses have not yet been completed, preliminary results indicate little or no contaminant uptake in cattle or deer above the uptake in the reference area animals.

F. Quality Assurance and Quality Control

This public health assessment incorporates environmental sampling data provided by DOE and MACTEC Environmental Restoration Services (formerly RUST Geotech, Inc., then formerly Chem-Nuclear Geotech), the primary DOE contractor at the mill site. ATSDR staff members assumed that adequate quality assurance and quality control (QA/QC) measures, as outlined in the August 1992 Sampling and Analysis Plan for Environmental Monitoring, were followed with regard to chain-of-custody, laboratory procedures, and data validation/reporting. The QA/QC measures applied to the media sampling data in the documents provided to ATSDR scientists appear to be consistent with standard protocols for environmental sampling and analysis.

G. Physical Hazards

Physical hazards observed at the mill site were heavy equipment operation, vehicular traffic, and load handling. However, only DOE employees and contractors who have received prior safety training are permitted to work on site. General public access is restricted. Staff members from the mill site's Occupational Health and Safety (OH&S) Office are present during the workday, conducting safety inspections and monitoring personnel exposure. There has been a fence around the mill site since August 1975, and lockable gates control access. Site visits did not produce any evidence of trespassing. ATSDR staff members did not observe any physical hazards that would threaten the general public's health.

ATSDR scientists will continue to review any future environmental contamination and other hazards resources that become available. Should additional information become available that alters the findings of this public health assessment or addresses issues described herein, this public health assessment will be modified as needed.

PATHWAYS ANALYSES

There are five main pathways into the human body for radioactivity and tailings-related substances from uranium mill sites:

1. inhaling radon and radon daughters,
2. inhaling and ingesting radioactive and chemical particles,
3. ingesting contaminated foods produced in the area contaminated by radionuclides and nonradionuclide chemicals,
4. drinking water contaminated by radionuclides and chemicals, and
5. encountering external gamma ray exposure (1).

ATSDR scientists reviewed substantial information regarding exposure to and uptake of radionuclides in the environment and the impact(s) on the public's health as we prepared this document. We used a pathway model to look at the movement through entry points into the human body.

To determine whether people are exposed to contaminants migrating from a site, ATSDR representatives evaluate the environmental and human components leading to human exposure. An exposure pathway consists of five elements: 1) a source of contamination, such as tailings piles or waste pits; 2) an environmental medium in which the contaminants might be present or from which they might migrate, such as groundwater or soil; 3) points of human exposure, such as drinking water wells or work areas; 4) routes of exposure, such as inhalation, ingestion, or dermal absorption; and 5) a potentially exposed population.

A completed exposure pathway occurs when the five elements of an exposure pathway link the contaminant source to a receptor population. Should a completed exposure pathway exist in the past, present, or future, the population is considered exposed.

A potential exposure pathway exists when one or more of the five elements are missing. Potential pathways indicate that exposure to a contaminant could have occurred in the past, could be occurring now, or could occur in the future.

A. Pathways Model

Scientific studies identify the waste streams as they form and move through a plant such as the mill. The plant's waste streams can be solid, liquid, gas, or any combination of the three. Each stream will take some course through the environment and might eventually reach humans. This study traces those streams through the environment and shows ways they expose the human community. Placing the streams on a chart known as a pathways model makes them easy to understand.

Figure 18, Appendix F, is a pathways model for a typical uranium mill. It applies to both radioactive and nonradioactive materials. To use it, start with the top block, marked Operating Uranium Mill. Then trace along the arrows from block to block, noting the title of each block in order until the path ends. As an example, you could find out how radioactive material or chemicals from the mill site get into hamburgers. One way is the air-soil-pasture grass-grazing animal-meat pathway. This pathway existed when the mill operated. Uranium oxide left through the roaster stack and followed the gaseous waste pathway into the air. From there it took several paths, and in one it settled out onto the soil. The pasture grass absorbed it through the root system. Then grazing cattle ate the grass. The cattle were slaughtered for meat, and humans ate hamburgers and steaks. Figure 18, Appendix F, shows several pathways by which the uranium oxide exhausted into air reached humans via the meat they ate.

Some pathways are more important than others for exposing people to radiation. Each individual's lifestyle, work and home locations, and eating habits constitute a unique pattern that results in various ways an individual might be exposed to radiation. Figure 19, Appendix F, shows the pathways that are perhaps most significant to the average person in the Monticello community today. They are the ones that lead to inhaling radon gas and receiving direct radiation from radioactive material deposited on soil. Others would include direct radiation from working with construction materials and eating food crops that contain radioactive materials either inside or on the surfaces. The same food washing practices that are important from a hygiene standpoint will probably be effective in removing radioactive material from the vegetables' surfaces as well. Most pathways have low potential with little chance of producing measurable exposure. Human radiation exposure from both inhaled radon gas and the tailings themselves is expected to be negligible once the tailings piles are removed and capped and all other contaminated areas are remediated.

Special pathways can be added for unique circumstances, such as a child playing on the tailings piles. The solid waste-tailings piles-playing on tailings-direct radiation pathway would perhaps give the largest dose equivalent. Incidental ingestion of dirt might also be an important source of exposure.

B. Completed Exposure Pathways

As Table 12 shows, we identified two completed surface soil pathways and one completed air pathway.

Table 12. Completed Exposure Pathways

Path Name	Compounds	Exposure Pathway Elements				
		Source	Media	Point of Exposure	Route of Exposure	Exposed People
On-Site Surface Soils	Radium-226 Radon-222	Tailings Piles	Surface Soils	On-Site	Ingestion Inhalation Dermal Absorption	Workers
Off-Site Surface Soils	Beryllium Chromium Lead Nickel Thallium	Tailings Piles	Surface Soils	Off-Site	Ingestion Inhalation Dermal Absorption	Residents Farmers Ranchers Hunters Golfers
Off-Site Air	Radium-226 Radon-222	Tailings Piles	Air	Off-Site Buildings	Inhalation	Residents

B.1 On-Site Surface Soil Pathway

Past, current, and future completed exposure pathways are possible because of surface soil contamination. All soil contamination originated from the tailings piles. There has been no nonradioactive surface soil sampling on site before 1995. The assumption is that, because most of the surface soil has radium-226 levels above 15 pCi/g, nonradioactive contamination is also present. Workers employed in sampling and remediation activities at the mill site have the potential for occupational exposure to the previously discussed contaminants of concern through inhalation, ingestion, and dermal absorption. They could be exposed to chemicals at the mill site while handling of waste materials through soil disturbance. Adhering to proper work practices and procedures as defined by state or federal regulatory or permitting authorities can eliminate these possible exposures.

Workers may also be exposed by inhaling radon-222. Radon-222 comes from the radioactive decay of radium-226 in the tailings. Radon is a noble gas and therefore does not enter into chemical reactions that would fix or immobilize it; it subsequently migrates from the tailings into the atmosphere. On-site radon-222 measurements show levels above normal background. Radiation doses from inhaled or ingested radionuclides are adjusted using a series of modifying factors that account for the different decay types and energies. By this method, internal and external doses can be summed.

Exposure to external gamma radiation from the tailings also poses a potential health hazard. The Thermoluminescent Dosimetry (TLD) Quarterly Measurement Program began in April 1991, and the data were reviewed for three quarters in 1991; no data are available for the period since 1992. Results from these stations, most of which are near the mill site boundary, indicate rather significant annual doses delivered to the near-boundary vicinity. Measured exposure rates, at three locations, are approximately 200 to 300 millirem per year (mrem/yr) above the nominal 100 mrem/yr background found at the mill site. The three points with highest exposure are sites 5, 6, and 12 (Figure 20, Appendix F) (31).

Only DOE employees and contractors who have received prior safety training are permitted to work on site. The general public's access is restricted. Staff members from the mill site's Occupational Health and Safety (OH&S) Office are on site during the workday, conducting safety inspections and monitoring personnel exposure. To limit radiation exposure, and comply with the site safety plan, OH&S staff members conduct routine radioactive surveillance that includes radiation surveys, surface contamination surveys, and air monitoring; they also establish controls for access to posted hazardous areas. Employees working on the mill site are required to participate in an occupational health program involving medical surveillance and exposure monitoring.

There is a chain-link fence around the mill site, and lockable gates control access. Site visits did not produce any evidence of trespassing. The restricted access to the mill site limits the potential hazard to workers involved in site characterization and remediation activities.

B.2 Off-Site Surface Soil Pathway

Past, current, and future completed exposure pathways are possible because of surface soil contamination. The major source of contamination is the tailings piles on the mill site. However, throughout the operating period, mill tailings from the Monticello Mill Tailings Site were used as fill for open lands; backfill around water, sewer, and electrical lines; sub-base for driveways, sidewalks, and concrete slabs; and in backfill, plaster, and mortar for construction in the city of Monticello. The total amount of uranium mill tailings removed from the mill site for construction purposes, although never documented, is believed to be approximately 135,000 tons. The retrieval of contaminated tailings from the mill site was restricted by August 1975 (3).

Moreover, additional soils were windblown from the mill site to adjacent properties in Monticello and to stream sediments east of the mill site. The area east of the mill site is used for cattle pasture and crop (for cattle, not human consumption) production. The off-site elements deposited in pasture soils might enter the food chain when they are ingested with food crops and animal products. Contaminants have been and continue to be released from the tailings piles through natural events, such as rain and wind. Rain has washed contamination into Montezuma Creek. A major flood could release significant amounts of contamination into the Montezuma Creek and floodplain. Contaminants have either leached from the tailings piles or been windblown into other environmental media. Caps on each tailings pile have controlled this movement to a degree; however, contaminants have been detected in soils and sediments north and east of the mill site.

Soil contamination off site might generate possible pathways of exposure for several populations. Residents whose properties were contaminated by windblown erosion or whose structures were constructed with tailings might be exposed through several routes. Ingestion of food potentially contaminated through uptake and accumulation of nonradioactive and radioactive substances by plants and animals is one route. Other routes include inhalation of contaminated dust particles and radon-222, dermal contact with contaminated soil, or direct exposure to gamma radiation. Hunters, ranchers, and farmers are potentially exposed to contaminants through ingestion of contaminated food, dermal absorption, inhalation of contaminated particulates, or direct exposure to gamma radiation.

The Public Health Implications (A. Toxicological Evaluation) section of this public health assessment contains further discussion of potential adverse health effects resulting from ingestion, inhalation, and dermal absorption of contaminants from off-site surface soils.

B.3 Air Pathway

Off-site past, current, and future completed pathways are possible because of radium contamination at the mill site. Various levels of radon-222 gas have been detected during routine monitoring of off-site structures. The radioactive decay of radium-226 in the soil generates radon-222 gas. Radon is a noble gas and therefore does not enter into chemical reactions that would fix or immobilize it; it subsequently migrates from the contaminated soil into the atmosphere. Inhalation of radon and its alpha-emitting decay products in confined spaces may increase human cancer risk. While this report has summarized outdoor concentrations of radon-222, we cannot make a complete evaluation of exposure to residents or workers until we analyze data from indoor measurements.

The Public Health Implications (A. Toxicological Evaluation) section of this public health assessment contains further discussion of potential adverse health effects resulting from inhalation of radon-222 gas.

C. Potential Exposure Pathways

Table 13 contains information on the groundwater, surface water, and food chain potential exposure pathways.

Table 13. Potential Exposure Pathways

Path Name	Compounds	Exposure Pathway Elements					Time
		Source	Media	Point of Exposure	Route of Exposure	Exposed Population	
Groundwater Upper Aquifer	Arsenic Molybdenum Nitrate Selenium Vanadium Gross Alpha Radium-226,-228 Uranium-234,-238	Tailings Piles	Groundwater	Off-Site Private Wells Used for Drinking Water	Ingestion	Private Well Users Tapping the Upper Aquifer (unknown number) (Most likely an improbable occurrence and will remain incomplete, although there is a potential for use in the future.)	Future
Surface Water	Arsenic Molybdenum Nitrate Selenium Vanadium Gross Alpha Radium-226,-228 Uranium-234,-238	Tailings Piles	Surface Water	Off-Site Montezuma Creek	Ingestion	Farmers Ranchers Hunters	Past Current Future
Food Chain	Arsenic Molybdenum Nitrate Selenium Vanadium Gross Alpha Radium-226,-228 Uranium-234,-238	Tailings Piles	Surface Water Uptake Into the Food Chain	Contaminated Meat/Plants	Ingestion	Consumers	Past Current Future

C.1 Groundwater Potential Pathway

Contaminants from the tailings piles (arsenic, molybdenum, nitrate, selenium, vanadium, gross alpha, radium-226, radium-228, uranium-234, and uranium-238) have leached into the shallow alluvial aquifer. Those contaminants have been detected in the shallow aquifer at concentrations exceeding comparison values. However, direct human contact with groundwater from the shallow aquifer, resulting in a completed exposure pathway, appears unlikely for two reasons. First, the shallow aquifer is not presently used as a source of potable water and is unlikely to be used in the future as a public water supply because of the unreliable well yield and limited saturated thickness. Residents in the area downgradient of the mill site currently obtain their water from the Monticello public water supply, which uses uncontaminated, topographically upgradient surface water sources. Second, the extent of the aquifer, which is physically confined to the narrow boundaries of the Montezuma Creek alluvial gravels, is limited. The aquifer downgradient of the mill site is estimated to be no more than 500 feet wide, and the contamination plume extends no more than a mile downgradient before it discharges into the creek. The plume has, therefore, reached its maximum dimensions. To prevent use of the contaminated alluvial aquifer as a source of potable water, institutional controls (establishing local ordinances that prevent the installation of wells screened in the contaminated alluvial aquifer) are effective in ensuring that the aquifer is not used during the time required for restoration.

The shallow alluvial aquifer overlies the deeper Burro Canyon Aquifer, which is used as a drinking water source. The Mancos Shale and shale units on the Dakota Sandstone, which separate the Burro Canyon Formation from the alluvial aquifer, act as aquitards to limit downward migration from the alluvial aquifer.

Water sampling data for private residential drinking water wells in areas surrounding the Monticello Mill Tailings Site are not available; furthermore, it is possible that additional undocumented private wells border the mill site, although we do not know that specifically. Potential for future exposure exists if any residents should use water in the future from contaminated portions of the shallow alluvial aquifer.

The Public Health Implications (A. Toxicological Evaluation) section of this public health assessment contains further discussion of potential adverse health effects resulting from ingestion of contaminated groundwater from the shallow alluvial aquifer.

C.2 Surface Water Potential Pathway

Tailings-related contaminants enter Montezuma Creek where the contaminated alluvial aquifer discharges into the creek about a mile downstream of the mill site and by direct surface runoff from the tailings pile soil covers. Contaminants detected in surface water at concentrations exceeding comparison values include arsenic, molybdenum, nitrate, selenium, vanadium, gross alpha, radium-226, radium-228, uranium-234, and uranium-238. The major source of contamination is presently confined to the tailings piles on the Monticello Mill Tailings Site. A potential worst-case migration scenario would require that the pile cover be stripped away by a major flood and subsequently contaminate Montezuma Creek with contaminated mill site drainage. Ultimately, the tailings would be deposited with downstream sediments.

Historically, the highest off-site concentration of site-associated elements in the surface water occurs downstream, east of the tailings site, where the alluvial aquifer recharges Montezuma Creek. Further downstream, contaminant concentrations are diluted to levels below comparison values at the confluence of Montezuma Creek with the San Juan River.

Montezuma Creek is not used for fishing or swimming or as a source of potable water; however, the potential exists for farmers, ranchers, and hunters to drink from Montezuma Creek occasionally. Interviews with local residents indicate that the resulting exposures would be incidental and short term. The Public Health Implications (A. Toxicological Evaluation) section of this public health assessment contains further discussion of potential adverse health effects resulting from those potential exposures.

C.3 Food Chain Potential Pathway

The potentially exposed population includes farmers and ranchers living near the Montezuma Creek floodplain, one adjacent to the mill site and others within a few miles east of the mill site. The rancher raising livestock adjacent to the mill site uses Montezuma Creek as a source of water for his livestock. Another rancher raises cattle in a pasture along the creek and uses creek water to irrigate alfalfa, on which the cattle graze. We do not know whether additional farmers downstream use Montezuma Creek water. Because tailings-related contaminants have entered the creek through discharge of the shallow alluvial aquifer beneath the tailings site and in direct surface runoff from the tailings pile soil covers, this water might be a potential cause of elevated soil concentrations in the grazing area. By ingesting contaminated creek water, alfalfa, and soil, the cattle can potentially accumulate tailings-related contaminants in their flesh, and then humans consuming the beef could potentially be exposed. Humans could potentially experience exposure by eating vegetables that accumulate contaminants if they were to be grown in the area in the future. In summary, contaminants detected in surface water, soils, and sediments can enter the food chain and ultimately result in exposure to humans who eat the contaminated meat and vegetables.

The Public Health Implications (A. Toxicological Evaluation) section of this public health assessment contains further discussion of potential adverse health effects resulting from ingestion of contaminated beef and vegetables.

ATSDR scientists will continue to review any future exposure pathways resources that become available. Should additional information become available that alters the findings of this public health assessment or addresses issues described herein, this public health assessment will be modified as needed.

PUBLIC HEALTH IMPLICATIONS

A. Toxicological Evaluation

Substances released into the environment do not always result in human exposure. Human exposure to a nonradioactive chemical contaminant can occur only if humans come in contact with the chemical contaminant either by ingestion (eating or drinking a substance containing the chemical), inhalation (breathing air containing the chemical), or dermal absorption (skin contact with a substance containing the chemical). In the case of radioactive substances, human exposure can occur also when humans enter fields emanating from the substances.

To understand the type and severity of health effects that exposure to a specific chemical contaminant may cause, we must consider several factors related to an exposed individual's interaction with the chemical. Such factors include the amount or dose of the chemical to which a person is exposed, frequency and duration of exposure, route of the chemical's entry into the body (ingestion, inhalation, or dermal absorption), and the multiplicity of exposure (combination of chemical contaminant exposures).

Health effects are also related to such characteristics as age, sex, nutritional habits, health status, lifestyle, and family traits, all of which may influence how a specific chemical is absorbed (taken up by the body), metabolized (broken down by the body), and excreted (eliminated from the body).

To determine the possible health effects specific chemicals can produce, ATSDR representatives consider those physical and biological factors as well as a variety of informational sources, such as scientific literature, research reports, and reports from other agencies.

The following sections evaluate the potential health effects from exposure to contaminants from the Monticello Mill Tailings Site. The toxicological evaluation for each contaminant assesses probable health effects from exposure to the contaminant. These health effects relate to contaminant concentration, exposure route, exposure frequency, and population potentially exposed. Populations known to be or suspected of being sensitive to exposure to the contaminant are included. The information is presented for those pathways identified as completed exposure pathways for on-site and off-site surface soils and ambient air and for potential exposure pathways involving groundwater, surface water, and bioaccumulation of contaminants in the food chain.

A.1 Radioactive Contaminants

a. Radon-222

Although ATSDR representatives have not yet completed their review and analysis of the data needed to estimate the risk to health from all radon-222 exposures, both indoors and outdoors, adverse health effects from exposure of the public to this gas outdoors in the vicinity of the mill site are highly unlikely. Two considerations led ATSDR scientists to the conclusion about outdoor exposure near Monticello:

1. Outdoor ambient radon-222 activity was not reported higher off site than 2.98 pCi/L (48). This level is less than the guideline of 4 pCi/L used by EPA as adequately protective against lung cancer from continuous long-term indoor exposure (49).

2. Outdoor exposure to radon in general is much less hazardous than indoor exposure because radon-222 gas itself is not directly capable of causing human lung cancer. Any radon-associated carcinogenic effects are from the radon daughters (products of the radioactive decay of radon-222) that are discussed in Appendix C. Unlike radon-222, the daughters are not gases, but solids. They form small particles suspended in the air. The particulate daughters typically dissipate more rapidly outdoors than indoors due to increased air flow outdoors. Radon-222 gas is almost eight times as dense as the ambient air and could remain measurable for some time.

It is *indoor* exposure in poorly ventilated space, in which the particulate daughters are confined along with the parent gas, that could present a health hazard if radon-222 activities are elevated. Some of the foundations of the structures on Monticello Vicinity Properties were poured from concrete containing material from the tailings piles (3). This material contains radium-226, which decays radioactively to radon-222. The radon daughters that would accumulate in these structures would be confined along with the radon-222 gas. In the record of decision for the Monticello Vicinity Properties, Department of Energy (DOE) representatives estimated average lung doses for 15 Monticello Vicinity (indoor and outdoor) Properties, indicating that DOE has indoor concentration data (3). Moreover, DOE reportedly has indoor radon-222 data for more than 1,000 vicinity properties. Staff members at ATSDR are scheduled to begin analyzing the database that contains this information during calendar year 1998. The completion and success of this activity is dependent on the quality and quantity of data provided by DOE as well as the financial funding provided by DOE. Appendix C of this document contains other information about radon-222.

b. Radium-226

ATSDR representatives calculated the radiation dose due to ingestion of radium-226 for the average (27 picocuries per gram (pCi/g)) and maximum (7,185 pCi/g) concentrations found in publicly accessible areas. The dose is based on the following scenario: persons playing outside 5 days per week for 1 hour per day. The route of exposure is via incidental soil ingestion (100 mg_{soil}/day).

The dose calculated using the assumptions described above for the average concentration is 0.05 millirem per year (mrem/yr) and for the maximum is 14.40 mrem/yr. Both doses include the radiation dose contributed by radium-226 naturally in the soil, and both are below the recommended dose limit of 100 mrem/yr (50). In addition, there is no apparent risk of increased cancer and no apparent health hazard due to long-term (in this case, assumed to be 45 years) chronic ingestion of radium-226 in the scenario.

c. Uranium-234 and Uranium-238

People are unlikely to suffer adverse health effects from the uranium present in water sources known to supply drinking water. However, the uranium content of the alluvial aquifer, which could potentially be tapped for drinking water in the future, could cause kidney problems if someone drank water from wells drilled at some future time (37, 42, 51). Because uranium was not reported at levels of concern in soil or sediment, amounts sufficient to cause adverse health effects are unlikely to have entered the food chain by bioconcentration from soil (51).

The hazard posed to the kidney by the chemical toxicity of uranium (especially so for its soluble forms) is greater than that posed by its radioactive properties (51). Drinking water used by residents near the mill site is either supplied by the city from surface water taken upstream of the mill site or taken from wells that tap the Burro Canyon Aquifer. These water sources have not exceeded activities of 30 to 43.5 pCi/L for uranium (43 to 62 μg uranium/L) (42, 51). The range of concentrations in water taken from city water upstream of the mill site or the Burro Canyon Aquifer is unlikely to result in kidney damage to children or adults from the chemical toxicity of uranium, nor would it pose a significantly increased likelihood of cancer from uranium radioactivity (52).

Since 1984, the alluvial aquifer rarely exceeded uranium activities of 533 pCi/L, although concentrations as high as 2,870 pCi/L have been reported recently (42). No wells are known to draw from this aquifer. However, it is possible that some wells might do so now or in the future in the absence of institutional controls, such as ordinances to prevent screening this aquifer. Children and adults who drink this water in the future would be at risk for kidney injury. If people use this water in the future as their sole drinking water source for their entire lifetimes, they could have, in the future, a moderately increased risk of cancer from the radioactive properties of uranium (52).

A.2 Nonradioactive Contaminants in Soil and Sediment

a. Beryllium

The concentration of beryllium in soil (1 part per million [ppm]) is insufficient to cause cancer or noncancer health effects through soil ingestion (37, 53). No significant adverse effects were produced in any of the studies in which animals were orally exposed to greater amounts than humans could be assumed, by the most conservative scenarios, to ingest from this soil (52, 53). Beryllium is known to cause lung cancer in humans and animals exposed by inhalation, although not all beryllium is capable of producing lung cancer. Very specific forms of beryllium oxides have the proven potential, but other forms are relatively inert. However, calculations described in Appendix C established the fact that windborne soil would not contain enough beryllium to present a significantly increased risk of cancer by inhalation. The concentration of beryllium in off-site soils is well within the range of beryllium soil concentrations reported for the United States in general and for Utah soils and sediments in particular (37, 54). Bioconcentration of soil beryllium by locally grown produce or grazing animals is not expected to generate dietary beryllium intake greater than would normally exist.

b. Chromium

The 22 ppm chromium maximally present in off-site soil and sediment samples is well within the soil chromium concentration range found in the state of Utah and is not a threat to the public's health (37, 52, 54). Environmental chromium occurs primarily in two chemical states: chromium-III (Cr-III) and chromium-VI (Cr-VI). Cr-III, which is environmentally very stable, is nutritionally essential for health and not harmful at soil concentrations 100 times that maximally reported (52). Even if all the chromium originally released to the soil were Cr-VI, which is much more toxic, especially if inhaled, it would be readily converted to Cr-III (55, 56, 57). The concentration of chromium in the soil (22 ppm) off site could be of concern to children who play in and daily ingest large quantities of the soil only in the highly unlikely event that nearly all the chromium had persisted in the environment as Cr-VI for the 30 years since the mill closed. We did not analyze air for respirable chromium in either oxidation state, but using the method described in Appendix C for beryllium, the soil chromium content, even if entirely Cr-VI (unit inhalation risk of 1.2×10^{-2} ($\mu g/m^3)^{-1}$), could not present a significant risk of cancer through inhalation (52).

The off-site soil concentration reported is well within the range of chromium soil concentrations reported for the United States in general and for Utah soils and sediments in particular (37, 54). We believe that even persons whose entire diet consists of homegrown items will take in chromium within the general range ingested within the United States -- 0.025-224 mg/day -- an intake level not expected to produce adverse effects (58).

c. Lead

Lead was present in off-site soil and sediment at concentrations up to 22 ppm (37). ATSDR does not regard lead soil concentrations in this range to be a significant threat to human health (59). The concentration of lead in off-site soils is well within the range of lead soil concentrations reported for the United States in general and for Utah soils and sediments in particular (37, 54). Bioconcentration of soil lead by locally grown produce or grazing animals is not expected to generate dietary lead intake greater than would normally be the case. For more details about adverse health effects that might be seen in children residing where soil lead concentration was reported at higher levels than found adjacent to Monticello, see Appendix C.

d. Nickel

No adverse effects are anticipated from the reported concentrations of nickel in off-site soil (37, 52). The absence of nickel at levels of concern in groundwater or surface water suggests that the soil nickel is in a poorly soluble form and likely to be poorly absorbed if ingested. Moreover, nickel was present in off-site soil at 16.2 ppm, a concentration well within the natural background of Utah soils and alluvial sediments (37, 54). Bioconcentration of soil nickel by locally grown produce or grazing animals is not expected to generate dietary nickel intake greater than would normally be the case.

e. Thallium

Thallium might be present in off-site soil at concentrations above 0.2 ppm and might therefore be sufficient to cause adverse health effects in children who exhibit pica behavior -- i.e., children who ingest non-nutritive substances, such as soil (37, 60). This substance, which ranged up to 3 ppm in soil on site, was below its quantitation limit of 2 ppm in off-site soil (37). The concentration of thallium normally occurring in Utah soil is not known (54). Thallium is absorbed by plants from soil and enters the food chain; dietary intake is probably the major source of human exposure to thallium (61). ATSDR scientists did not have necessary data on the concentration of thallium in locally grown produce to evaluate the potential for adverse health effects from eating food grown in residents' backyards. For information about the toxicity of thallium, see Appendix C.

A.3 Nonradioactive Contaminants in Groundwater

a. Arsenic

The arsenic present in known drinking water sources is insufficient to cause adverse health effects, and there is little likelihood that the arsenic in one potential future source of drinking water (future wells that may draw from the alluvial aquifer) could cause health problems (see Appendix C). The average United States diet supplies about 50 μg arsenic each day, much of it because of arsenical pesticides, a more likely source of arsenic in home-grown foods than is bioconcentration of site-related arsenic in irrigation water (62).

When the facility was in operation, children swam in the tailings ponds. Dermal exposure to arsenic is not known to cause harmful effects other than contact dermatitis. The children might have ingested some of the water while playing, and their likelihood of being harmed would depend on the arsenic concentration in the ponds at that time. That concentration of arsenic is not known, although it might have reached or exceeded the level of 48,000 μg/L (48 ppm) reported in groundwater in some western mining areas (62). Water in the tailings pond could have been higher because of its origin -- direct runoff from the tailings pond. A small (10-kg or 25-pound) child playing in the water could swallow 50 ml (1-2 tablespoons) of water each swim. Repeated splashing and dunking could lead to ingestion of several times that amount on a single warm afternoon, with the child ingesting as much as 10 mg arsenic (1 mg/kg/day), if the water at the tailings pond was contaminated to that extent. ATSDR scientists found reports that 1 to 2 mg/kg/day of inorganic arsenic from contaminated water resulted in nausea and vomiting, followed by severe abdominal pain, bleeding in the digestive tract, and in some cases, death by renal failure (62). Children who had no acute adverse effects after swimming in the ponds on several occasions or who stopped swimming in the ponds because it made them feel sick are unlikely to be at risk now. Levels of arsenic insufficient for such acute effects but substantially above that in current drinking water, if ingested daily over many years, could cause the chronic arsenic poisoning (blackfoot disease, symptoms similar to Raynaud syndrome, and cancers of the skin, liver, and lung). For additional information, see Appendix C.

b. Molybdenum

Molybdenum was not present at levels of health concern in known drinking water sources or in off-site soil (37). However, if in the future some off-site residents draw drinking water from the alluvial aquifer and at the same time derive a substantial proportion of their food from homegrown produce, they could be at risk for gout-like illnesses (52). Up to 213 parts per billion (ppb) molybdenum was present in the alluvial aquifer downgradient of the mill site, and up to 340 ppb molybdenum was present in surface water used for irrigation downstream of the mill site (1, 42). Plants may bioconcentrate molybdenum from the irrigation water so that their molybdenum content is increased by five times the molybdenum content in the soil in which they grow (63). Data on the molybdenum content of grains, fruits, and vegetables grown on properties near the Monticello Mill Tailings Site are not available. Therefore, ATSDR scientists are not able to determine whether total molybdenum intake levels are sufficient to cause adverse health effects.

Between 1984 and 1995, well after the end of milling operations, surface water (Montezuma Creek) on site has been contaminated with as much as 3,420 ppb molybdenum (42). During operations and in the decades immediately following, Montezuma Creek molybdenum concentrations may have reached higher values than 3,420 ppb. It is possible to speculate that similar concentrations of molybdenum were present in the tailings ponds when the facility was in operation. If children swam in the ponds often over many years, they could have ingested enough molybdenum to have interfered with their ability to use dietary copper and put them at risk for hypochromic microcytic anemia (52).

c. Nitrate

Nitrate was not present at levels of health concern in known drinking water sources (37). If in the future, some families living off site draw their drinking water from the alluvial aquifer downgradient of the mill site (33 ppm), their newborn infants could be 10 times more likely than those drinking water from the alluvial aquifer upgradient of the mill site to become cyanotic (turn blue) from increased levels of methemoglobin (an oxidized red blood cell pigment that has lost its ability to carry oxygen) in their blood (42, 52). There are several reasons why these babies could be vulnerable. Shallow wells, such as those that in the future might draw from the alluvial aquifer, are more readily contaminated by bacteria than are deeper wells, such as those that draw from the Burro Canyon Aquifer. The stomach juices in newborns, especially those 3 months old or younger, are less acid than those in older babies, children, and adults. The low acidity favors bacterial growth in the stomach. Stomach bacteria can convert ingested nitrate to nitrite. Because of the lower acidity in the infant's stomach, the conversion can proceed to a greater extent than the 5% to 10% that occurs in adults. Nitrite attacks hemoglobin, resulting in the cyanosis described above when infants drink water containing more than 10 ppm nitrate (52).

Nitrates are used to fertilize soils to improve plant growth. The effectiveness of this practice stems from plant metabolism of inorganic nitrate to precursors of plant proteins. Minor additional quantities of nitrates from use of the alluvial aquifer for irrigation are not expected to result in toxic levels of nitrate in the local diet.

d. Selenium

Selenium was not present at levels of health concern in known drinking water sources (37). Selenium is an essential element in human nutrition; the National Academy of Sciences recommends adults consume 55 to 75 μg selenium per day to prevent deficiency (64). If the intake from food and water is as low as 7 to 11 μg/day, the deficiency causes adverse effects to cartilage tissue and the heart (65). These effects can be treated with supplements of 230 to 920 μg/day (65). The mean United States daily intake is 83 to 129 μg/day (64). Ingestion ranging from 240 to 1,510 μg selenium per day, an amount that could require drinking 4 gallons of off-site alluvial groundwater daily (should future wells tap this aquifer) does not produce harmful effects (1, 42, 65). However, excessive selenium intake can cause adverse health effects; continuous total intake of 3,200 to 6,690 μg selenium per day has caused damage to nails and hair, blistered skin, tooth decay, numbness in hands and feet, paralysis, and convulsions (65).

Between 1984 and 1995, well after the end of milling operations, surface water (Montezuma Creek) on site has been contaminated with as much as 3,110 ppb selenium (42). During operations and in the decades immediately following, Montezuma Creek selenium concentrations may have reached higher values than 3,110 ppb. It is possible to speculate that similar concentrations of selenium were present in the tailings ponds when the facility was in operation. Children who swam often in the tailings ponds for many years could have been at risk.

Moreover, Utah is one of the states known to have highly seleniferous soils and plants that can cause ingestion of amounts of selenium that could be of health concern (65). It is possible that use of irrigation water drawn from the alluvial aquifer could increase the potential for adverse health effects from naturally occurring selenium in produce and meats from Utah.

e. Vanadium

Vanadium has not been associated with cancer in people or animals by any route of exposure (66). The substance was not reported in sufficient concentration for acute exposure to gusts of wind to cause bouts of coughing and other signs of respiratory irritation to on-site workers or off-site residents (1, 37, 66). Should the highest reported on-site concentration occur frequently off site, however, persons with asthma and others with chronic respiratory problems might experience increased symptoms (66). Adverse effects to workers from prolonged exposure are not anticipated because the highest on-site concentration reported is below the threshold limit value required by the Occupational Safety and Health Act (67).

Vanadium has not been identified at levels of health concern in known drinking water sources (37). The likelihood of kidney damage to people who might in the future have wells that tap the alluvial aquifer or to children who frequently swam in the tailings ponds for many years is unclear (1, 66). Contamination of foodstuff is more likely to result from adhesion of vanadium-containing fertilizers than from bio-uptake of contaminated water (66). For additional information about the toxicity of vanadium, see Appendix C.

A.4 Nonradioactive Contaminants in Air

Sulfur Oxides, Sulfurous Acid, and Sulfuric Acid

Oxides of sulfur and the acids (sulfuric and sulfurous acid) they form on contact with moisture could have resulted in an increase in respiratory diseases among nonsmokers depending on the concentrations that were present in the ambient air, although it is not clear whether the adverse effects might have persisted to the present. These substances, in unknown concentrations, were probably responsible for the sulfur odor and damage to clothing and automobile chrome trim noted by off-site residents when the plant was operating (see the Community Health Concerns sections). At that time (1960 or earlier), the ambient air concentration of these substances exceeded the odor threshold for sulfur oxides (0.007 to 0.03 ppm) by an undocumented quantity which was, however, sufficient to cause the damage described earlier (68). Concentrations of sulfur dioxide as low as 0.04 ppm have been associated with chronic obstructive lung disease in nonsmokers (69). The study reporting this association did not examine the persistence of respiratory injury. However, another study reported decreased mortality due to chronic bronchitis that lagged about 4 years behind improvement in air quality resulting from pollution controls designed to lower ambient sulfur oxide concentration (70). These two unknown quantities (the concentration of sulfur oxides present during mill operation and the persistence of injuries that might have resulted from exposure at that time) add considerable uncertainty to the possibility of predicting the likelihood that current respiratory disease might stem from past inhalation of the mill's sulfur oxide emissions.

B. Health Outcome Data Evaluation

Representatives of ATSDR and Boston University identified and reviewed many sources of health outcome data for the Monticello area. In response to the large number of health concerns voiced by former workers at the Monticello Mill Tailings Site, they conducted a search of available literature on studies of uranium mine and mill workers. A few of the studies mentioned the Monticello mill with respect to industrial hygiene surveys. ATSDR staff members were able to determine from those studies what the conditions were like in and around the mill and whether the types of diseases present in the mill workers were also present in the community surrounding the mill.

Worker Issues

Representatives of the occupational health program of the U.S. Public Health Service performed environmental surveys in many uranium mills in the western United States, including the Atomic Energy Commission (AEC) mill in Monticello, during the 1950's. Workers in most of the mills where industrial hygiene surveys were done experienced a chronic irritation of the upper respiratory tract, presumably caused by the vanadium fumes escaping from the fusion furnaces. Workers in the vanadium processing areas of the mill(s) had a green coating of the tongue and teeth, and workers in the uranium leaching process had a yellow coating of the tongue and teeth (71, 72). The surveys revealed that 26.5% of the white millers showed more than usual pulmonary fibrosis compared with 7.5% in the control group. Twenty percent of the Indian millers showed more than usual pulmonary fibrosis compared with none in the control group.

One of the initial uranium mill worker studies involved medical examinations of 715 participants from 6 mills between 1950 and 1953. The mills were in the Colorado Plateau states (Colorado, Utah, New Mexico, and Arizona). The workers were followed over time, and 104 of them died between 1950 and 1967. The rate was nearly the same as the expected 105.11 rate (71, 72). However, the excess deaths due to malignant diseases of the lymphatic and hematopoietic tissue other than leukemia did appear to be meaningful, even though the numbers involved were small.

Representatives of the Health and Safety Laboratory of the AEC also performed a study of approximately 215 workers at the Monticello Ore Concentrating Plant in 1957 to determine the levels of radioactive dust exposures workers were experiencing. The study revealed that there was no effective dust control equipment throughout the plant. It also showed that 86 employees out of the total plant population were exposed to average dust concentrations above the maximum allowable concentration (MAC). Nineteen of those were exposed to greater than five times the MAC. The areas in the mill that exceeded the MAC were the ore sample plant, crushing areas, sample preparation area, and yellow cake drying area (73). The survey showed that workers in the mill experienced no hazard from external radiation (beta plus gamma or gamma only) (73). According to the survey, there had been a urine sampling and assaying program in place since 1956. All plant personnel were included in the program, and those workers in areas having higher air dust levels were sampled weekly. ATSDR scientists have not been able to obtain documentation of that program.

In 1971 and 1972, representatives of the National Institute for Occupational Safety and Health (NIOSH) performed a retrospective cohort study of 2,002 uranium mill workers who had worked at one or more of seven mills in the Colorado Plateau region. The study sought to determine the possible relationship between exposure(s) to uranium, thorium, and radium and the development of malignant and nonmalignant diseases. The risk of mortality among the uranium mill worker cohort was analyzed from 1940 to 1977. Results from the study showed no statistically significant excesses of any malignancies. However, although not statistically significant, there was an excess of chronic renal disease. There was also a significantly elevated standard mortality ratio (SMR) because of nonmalignant respiratory disease. Analysis of the study determined that the elevated ratio was caused by emphysema, fibrosis, silicosis, and chronic obstructive pulmonary disease (74). The study revealed that, in those workers who had worked for more than 10 years in the mill, there was only 1 lung cancer death observed, compared with the 5.7 expected (74). This particular study did not reveal an association between lung cancer and working in uranium mills. There were no subcohorts identified and most likely there are none that exist.

ATSDR representatives have used this information as background as we looked for similar adverse health effects in the community of Monticello. It appears that the green and yellow coating of the mouths and on the tongues of the workers were acute, short-term effects and consequently would not be listed in any type of health-related database. ATSDR staff members did not receive any concerns regarding such coatings in any of their public availability sessions. Most of the concerns that came from the public availability sessions were about cancer.

Cancer

Cancer has been a reportable disease in Utah since 1948, but there was not a statewide population-based registry until 1966. The Utah Cancer Registry is part of the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) program. Utah has the lowest overall cancer incidence in the SEER system and the lowest overall cancer mortality rate of any state. The main reason seems to be the low smoking rates and the associated low rates of smoking-related cancers. Since becoming part of the SEER system, Utah has had an incidence rate approximately 16% below national rates, and mortality rates are approximately 28% below the national average. As of September 1992, Utah males have a lifetime risk of developing cancer of approximately 20%, and Utah females have a lifetime risk of approximately 24% (75).

In the publication Cancer In Utah, there were cancer incidence rates for each county in 10-year increments. Incidence rates are the number of new cases of disease in a population over a period of time. The incidence rates measure the probability that healthy people will develop a disease during a specified period of time. (The numbers for some years were so small that comparisons would not have been statistically significant with less than a 10-year increment.) The Utah Cancer Registry also provided statistical tables summarizing cancer incidence in Monticello and Blanding residents diagnosed between 1967 and 1992. For most of the analyses of cancer, the population exposed was assumed to be the entire population of Monticello, primarily because the documented radioactive hazards were quite widespread in the community, and there were several potential pathways for exposure. Table 14 shows the number of cancer incidence cases for Monticello and Blanding, both located within San Juan County.

In general, cancer rates for San Juan County tend to be below the rates for the rest of Utah, but these data are not adjusted for different proportions of the population of different ethnic or religious origins; however, they are age-adjusted. The sites and cancer types reviewed included the following: bladder, breast, cervix, colon/rectum, leukemia, lung, lymphoma, melanoma, pancreas, prostate, and uterine corpus. The years reviewed were 1966 to 1975 and 1981 to 1990. Table 15 shows the cancer incidence ratio of San Juan County compared with the ratio for the state of Utah. Cancer of the cervix is the only type of cancer whose rate is significantly elevated in San Juan County as compared with rates for the state of Utah. This type of cancer would not be associated with the contaminants present at the mill site.

ATSDR representatives searched the CDC Wide-Ranging Online Data for Epidemiologic Research (WONDER) database for incidents of malignant neoplasms of the respiratory and intrathoracic organs in San Juan County and compared the age-adjusted rates with the state of Utah rates. Intrathoracic organs include the larynx, trachea, bronchus, and lung. The white population rate in the county was 39.9, while the state rate was 24.6 (76). Rates for all other races were below the state age-adjusted rate.

ATSDR representatives reviewed EPA's Riggan's Mortality Tapes and identified two large percentage rate changes for white males living in San Juan County between 1950 and 1970. Between the years of 1950 and 1959 and 1970 and 1979, there was a 395% increase in trachea bronchus lung pleura cancerous deaths (77). Tracheobronchial lymph nodes tend to be the site of greatest concentration for inhaled uranium and thorium (71, 72). There was also a significant excess of deaths from prostate cancer between 1960 and 1969 compared with rates for the U.S. population during the same period. Prostate cancer is the most common type of cancer among Mormon males (78). Radiation has not been shown to be a factor in increasing the chances of developing prostate cancer. Between 1960 and 1969 and 1970 and 1979, there was a 287% increase in breast cancer mortality in white females living in San Juan County (77). Exposure to high levels of radiation is known to increase females' chances of developing breast cancer.

ATSDR staff members also noticed that the population of Monticello made up approximately 15% of the county population during the years 1966 to 1975 and 1981 to 1990; however, Monticello's cancer cases during those periods made up 27% of the cancer cases in San Juan County (77).

Insoluble uranium tends to be retained in the alveolar passages of the lung, whereas soluble uranium is retained in the bone (79). Three mortality cases due to bone/jaw cancer were reported between 1950 and 1979 in San Juan County. Although studies have indicated a possible link between long-term, low-level exposure to enriched uranium produced in enrichment facilities, a relationship has not been observed for natural uranium which is found at the mill site.

Cancer mortality in general and lung cancer mortality in particular were examined among Monticello residents. Data provided by the Utah Department of Health made it possible to compare cancer mortality among Monticello residents with rates for San Juan County and the state of Utah. We compared Monticello residents' odds of dying of lung cancer to their odds of dying from some other cancer with similar odds for other San Juan County residents. The risk of dying of lung cancer among Monticello residents during the period 1967 to 1992 was 2.5 (95% confidence interval 1.03-5.8). This comparison provides some limited evidence that during these years there was excess risk of dying of lung cancer in Monticello compared with risk for a county (San Juan) with a low overall risk of death from this disease. When the lung cancer mortality data were broken down into shorter time intervals, or for males and females separately, the numbers were too small for meaningful analysis.

A memorandum to the director of the National Communicable Disease Center reported that, between 1956 and 1965, four children who were residents of Monticello, Utah, (1960 population: 1,845) developed acute leukemia. On the basis of the leukemia mortality rate for the United States in 1960, only one leukemia case in 30 years would be expected among children in a town the size of Monticello (80). A review of the childhood cancer cases for Monticello between 1967 to 1992 revealed only one cancer, a case of acute lymphoblastic leukemia diagnosed in 1970 (75). The cause of the leukemia clustering is still not known. ATSDR staff members were told that a leaking underground gasoline storage tank, which was in the area of the cluster, had been removed shortly after the cases were identified (81). ATSDR representatives checked the state records for underground storage tank removals in Monticello, however, and there was no record of one being removed from the area of the cluster (82).

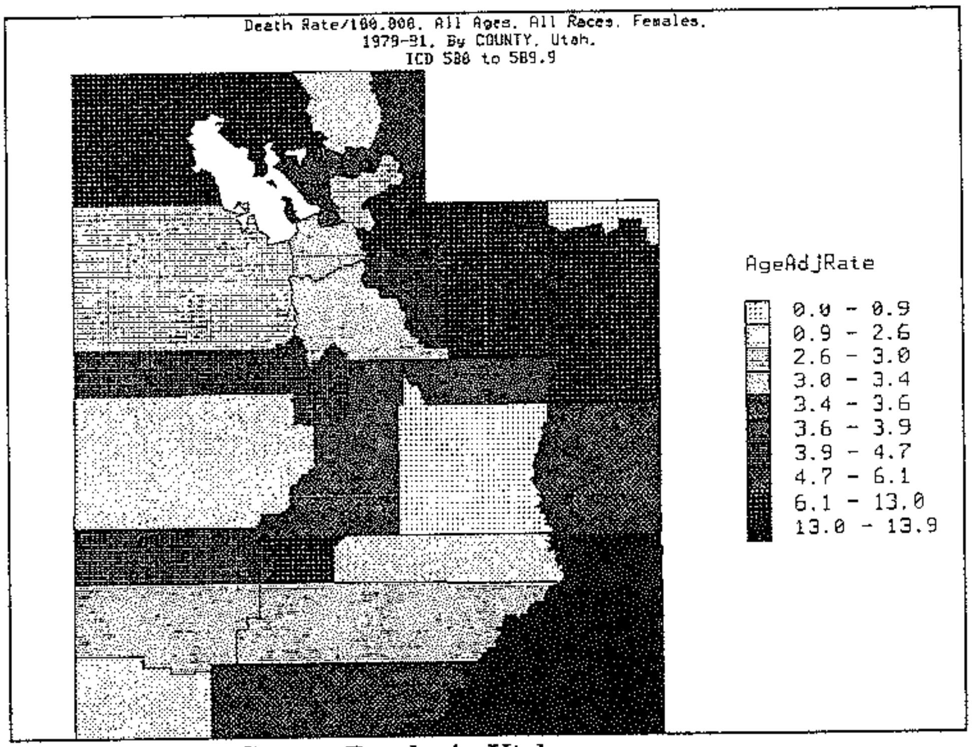
Table 14.	Cancer Incidence Cases (1967-1992) (75)	
Cancer Sites	**Monticello**	**Blanding**
Lip	2	3
Stomach	1	4
Colon	4	9
Rectosigm	2	2
Rectum	3	3
Pancreas	3	4
Lung	11	14
Blood System	7	7
Skin	3	7
Breast	8	17
Vagina	1	1
Cervix Uterine	5	8
Corpus Uterine	2	6
Ovary	2	2
Prostate	16	22
Kidney	3	3
Bladder	5	3
Brain	2	2
Thyroid	2	1
Lymph Node	6	4
Unknown	3	8

Table 15.	**Cancer Incidence Ratio of San Juan County Compared With That of the State of Utah** (75)	
Cancer Type or Site	1966-1975	1981-1990
Bladder	.643	.168
Breast	.811	.497
Cervix	1.286	2.567
Colon/Rectum	.289	.523
Leukemia	.907	1.042
Lung	.679	.963
Lymphoma	.532	.394
Melanoma	.631	.519
Pancreas	.851	1.549
Prostate	.950	.477
Uterine Corpus	.795	.823
All Sites	.705	.684

Damage to the kidneys seems to be the primary systemic health risk in humans from exposure to non-enriched uranium. Statistically significant increases in deaths due to chronic and unspecified nephritis and renal sclerosis have been reported for uranium millers (74). One noncancerous cause of death, end-stage renal disease, was considered, based on toxicologic effects of uranium.

We used the CDC WONDER system to review renal failure for males and females in San Juan County. The database covers mortality for the years 1979 to 1991. There were four cases for males, and the age-adjusted rate was equal to the average rate for all counties in Utah that had reportable cases during the same period. There were 11 cases for females, and the age-adjusted rates were higher for San Juan County than for any other county in Utah. The age-adjusted rate for white women was double the rate for all other races in San Juan County (76). The map following depicts the rates of renal failure for each county in the state (76).

Staff members at the University of Michigan maintain a special database on end-stage renal disease, the U.S. Renal Data System, for the National Institutes of Health. The data primarily reflect Medicare reporting of kidney dialysis, and they are available only for the recent past; however, 1991 data were available for San Juan County and for the state of Utah. These data indicated that there were five cases of end-stage renal disease in San Juan County and 445 cases in the rest of Utah. This number does not represent a disproportionate percentage of cases of this disease in the county; the database does not indicate how many of the cases were in Monticello.



EpiMap: Renal Cancer Deaths in Utah

The rate of infant mortality in Utah has consistently been lower than rates for other parts of the United States (83). Studies have shown that congenitally malformed children are more frequently born to mothers who use alcohol, drugs, or tobacco than to mothers who refrain from using such products. Seventy percent of the study population included members of the Church of Jesus Christ of Latter-day Saints (Mormons), who discourage the use of alcohol, tobacco, and other drugs. However, Seegmiller and Hansen were unable to show through their research that the decreased use of these products had any effect on the rate of congenital malformations in the state. Their research concerning congenital malformations in children born in Utah during the years 1968 to 1972 shows that San Juan County had the highest rate of any county in the state of Utah. The results show that San Juan County had the highest percentages of mothers receiving late or infrequent prenatal care and the lowest mean level of public education (84). Interhospital variation in reporting might have had an effect on the higher rates reported for San Juan County.

There were no relevant hospital discharge data to review because the system for centralized reporting was only established in 1992. There were no other major causes of death for which there were sufficient numbers of decedents in Monticello or for which there was a plausible end-point based on the pathways and exposure analysis described in previous sections of this document.

The major problem in evaluating all the health outcome data described in this section has to do with numbers: the small size of the Monticello population, the small numbers of health outcomes observed, and the uncertainties about the size of the exposed population. The small number of cases makes it difficult to calculate meaningful age-adjusted disease or mortality rates. Once the rates are calculated, there tend to be large standard errors and little statistical significance. Therefore, rate comparisons or odds ratios may not be representative of the true risk of disease because it was impossible to adjust for different age distributions in the compared populations. Furthermore, several of the databases are available only at the county level, whereas the likely exposed population may be limited to parts of Monticello. In addition, persons exposed to contaminants from the uranium mill may have moved away years before they developed health problems or died of them. These former residents will not be identified in the databases we reviewed while preparing this document.

ATSDR scientists will continue to review any future health outcome data resources that become available. Should additional information become available that alters the findings of this public health assessment or addresses issues described herein, this public health assessment will be modified as needed. There are completed exposure pathways and the allegation of substantial exposure and serious diseases. Health studies need to be considered that would address the level of current and past exposures and their relationships. ATSDR scientists plan to thoroughly investigate and analyze DOE's residential/property database, which contains environmental data for each off-site property. The completion and success of this activity is dependent on the quality and quantity of the data as well as the financial funding provided by DOE. The community's Monticello Uranium Mill Impact Survey and the leukemia study performed in the 1980s both contain pertinent information. All these resources are an integral part in helping more clearly define exposure and disease rate and to determine what is occurring medically.

C. Community Health Concerns Evaluation

Exposure Concerns

Potential mill site-related health effects for the Monticello residents fall into two categories:

1. Nondeterministic (the probability of the effect occurring varies with the dose without threshold, e.g., heredity effects and cancer), and
2. Deterministic (the severity of the effect varies with the dose, and there may be a threshold, e.g., cataracts and infertility) (85).

The source and intensity of irradiation, radionuclide particle size of emitted material, dose rate, and pathway influence the degree of public health risk, influencing induction of nondeterministic and deterministic effects. Normally, deterministic effects are associated with chemical toxicity or acute high doses of radiation exposure. On the other hand, carcinogenic effects can be related to radiation. Animal studies have shown that external radiation exposure advances the onset of naturally occurring malignancies, especially leukemia and breast cancer; internal radiation normally affects the tissues where the radionuclides concentrate, e.g., lung and bone cancer (86).

Studies have shown that lower level exposure has constituted an occupational hazard in radiologists and physicists with the prevalence of acute and chronic myelogenous leukemia; cases involving both irradiated Western populations and Japanese populations show similar results. However, humans exposed to ionizing irradiation have not shown significant cases of chronic lymphatic leukemia (87).

Workers at the Monticello Mill Tailings Site experienced situations that led to their inhaling radioactive particles and radon gas. Figure 19 in Appendix F contains an illustration of the air-inhalation pathway. One concern was the workers' exposure to yellow cake. Inhaling or swallowing yellow cake can induce chemical toxicity of the lung, kidney, and liver. Both animal and epidemiologic studies indicate that kidney failure is the most likely chemical health effect of uranium in humans, whereas bone cancer is the most likely radioactive health effect. The evidence also suggests that chronically inhaling uranium dust in the workplace can cause lung cancer. The case for this is so weak, however, that we cannot determine the level of risk (88). One should expect, however, that people who did not work at the plant should not develop lung cancer from breathing the dust. Breathing the dust includes breathing the ore that mining trucks dropped on the way to the mill and vehicle traffic resuspended as well as breathing the dust shaken from a miller's work clothes before washing them. Such dust is inhaled for short intervals or at low concentrations, causing much lower exposures than the mill workers received. Because uranium intakes can be detected years later, some Monticello residents were tested. Their internal levels of radioactive material were below those of the control subjects in the studies (13).

Other people lived on the mill site during the period when the mill was operating. Depending on the prevailing wind direction, they could have received more radiation exposure than local residents. The exposure would have been from direct radiation from the mill site, radon gas, ore dust, and the chemical and radioactive effluents. Their cancer risk would depend on the radiation levels at those locations, the concentration in the air, and their individual life-styles.

Children were observed playing on the tailings piles for several years after the mill ceased operation. Based on the exposure rates from those tailings and their exposure time, their dose was well within the public dose limits and should not have caused any adverse health effects. The probability of their developing childhood leukemia was remote. Other childhood and adult diseases that would be more likely to occur as a result of radiation exposure have not been observed.

Occupations that involve soil excavation will temporarily expose workers to elevated levels of radon gas and its daughters. This phenomenon is normal, and these increased levels are expected regardless of the location because radon gas escapes naturally from the earth at all times. The rate at which radon gas escapes is determined by the soil's uranium and thorium content, its moisture level, and the prevailing temperature and pressure. The digging process loosens the soil and allows the radon gas to escape more rapidly for a time. The radon typically dissipates quickly and the levels return to normal, causing no harm. Shallow ditches and graves can be dug without concern for radon levels. Deep holes with small entrances will create higher and more lingering concentrations of radon and other gases because of poor ventilation. They should be ventilated and certified gas free before people enter, as is standard with underground mines, tunnels, and storm drain systems. If the digging will unearth thick tailings on the mill site, as when wells are dug, enhanced concentrations will occur. Such processes should be controlled by appropriately trained and equipped personnel (89).

Test wells have been bored at numerous locations throughout and beyond the mill site. The wells are sampled periodically for identification of any migration of radioactive materials from the mill site. They will be maintained as sampling points to assure that remediation efforts are effective. It is occasionally necessary to rebore a well to maintain its integrity. Reboring should be done under controlled conditions to protect the workers and contain any contamination.

DOE representatives found that 1,608 curies of radon gas escapes annually from the tailings piles (31). The rate is 160 picocuries per square meter second (pCi/m^2s) averaged over the entire mill site. This is 8 times the EPA guideline of 20 pCi/m^2s (90) and 400 times the world average of 0.42 pCi/m^2s (91). Moving the tailings to another location or covering them with a sufficiently thick layer of claylike material will create a satisfactory reduction. These levels will soon be lowered; the piles are only temporary storage for materials from the remediated properties. Once remediation is completed and the tailings are removed or covered effectively, only the natural levels of radon should remain.

Radon gas is also present inside buildings. Scientists measured the radon levels inside Monticello homes of the persons who experienced severe health effects. The EPA studies were conducted in 1986. The radon levels measured were very low. Some data were reported in units of picocuries per liter (pCi/L) while others were in units of working levels (WL)[1] . EPA often assumes that the isotopes to which radon decays are at one-half the concentration they would reach if left undisturbed in a closed area. Under these normal conditions, 1 pCi/L is equal to 0.005 WL. The data below use this conversion. The average radon concentration measured by the scientists was 5.0 pCi/L in winter and 3.6 pCi/L in the spring (22). The average value of 4.3 pCi/L is slightly above the EPA recommended guideline 4 pCi/L. EPA representatives also studied radon in several homes. Their measurements ranged from 0.4 to 1.6 pCi/L in the winter and 0.2 to 0.6 pCi/L in the summer (92). These values are below the EPA guideline (90). Monticello remediation studies have shown that elevated indoor radon levels are more likely to occur if contaminated mortar is used for such indoor applications as constructing fireplace mantels. These applications can be corrected by either replacing the affected mortar or applying barrier sealants to retard radon penetration. A thorough radioactive survey before beginning such efforts can help scientists set priorities and determine the most appropriate response measures.

The operating mill released both radioactive and chemical effluents through the roaster stack, but it is the chemicals that would cause the greatest effects in animals and vegetation. Animals were exposed by drinking contaminated water and grazing on soil contaminated by airborne deposition and irrigation water. The radioactive material measured in those waters in recent years has been observed to exceed the state of Utah standards as far as 2 to 3 miles downstream of the property (31). Even higher levels existed during mill operations. However, cattle were known to be watered from springs whose concentrations were lower than those found in the river water. The radiation exposure is not expected to have been life threatening to either animals or plants, but the chemical effects could have been more pronounced. The chemicals include the yellow cake and black cake oxides of uranium and vanadium as well as sulfuric and hydrochloric processing acids. Uranium and vanadium are chemically toxic. In humans, uranium affects the kidney and vanadium irritates the intestines. Cattle may be affected similarly, with the magnitude depending on the intake. Fortunately, this pathway is not likely to affect human health because uranium is poorly

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[1]Working level (WL) is a unit of measure developed to measure concentrations of radon gas and its daughters in air. A working level is defined as any combination of the short-lived daughters of radon-222 in 1 liter of air that will ultimately emit a total of 130,000 MeV of alpha-particle energy. The Environmental Protection Agency often assumes that radon daughters in air exist at one-half their equilibrium concentration. Under these conditions, 1 pCi/L equals 0.005 WL.

transferred from cattle forage to the meat humans eat (93). The plant damage reported by the local population could have been from the processing acids. Sufficient exposure to sulfuric and hydrochloric acids causes plant browning and death. These acids also corrode metals and could have caused vehicle bumpers, fences, and screen doors to rust.

Some individuals are known to grow home vegetable gardens in soil contaminated with tailings. Three pathways exist for eating crops contaminated with radioactive material, but the tailings pile-soil-food crops pathway seems to be the most important. In that pathway, an individual has used tailings to fill a home garden. We can check samples of vegetables grown in that soil to see how readily the plants have absorbed radioactive materials. Then we can estimate the dose (12).

Areas where people work or live that are contaminated with radioactive ore or tailings should receive high priorities for remediation. The occupants of those areas should prudently keep their radiation exposures as low as reasonably achievable. Adequate ventilation of the building they occupy is one good way to do that. Residential properties and commercial areas, including the three ore storage sites, are now being remediated to bring them into compliance with standards for public health protection. Radioactive surveys are performed after each site is remediated. Where there is reason to believe that a property has been recontaminated through dusting from other properties, an evaluation is in order. Once workers complete remediation of the vicinity properties, the tailings piles will be moved. Performing an overall survey after all remediation is complete will determine whether the entire job is satisfactory. If it is, the public health risk should be insignificant.

Specific Health Outcomes Concerns

1. **Could the following non-carcinogenic health effects be related to the mill site: miscarriages, stillbirths, birth defects, mental retardation, respiratory problems (including bronchitis, pleurisy, pneumonia, asthma, frequent coughs, and sinusitis), emphysema, pneumoconiosis, heart disease (including mitral valve prolapse, high blood pressure), anemia, high hematocrit, nosebleeds, slow healing of cuts, frequent infections, diabetes, bone problems (including spinal curvature and brittle bone disease), arthritis, dental problems (poor teeth, many cavities, soft teeth), headaches (severe, chronic, migraine), muscle spasms, loss of coordination, tremors, dizziness, blackouts, eye disease, vision problems, kidney disease, lumps/growths/moles, digestive tract problems, thyroid disease, neurofibromatosis, chronic fatigue syndrome, Parkinson disease, Crohn disease?**

Based upon the available environmental sampling data that ATSDR staff reviewed concerning the Monticello Mill Tailings Site, there is no indication that the chemical contaminants are at levels that would result in adverse health effects. It is apparent from community responses that in the past children swam in the tailings ponds. However, ATSDR scientists do not have any environmental sampling data from those ponds; therefore, it is impossible to determine the concentrations of arsenic, molybdenum, selenium, and vanadium to which the children were exposed. One must come in direct contact with the tailings ponds (e.g., swimming) to have exposure. If one lived near the pond, but never swam in the water, or if they did swim in the pond, but never swallowed any of the water, the contaminants in the pond could not have caused their illnesses. See the Toxicological Evaluation subsection of the Public Health Implications section of this public health assessment for a discussion of possible adverse health effects from the chemicals mentioned above.

There is no known association between radiation and heart disease, Crohn disease, Parkinson disease, or neurofibromatosis. Miscarriages, stillbirths, birth defects, and mental retardation were all observed in survivors of the atomic bomb incident, but the levels of radiation were several orders of magnitude more than levels detected in and around Monticello. Infertility is considered to be a high-dose effect, not likely related to low-dose gamma radiation from environmental sources. Loss of coordination, tremors, dizziness, and blackouts are symptoms of high doses of radiation over a short period, followed by death a few hours to a day after exposure. Digestive tract problems would result from similar high doses over a short period of time, although death may not occur for several days or weeks.

Diabetes has not been shown to be related to radiation exposure. Eye disease, vision problems, slow healing of cuts, and frequent infections are symptoms of diabetes. Without specific medical diagnosis, it is not possible to determine whether lumps, growths, and moles are results of radiation exposure.

Thyroid disease is related primarily to iodine 131 exposure. Thyroid problems should not result from exposure to contamination generated at the Monticello Mill Tailings Site.

Respiratory problems, emphysema, pneumoconiosis, and sinusitis could be related to past or current activities at the mill site. At the time the mill was in operation, conditions inside it were most likely dusty, and workers were not required to wear respiratory protection. Inhalation of dusts and particulates are known to interfere with breathing passages and can affect persons who are sensitive to dusty conditions. Workers performing clean-up operations today are required to adhere to the Occupational Safety and Health Administration (OSHA) regulations cited in Title 29, Code of Federal Regulations (CFR), Part 1910.120, Hazardous Waste Operations and Emergency Response. The other symptoms or conditions relate to poor hygiene (dental problems), old age (arthritis), lifestyles (headaches), or to unidentified causes (chronic fatigue syndrome).

2. Can we compare disease rates with rates for other towns or with state and national data? How do registries record medical data (e.g., by hometown or by place of diagnosis/death)?

In the Health Outcome Data Evaluation section of this public health assessment, ATSDR scientists compare the incidence of various types of cancer in San Juan County with incidence in the state of Utah. Cancer statistics for Monticello are also compared with those for Blanding. Utah has the lowest incidence of cancer among the states in the nation. Comparing city or county rates with the rest of the nation would not show a good representation of health outcomes, i.e., rates may be much lower compared to the nation but still may be elevated for the city or county. The state of Utah records the medical data in its registries by the person's place of residence and not the place of diagnosis/death.

3. What are the synergistic effects of smoking and uranium exposure leading to cancer?

The National Academy of Sciences Biological Effects of Ionizing Radiation (BEIR) Committee has concluded that "... exposure to natural uranium is unlikely to be a significant health risk in the population and may well have no measurable effect." Studies have been conducted on radon-222, a decay or daughter product of natural uranium, to determine the implications for the risk of lung cancer. Doctors in Sweden determined that the effects of the interaction between radon exposure and smoking regarding lung cancer exceeded additivity and more likely represented a multiplicative effect (94). However, a study conducted in the United States determined that increased radon correlates strongly with decreased lung cancer rates. Also, when smoking was accounted for, there was no effect on the regression of lung cancer rates (95). There is evident need for more studies to determine what effects smoking and uranium and its associated daughter products have on the development of various forms of cancer.

4. What are the possible harmful public health effects of the solutions that went into the waste stream from the tailings piles?

Publicly accessible waste streams from the tailings piles could include windborne tailings that deposited on off-site soil or rainwater leachate that carried contaminants to the alluvial aquifer and to Montezuma Creek downstream of the mill site. The deeper aquifer known to be tapped by private wells for household use was found to be uncontaminated by tailings leachates. During operation, leachate collected in tailings ponds in which children swam. Off-site residents used some of the tailings for construction purposes.

Of the nonradioactive substances in the soil detected in off-site soil, concentrations of beryllium, chromium, lead, and nickel are insufficient to cause adverse effects to human health.

The alluvial aquifer is not known to be used for household water. Because it could potentially be tapped for future household use, however, we evaluated this aquifer for its potential to affect the public health. Contaminants from the tailings piles (arsenic, molybdenum, nitrate, selenium, vanadium, gross alpha, radium-226, radium-228, uranium-234, and uranium-238) have leached into the shallow alluvial aquifer. Those contaminants have been detected in the shallow aquifer at concentrations exceeding comparison values. However, direct human contact with groundwater from the shallow aquifer, resulting in a completed exposure pathway, appears unlikely for two reasons. First, the shallow aquifer is not presently used as a source of potable water and is unlikely to be used in the future as a public water supply because of the unreliable well yield and limited saturated thickness. Residents in the area downgradient of the mill site currently obtain their water from the Monticello public water supply, which uses uncontaminated, topographically upgradient surface water sources. Second, the extent of the aquifer, which is physically confined to the narrow boundaries of the Montezuma Creek alluvial gravels, is limited. The aquifer downgradient of the mill site is estimated to be no more than 500 feet wide, and the contamination plume extends no more than a mile downgradient before it discharges into the creek. The plume has, therefore, reached its maximum dimensions. To prevent use of the contaminated alluvial aquifer as a source of potable water, institutional controls (establishing local ordinances that prevent the installation of wells screened in the contaminated alluvial aquifer) are effective in ensuring that the aquifer is not used during the time required for restoration. Where produce was grown in soil irrigated by Montezuma Creek, the selenium in the creek might have added to the natural selenium content of the produce. If people eat large quantities of that produce, they might lose hair and their fingernails or toenails might crack or fall off.

ATSDR representatives are reviewing data on the quantity of radon and radium to which residents are being exposed because of the use of tailings in construction materials. When these reviews are completed, it will be possible to evaluate whether the exposure is sufficient to affect the residents' health.

Remediation Concerns

1. **What will happen to residents who live next to the mill site during the cleanup?**

Representatives of the Department of Energy Grand Junction Projects Office (DOE-GJPO) have no plans to relocate or buy out any property owners. Proper safety procedures such as dust control and continuous radioactive air particulate monitoring during removal operations should ensure the safety of nearby residents.

2. **What measures will be taken during remediation of the mill site to prevent recontamination of previously remediated properties?**

Tailings removal from the mill site will be continuously monitored to ensure that off-site releases of radioparticulates do not exceed required standards. Dust control measures will be employed as they have been at other mill tailings sites to prevent the spread of radioparticulates.

3. **Can remediated properties become recontaminated by resuspension of dust?**

It is unlikely that remediation of a vicinity property will contaminate an adjoining property unless large volumes and high concentrations of material are involved. Successful remediation will limit the concentration of radium-226 in the top 15 centimeters (cm) of soil to 5 pCi/g above the natural level of radium in that soil. Preliminary indications are that concentrations for many properties will be well below that level. In order for a property to be recontaminated, a sufficient thickness and concentration of dust would have to be deposited. For example, assume that the soil concentration at a newly remediated property is 4 pCi/g, concentration at the adjacent contaminated property is 10 pCi/g, and the natural background concentration is 1 pCi/g. The thickness of dust required to recontaminate the clean property would be about 5 cm. If the contaminated property is at 100 pCi/g, the dust layer will have to be 0.3 cm thick. Higher concentrations require thinner dust layers. Because of this relationship, it might be necessary to consider dust control measures when decontaminating highly contaminated properties where thin layers of dust could recontaminate adjacent properties. An integral part of any soil remedial action includes extensive dust control.

4. What are possible corrective actions for homes with radioactive mortar?

Possible corrective actions include partial rebuilding, ventilation, and masking. Mortar, bricks, and blocks made from mill tailings can increase the radiation level as well as the radon air concentration inside the building. If the radiation levels are too high, the only course is to remove the affected material and rebuild the part of the building containing the contaminated material. If the radon air concentration is too high, there are two options, ventilation and masking. Ventilation of the living spaces, or the basement or attic that feeds radon to the living spaces, will direct the radon out of the building. There are several ways to accomplish the ventilation: open windows; add a static precipitator to the ventilation system; or force ventilate the rooms, basement, or attic with mechanical devices. Also, if the contaminated mortar is accessible from the occupied side, as in a fireplace mantel, painting it with a heavy epoxy-type coating can reduce the radon emissions and air concentration. Before such efforts are started, there should be a clear understanding of how much each option can cost and how likely it is to improve the condition.

5. How can a resident find out a property's history?

Monticello and area residents with questions or concerns about their property and radioactive materials can contact the DOE-GJPO at the following toll-free telephone number: 1-800-269-7145. Residents can also contact DOE in Monticello at (801) 587-4000.

6. What criteria were used to decide the order of remediation for vicinity properties?

Vicinity property remediation plans were designed to clean up the most heavily contaminated properties first. A city block concept provided for grouping properties into procurement packages that would be the most conservative of remediation funds. DOE representatives said socioeconomic status was never a consideration.

7. Why have some properties have been remediated a second and even a third time?

Some properties have been remediated a second or even a third time because of the discovery of additional contaminants or because the property failed to meet air quality requirements. Other vicinity property projects have experienced similar secondary or tertiary remediations because not all materials that can contribute to interior air quality were discovered initially. In fact, at the levels the DOE must achieve, natural contributions from certain rock units can create additional remediation requirements.

8. Was asbestos removed from the mill site and disposed of in a local sanitary landfill? What are the possible public health effects?

Asbestos was used as an insulating medium in mill buildings, pipe cladding, and vinyl asbestos tile. Similar composite materials were being used for residential, commercial, and industrial purposes throughout the country at the time the mill site was operational. Unneeded or unwanted asbestos-containing materials may certainly have gone to the local landfill.

Asbestos is the name for several minerals that occur in nature in the form of fibers. Because they are heat- and fire-resistant, they have long been used in building materials, friction-reducing products, and heat-resistant fabrics. Fibers can break away from natural asbestos (e.g., during mining operations) or from products containing asbestos (e.g., as they are manufactured). Fiber fragments that become airborne can be inhaled. The healthy human lung is able to remove very short asbestos fiber fragments after the fibers are inhaled. However, the longer fiber fragments cannot be easily removed from the lungs, and some of the shorter fibers are poorly removed by lungs that have been damaged (e.g., by smoking cigarettes). Large numbers of fibers retained in the body for many years could lead to adverse health effects.

The very low concentrations of these fibers normally present in indoor or outdoor ambient air have not been shown to be harmful to health. Brief one-time exposures to low or moderate fiber concentrations have not been shown to cause harm. Adverse health effects such as cancer and asbestosis have appeared in people, especially smokers, occupationally exposed to high fiber concentrations. However, the demolition of mill site facilities and the disposal of the demolition debris in a properly managed landfill are not expected to result in significant amounts of exposure. People who are concerned that they may have been harmed by exposures to asbestos can ask their physicians for chest Xrays. They and their physicians can learn more about the health effects of asbestos from ATSDR's *Toxicological Profile for Asbestos (Update, 1994)* and from ATSDR's *Case Studies in Environmental Medicine: Asbestos*.

9. Were on-site storage buildings, building components, and tanks relocated off site?

We do not have specific information on the disposition of all the buildings, tubing, metal sheeting, and metal framework components from the mill site. Building components were rumored to have gone to the state prison. A field examination performed by DOE-GJPO project personnel did not confirm the presence of such materials at the prison. We do not know the disposition of tanks from the mill site. DOE representatives say no evidence exists that the materials mentioned above are radioactively contaminated.

Concerns were expressed about the granary. The granary is a privately owned site where six silos once stored seeds of beans, corn, wheat, and other crops for farmers. It may also have been an ore storage or ore truck cleaning site. It is west of the mill site across Utah State Road 191. This site was difficult to assess due to limited access and the presence of contamination beneath concrete pads and large silos.

The first radioactive assessment began in March 1989, and the site (granary) was added to the DOE remediation list that year. The site was scanned to identify areas exceeding the area background of 17 microroentgen per hour (μR/hr) plus 30%. Surface contamination was found around the perimeters of five silos and two concrete pads and in a few other small areas. The owner at the time did not allow cores to be taken through the concrete floors of the silos, so investigators used a borehole logger to measure the contamination depth around the silo perimeters. They assumed a uniform depth of contamination. The surveys of the largest slab found hot spots across the slab and an elevated reading on contact with one of the slab's steel reinforcing tubes where the slab's concrete covering had broken away. The hot spots indicated that the slab contains some ore rocks and the tubing is contaminated; however, borehole logging of some of those tubes did not identify any contamination. The tubes may have come from the mill site. Negotiations with the owner will determine the fate of this contamination. Negotiations with the granary's property owner were completed in 1996. The site has been included in the Monticello Vicinity Properties Remedial Action Program. See Appendix D of this document for more details about radioactive surveys and response actions at the granary.

10. Is the golf course in Monticello contaminated?

ATSDR and National Air and Radiation Environmental Laboratory (NAREL) staff members reviewed DOE engineering design documents.

The City of Monticello owns the nine-hole public golf course. The course is southwest of the mill site across Utah State Road 191. The surveys indicated that the mill tailings had been used as fill and top dressing, and 40 areas were found that exceeded the Monticello background of 14.6 μR/hr plus 30%. Elevated soil concentrations existed from 6-inch to 66-inch depths, with the average being 11 inches. Cleanup involved removing approximately 27,000 cubic feet of tailings over 30,000 square feet of land, plus any overlying asphalt roadway.

The contaminated sites were included in the remediation schedule in March 1992. Excavation began in July 1994 and is now complete, and backfilling with clean soil is under way. See Appendix D of this document for more details about radioactive surveys and response actions at the golf course.

11. Is the cemetery contaminated? Are there plans to remediate the cemetery?

ATSDR and NAREL staff members reviewed DOE post-construction radioactive as-built drawings.

The cemetery is the main burial ground for the town and is north and northeast of the mill site. Radiation levels in 6 areas exceeded the Monticello background of 14.6 μR/hr plus 30%. Remediation involved removing approximately 20,000 cubic feet of soil in layers ranging from 4 to 24 inches over 33,000 square feet of land.

This site was included on the remediation list in October 1991. Phase I of the remediation construction started in May 1993 and ended in June 1993. Phase II was included in September 1993, the plan was approved in August 1995, and remediation construction was completed on June 19, 1996. See Appendix D of this document for more details about radioactive surveys and response actions at the cemetery.

12. Could wells on and near the mill site be contaminated?

Wells screened in the upper aquifer, especially wells in areas contiguous to the mill site and the old ore-buying stations, could be contaminated. Wells on the mill site are contaminated. Wells distant from the old ore-buying areas, Montezuma Creek Canyon, and the mill site are screened in the lower aquifer and are not associated hydrologically with the mill site activities. Therefore, we do not suspect that they are contaminated.

13. Does exposure to contaminated groundwater and surface water from the mill tailings leachate result in a long-term public health hazard?

Rainwater leachate carried contaminants to the alluvial aquifer and to Montezuma Creek downstream of the mill site. The deeper aquifer known to be tapped by private wells for household use was found not to be contaminated by tailings leachates.

The alluvial aquifer is not known to be used for household water. However, because it could potentially be tapped for future household use, this aquifer was evaluated for its potential to affect the public health. ATSDR scientists found that concentrations of arsenic and selenium in the aquifer were insufficient in themselves to cause harm.

Selenium in Montezuma Creek might have increased the natural selenium content of the produce grown in soil irrigated by water from the creek. If people ate very large quantities of that produce for many years while drinking only the water from the alluvial aquifer, they might have some hair thinning and cracking or splitting of their fingernails or toenails. If the aquifer became some people's sole source of drinking water and they also ate large quantities of homegrown produce irrigated by water taken from Montezuma Creek downstream of the mill site, molybdenum could cause gout-like illness. Contaminants in the produce would not be expected to cause harm in individuals drinking water from the deeper aquifer.

14. Will the final clean-up plan incorporate a suitable measure of public health protection for all present and future downstream uses of Montezuma Creek water?

The purpose of the Operable Unit (OU) III study was to collect sufficient information and data to characterize the nature and extent of environmental contamination in OU III, identify the sources of contamination, assess changes in contamination patterns over time once on-site sources (tailings piles) have been removed, and to calculate the levels of risk to human health and the environment from the contaminants associated with OU III. The OU III soil and sediment area, which is located entirely on private land, begins approximately 0.5 miles east of the eastern mill site boundary and extends downstream approximately 14,100 feet. The area is currently used for cattle grazing and recreational purposes; no residences are located within the OU III soil and sediment study area. Soil and sediment characterization began in 1994 and continued through September 1996. The primary source of soil and sediment contamination in the OU III soil and sediment study area is the mill site. Montezuma Creek, which flows through the tailings piles on the mill site, has been the primary transport mechanism for soils and sediments. The OU III Remedial Investigation draft report is currently under DOE review.

15. Does the groundwater plume extend further downstream than where testing and remediation is taking place? Will people be exposed to contaminants in the 60 years or so that passive restoration of groundwater is expected to take?

The initial findings of the OU III Remedial Investigation indicate that the alluvial aquifer contaminant concentrations decrease with increasing distance from the mill site, eventually matching natural background concentrations. The distances vary from 7,000 feet downgradient (east) of the mill site boundary for uranium, the most mobile site contaminant, to no further than the downgradient mill site boundary for radium-226, the most immobile site contaminant. The OU III Remedial Investigation report, currently under DOE review, will discuss contaminant plumes in detail as well as present final conclusions about future exposure scenarios.

16. Could radon gases be emitted from a permanent tailings repository?

Low levels of radon gas may be emitted from a permanent tailings repository; however, the repository is designed to make the release rates much lower so they will meet certain regulatory specifications in CFR 40.61 Subpart Q, National Emission Standard for Radon Emissions from the Disposal of Uranium Mill Tailings. According to this regulation, radon-

222 emissions to the ambient air from uranium mill tailings piles that are no longer operational shall not exceed 20 picocuries per square meter second (pCi/m^2s). This is much lower than the levels of radon-222 currently released from tailings piles in Monticello, which range from 100 to 700 pCi/m^2s.

17. Why are new remediation areas suddenly surrounded by yellow "DO NOT ENTER" tape and radioactive signs?

General construction and the disturbance of soils during removal actions can cause new hazards and intensify existing ones. Exposure to radiation and dusts is among the hazards. Remedial actions create greater need for short-term protection of workers and residents from these hazards.

18. Will ATSDR representatives follow up on former residents who have moved away from Monticello?

ATSDR staff members are making every effort to ensure that former residents of Monticello and the surrounding area are contacted. We have developed a site-specific mailing list of around 2,000 names. Approximately 25% of the individuals on the mailing list are former residents of Monticello and the area. These individuals have been contacted and given the opportunity to express their public health concerns and questions.

ATSDR staff members have heard from several of these former residents. We have sent public health information and literature packets to those individuals expressing further interest. We will continue to inform current and former residents of Monticello and the area of ongoing ATSDR activities.

If anyone reading this document has information on individuals who would like to be added to the mailing list, please provide names and addresses to the following office:

ATSDR/DHAC/FFAB/EFAS
Monticello Mill Tailings Site Project
1600 Clifton Road, NE
Mail Stop E-56
Atlanta, GA 30333
FAX (404) 639-6075

19. Can dose calculations for utility workers be evaluated?

We can evaluate any dose calculations that have been performed for utility workers to see if the calculations are reasonable. Those dose calculations would have factored actual data and assumptions into a model. If there is need for reevaluation, we should review the original data, assumptions made, and mathematical formulas used.

20. Will the properties containing contaminated sand from Dry Valley be remediated?

The properties containing sand from Dry Valley have been classified as disputed properties. The disputed properties that exceed the applicable standards for cleanup will be remediated as part of the Monticello project. The only difference between vicinity properties and disputed properties is the source of the radioactive materials (e.g., Monticello Mill Tailings Site, Dry Valley). ATSDR staff members do not have detailed information on the operations at Dry Valley.

21. What are the most likely health effects associated with working at the mill site?

Mill worker public health concerns should be referred to NIOSH, which has staff members who conduct research on the health effects of exposures in the work environment. ATSDR representatives will ensure that NIOSH researchers are aware of mill workers' public health concerns.

ATSDR scientists will continue to review any future community health concerns that become available. Should additional information become available that alters the findings of this public health assessment or addresses issues described herein, this public health assessment will be modified as needed.

CONCLUSIONS

The Monticello Mill Tailings Site (MMTS) is a public health hazard because of the radioactive tailings that are present on site. Public access to the mill site is restricted; only persons involved in remediation are allowed on site. Persons involved in the remediation are required to be monitored each time they leave the mill site.

Tailings from the mill site were also dispersed off site throughout the city of Monticello by the wind, in surface runoff, and by individuals who used the tailings for fill or construction purposes. Remediation of the vicinity properties is ongoing and is scheduled for completion in 1998. However, there are properties in the community that may not be addressed by current remedial actions for various reasons (i.e., properties whose owners have refused remediation, areas outside the 8-mile radius clean-up boundary, properties that contain naturally occurring radioactive materials (NORM), or properties where the brick veneer was left behind). The remaining number of refusal properties is less than 5, and it is the intention of DOE, EPA, and UDEQ to clean up all properties. Unless supplemental standards are approved, properties will be cleaned up to the 40 Code of Federal Regulation (CFR) 192.12 standard. EPA and UDEQ will consider supplemental standards (alternative clean-up levels including institutional controls) only if they are protective of human health and the environment and are in compliance with applicable or relevant and appropriate requirements. EPA and UDEQ have no statutory requirement to clean up NORM. Property owners with such materials will be contacted and given the opportunity to have NORM disposed of in a repository. The potential still exists for individuals to be exposed to low levels of radiation at those properties.

The shallow alluvial aquifer is contaminated from mill site releases, and there is concern because it overlies the deeper Burro Canyon Aquifer, which is used as a drinking water source. However, the Mancos Shale and fine-grained units on the Dakota Sandstone Formation, which separates the Burro Canyon Aquifer from the alluvial aquifer, act as aquitards to limit downward migration from the alluvial aquifer. Direct human contact with contaminated groundwater from the shallow alluvial aquifer appears unlikely, and we have no reports of this aquifer being used as a source of potable water; therefore, there is no current public health risk through this particular medium. Potential for future exposure also exists for anyone (e.g., residents, workers, tourists, hunters, hikers, and ranchers) who might use the shallow alluvial aquifer as a future water source.

Contamination in the soil and water represent a potential for contamination of game animals present on the mill site and Montezuma Creek area. The potential also exists for contamination of domestic cattle raised in the Montezuma Creek area. In the fall of 1996 the EPA and UDEQ staff conducted a study of the body burden of contaminants in tissues and organs of deer and cattle that consumed water and vegetation from the Montezuma Creek floodplain. Cattle and deer from a background reference area were also sampled. The meat, liver kidney, and ribs are being analyzed for radionuclides and nonradionuclide contaminants. Although the analyses have not yet been completed, preliminary results indicate little or no contaminant uptake in cattle or deer above the uptake in the reference area animals. Humans could potentially experience exposure by eating food crops that accumulate contaminants if they were to be grown in the Montezuma Creek area or in a contaminated yard.

Representatives of the Health and Safety Laboratory of the U.S. Atomic Energy Commission performed a study of approximately 215 workers at the Monticello Ore Concentrating Plant in 1957 to determine the levels of radioactive dusts exposures workers were experiencing. The study revealed that there was no effective dust control equipment throughout the plant. It also showed that 86 employees out of the total plant population were exposed to average dust concentrations above the maximum allowable concentration (MAC). Nineteen of those were exposed to greater than five times the MAC. The areas in the mill that exceeded the MAC were the ore sample plant, crushing areas, sample preparation area, and yellow cake drying area. The survey showed that workers in the mill experienced no hazard from external radiation (beta plus gamma or gamma only).

ATSDR representatives reviewed EPA's Riggan's Mortality Tapes and identified two large percentage rate changes for white males and one large percentage rate change for white females living in San Juan County between 1950 and 1970. Between the years of 1950 and 1959 and 1970 and 1979, there was a 395% increase in trachea bronchus lung pleura cancerous deaths in men. Tracheobronchial lymph nodes tend to be the site of greatest concentration for inhaled uranium and thorium. There was also a significant excess of deaths from prostate cancer between 1960 and 1969 compared with rates for the U.S. population during the same period. Prostate cancer is the most common type of cancer among Mormon males. Radiation has not been shown to be a factor in increasing the chances of developing prostate cancer. Between 1960 and 1969 and 1970 and 1979, there was a 287% increase in breast cancer mortality in white females. Exposure to high levels of radiation is known to increase females' chances of developing breast cancer. ATSDR representatives used the CDC WONDER system to review renal failure for males and females in San Juan County. The database covers mortality for the years 1979 to 1991. There were four cases for males, and the age-adjusted rate was equal to the average rate for all counties in Utah that had reportable cases during the same period. There were 11 cases for females, and the age-adjusted rates were higher for San Juan County than for any other county in Utah. The age-adjusted rate for white women was double the rate for all other races in San Juan County.

During ATSDR's public availability sessions, residents of Monticello reported deteriorating clothes on clotheslines and chrome trim on automobiles and disintegrating screen doors. We do not know the extent of emissions from the mill's roaster stack when the mill was operating; however, we believe that emissions of sulfur oxides and sulfuric acid from the stack might have accounted for the reported occurrences.

RECOMMENDATIONS

1. Establish local ordinances to prevent installation in the contaminated alluvial aquifer of wells that would supply potable water.

2. Continue to remediate those properties that exceed standards in 10 Code of Federal Regulations (CFR) 1020 and 40 CFR 192.12 and monitor all properties that have exceeded standards in either of these laws to ensure that remedial actions have removed the tailings.

3. Continue to monitor the wastewater treatment plant effluent to ensure that limits set by the Utah Department of Environmental Quality, Division of Water Quality are not exceeded.

4. Ensure that residents of Monticello scheduled to have their yards remediated do not consume edible food crops grown in their yards until remediation is completed.

5. Evaluate the need for sampling any food crops for human consumption that are grown in the future in the Montezuma Creek floodplain.

6. Continue sampling deer and cattle to determine if a potential food chain pathway exists for potential human uptake. ATSDR scientists concur with the activities and recommend that EPA and UDEQ continue to study and monitor the body burden of contaminants in tissues and organs of deer and cattle.

7. Continue to monitor the Burro Canyon Aquifer downgradient of the mill site. If site-related contaminants increase to levels of public health concern, initiate a definitive well survey and follow-up monitoring of any private wells identified in the survey.

8. Analyze the database containing radon measurements for the vicinity properties and determine what specific health actions are appropriate. ATSDR is scheduled to begin this evaluation during calendar year 1998. The completion and success of this activity depends on the quality and quantity of data as well as the financial funding provided by DOE.

9. Continue to analyze the radon concentrations that are being released from the tailings piles to determine whether off-site concentrations are at levels of public health concern.

PUBLIC HEALTH ACTIONS

Health Activities Recommendation Panel (HARP) Recommendations

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended, requires the Agency for Toxic Substances and Disease Registry (ATSDR) to perform public health actions needed at hazardous waste sites. To determine whether public health actions are needed, the data and information developed in the Monticello Mill Tailings Site (MMTS) and Monticello Vicinity Properties (MVP) Public Health Assessment were evaluated by the ATSDR Health Activities Recommendation Panel (HARP) for follow-up health actions. Because people have potentially been exposed to MMTS contaminants at levels of health concern in the past and present, follow-up health actions related to the MMTS and MVP are indicated at this time. Human exposure is believed to be occurring or to have occurred in the past because of human interaction with pathways of exposure, and there is an indication or allegation that adverse health conditions are occurring or have occurred in the area population that may be related to exposure to hazardous substances from the MMTS. HARP identified the need for site-specific environmental health education and the need for the consideration of health studies.

Public Health Action Plan

The public health action plan for the MMTS and MVP National Priorities List sites contains a description of actions to be taken by ATSDR staff members and other government agencies at and in the vicinity of the sites after completion of this public health assessment. The purpose of this public health action plan is to ensure that this public health assessment not only identifies public health hazards but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment.

ATSDR

The off-site area, the vicinity and peripheral properties, is being considered for follow-up public health actions. Exposure to contaminants from past and current activities at the MMTS suggests the need for health studies and further education efforts.

Health Studies

1. There are completed exposure pathways and the allegation of substantial exposure and serious diseases. The panel has determined that health studies need to be considered that would address the level of current and past exposures and their relationships. The ATSDR site representative is currently working with ATSDR's Division of Health Studies (DHS) representatives to formulate a plan of action.

2. The occurrence of renal failure will be investigated in conjunction with the health studies efforts.

3. ATSDR's Division of Health Assessment and Consultation (DHAC) representatives plan to thoroughly investigate and analyze the Department of Energy's (DOE) residential/property database which contains environmental data for each off-site property. DHS representatives will also integrate an analysis of the database into their health studies activities. The completion and success of this activity is dependent on the quality and quantity of data as well as the financial funding provided by DOE. The community's Monticello Uranium Mill Impact Survey and the leukemia study performed in the 1980s both contain pertinent information to the above efforts. These resources are an integral part of helping more clearly define exposure and disease rate to determine what is occurring medically.

Education

1. There are potential exposures where the community could be educated on specific actions that can prevent adverse health effects.

2. There are past completed exposure pathways where specific actions, knowledge, or education can prevent or mitigate future adverse health effects. For example, physician educational seminars, community information sharing sessions, and problem-specific solving sessions.

3. ATSDR staff will conduct a needs assessment as a basis for determining the appropriate preventative health education plan for the sites. We will identify the public health problems, community concerns, health professional and community-specific needs, and primary target populations for health education. Special needs groups, such as children, minorities, and the elderly, will be noted. ATSDR staff plan to collaborate with state and local health departments. Site-specific preventative health education needs will be categorized for either rapid response or for extended follow-up. The rapid response mechanism will be used for situations that require immediate implementation of education activities to address significant public health concerns. The purpose of the activities will be to provide health professionals and community members with the ability to minimize exposures to hazardous substances or reduce the potential for health impact. The extended follow-up mechanism will be used when the public health concerns do not require an immediate response. ATSDR scientists will provide DOE proposals for extended follow-up activities for comment.

ATSDR staff will continue to monitor the ongoing activities and occurrences in the Monticello area.

<u>DOE</u>

ATSDR recognizes and endorses the DOE, EPA, and state community involvement at these sites and agrees that further coordinated remediation activities are needed in this community. EPA and the state will continue oversight of DOE's activities and participation in community involvement.

Community Involvement

1. DOE has established a Site-Specific Advisory Board (SSAB) consisting of fourteen local residents from Monticello and Blanding to advise DOE on cleanup issues affecting the local community. The SSAB is involved in advising on local training and hiring as well as future land use of the Monticello Mill Site. All meetings are open to the public.

2. DOE and MACTEC Environmental Restoration services staff are in both Grand Junction, Colorado and Monticello. DOE has established a toll-free number (1-800-269-7145) for the public to call with questions or concerns.

Remediation Activities

1. DOE is the responsible party for remediating the Monticello Vicinity Properties (MVP) Site, and is further responsible for certifying that the remediation is completed at each of these properties. The total number of individual MVP included in the site as of December 1996 is 420, grouped into eight operable units. By the end of 1996, 389 properties were remediated. There are an additional 29 peripheral properties. As of May 1997, 11 of these peripheral properties have been remediated.

2. The contaminated materials from the off-site properties are being temporarily moved to the mill site and will be disposed of with the mill site tailings in a permanent repository immediately south of Monticello. DOE's contractor, OHM Remediation Services, will carry out the construction of the repository as well as perform mill site maintenance. Excavation of the repository was completed on April 27, 1996. All surface contaminants posing an unacceptable risk to human health and the environment will be placed in the permanent repository. In late May, 1997, DOE began placement of approximately 2.3 million cubic yards of mill tailings and other contaminated materials in the recently completed repository. The excavation activities will be completed by November 1998.

3. DOE's files of public information on the Monticello Cleanup Projects are at the Monticello City Office at 17 North First East, Monticello, Utah 84535. The Information Repository is a set of documents pertaining to the Monticello projects; it includes documents on site activities, general information about the Superfund program, site-specific information, and the Administrative Record. The Administrative Record, which is a subset of the Information Repository, contains all

information used to select a cleanup remedy for a particular site. The public can access the Information Repository and Administrative Record files by calling the Monticello City Office at (801) 587-2271 or visit during regular office hours between 8 A.M. to 4:30 P.M., Monday through Friday.

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APPENDICES

Appendix A

Population Data
Monticello Mill Tailings Site
Monticello Vicinity Properties

Table A1. Population Data Table

Variable	City of Monticello	San Juan County
Total persons	1,806	12,621
Total area, square miles	2.74	7,821
Persons per square mile	659	2
% White	87.5	43.6
% Black	0.1	0.1
% American Indian, Eskimo, or Aleut	4.3	54.3
% Asian or Pacific Islander	0.3	0.3
% Other races	7.8	1.7
% Hispanic origin	12.3	3.5
% Under age 18	41.4	43.3
% Age 65 and older	10.0	7.1

Source: 1990 Census of Population and Housing, Summary Tape File 1B Extract on CD-ROM (Utah) (machine-readable data files). Prepared by Bureau of the Census. Washington, DC: The Bureau (producer and distributor), 1991.

Housing Data
Monticello Mill Tailings Site
Monticello Vicinity Properties

Table A2. **Housing Data Table**

Variable	City of Monticello	San Juan County
Households*	542	3,375
Persons per household	3.26	3.70
% Households owner occupied	77.9	77.3
% Households renter occupied	22.1	22.7
% Persons in group quarters	2.3	1.0
Median value, owner-occupied households, $	55,300	42,800
Median rent paid, renter-occupied households, $	199	187

* A household is an occupied housing unit. The definition does not include group quarters, such as military barracks, prisons, and college dormitories.

Source: 1990 Census of Population and Housing, Summary Tape File 1B Extract on CD-ROM (Utah) (machine-readable data files). Prepared by Bureau of the Census. Washington, DC: The Bureau (producer and distributor), 1991.

Socioeconomic Data
Monticello Mill Tailings Site
Monticello Vicinity Properties

Table A3. Socioeconomic and Housing Variables Table

Variable	City of Monticello	San Juan County
Median household income, $	25,787	17,289
Per capita income, $	8,615	5,907
% Persons below the poverty level	12.6	36.4
% Persons aged >25 with high school equivalency or higher	79.9	59.7
% Occupied housing units lacking complete plumbing	3.7	28.8
% Occupied housing units on public water source	96.0	63.6
% Occupied housing units using private wells or other water source	4.0	36.4

Source: 1990 Census of Population and Housing, Summary Tape File 3 on CD-ROM (Utah) (machine-readable data files). Prepared by Bureau of the Census. Washington, DC: The Bureau (producer and distributor), 1992.

Appendix B

US EPA Contract Laboratory Program Target Compound List

VOLATILE ORGANIC COMPOUNDS

CHLOROMETHANE
BROMOMETHAN
VINYL CHLORIDE
CHLOROETHANE
METHYLENE CHLORIDE
ACETONE
CARBON DISULFIDE
1,1-DICHLORETHENE
1,1-DICHLORETHANE
1,2-DICHLORETHENE(total)
CHLOROFORM
1,2-DICHLORETHANE
2-BUTANONE
1,1,1-TRICHLOROETHANE
CARBON TETRACHLORIDE
VINYL ACETATE
BROMODICHLOROMETHANE
1,2-DICHLOROPROPANE
cis-1,3-DICHLOROPROPENE
TRICHLOROETHENE
DIBROMOCHLOROMETHANE
1,1,2-TRICHLOROTHANE
BENZENE
trans-1,3-DICHLOROPROPENE
BROMOFORM
4-METHYL1-2-PENTANONE
2-HEXANONE
TETRACHLOROETHENE
1,1,2,2-TETRACHLOROETHANE
TOLUENE
CHLOROBENZENE
ETHYLBENZENE
STYRENE
XYLENE(total)

BASE NEUTRAL/ACID EXTRACTABLES

PHENOL
bis(2-CHLOROETHYL)ETHER
2-CHLOROPHENOL
1,3-DICHLOROBENZENE
1,4-DICHLORBENZENE
BENZYL ALCOHOL
1,2-DICHLOROBENZENE
2-METHLYPHENOL
bis(2-CHLOROISOPROPYL)ETHER
4-METHYLPHENOL
N-NITROSO-D-N-PROPYLAMINE
HEXACHLOROETHANE
NITROBENZENE
ISOPHORONE
2-NITROPHENOL
2,4-DIMETHYLPHENOL
BENZOIC ACID
bis(2-CHLOROETHOXY)METHANE
2,4-DICHLOROPHENOL
1,2,4-TRICHLOROBENZENE
NAPHTHALENE(*)
4-CHLOROANILINE
HEXACHLOROBUTADIENE
4-CHLORO-3-METHYLPHENOL
2-METHYLNAPHTHALENE(*)
HEXACHLOROCYCLOPENTADIENE
2,4,6-TRICHLOROPHENOL
2,4,5-TRICHLOROPHENOL
2-CHLORONAPHTHALENE(*)
2-NITROANILINE
DIMETHYLPHTHALATE
ACENAPHTHYLENE(*)
2,6-DINITROTOLUENE

3-NITROANILINE
ACENAPHTHENE(*)
1,4-DINITROPHENOL
4-NITROPHENOL
DIBENZOFURAN
2,4-DINITROTOLUENE
DIETHYLPHTHALATE
4-CHLOROPHENYL-PHENYLETHER
FLUORENE(*)
4-NITROANILINE
4,6-DINITRO-2-METHYLPHENOL
N-NITROSODIPHENYLAMINE
4-BROMOPHENYL-PHENYLETHER
HEXACHLOROBENZENE
PENTACHLOROPHENOL
PHENANTHRENE(*)
ANTHRACENE(*)
DI-n-BUTYLPHTHALATE
FLUORANTHENE(*)
PYRENE(*)
BUTYLBENZYLPHTHALATE
3,3'-DICHLOROBENZIDINE
BENZO(a)ANTHRACENE(*)
CHRYSENE(**)
bis(2-ETHYLHEXYL)PHTHALATE
DI-n-OCTYLPHTHALATE
BENZO(b)FLUORANTHENE(**)
BENZO(k)FLUORANTHENE(**)
BENZO(a)PYRENE(**)
INDENO(1,2,3-cd)PYRENE(**)
DIBENZO(a,h)ANTHRACENE(**)
BENZO(g,h,i)PERYLENE(**)

(*) - Compound is a polycyclic aromatic hydrocarbon (PAH).
(**) - Compound is considered a carcinogenic PAH.

PESTICIDE/PCB

ALPHA-AHC
BETA-BHC
DELTA-BHC
GAMMA-BHC(LINDANE)
HEPTACHLOR
ALDRIN
HEPTACHLOR EPOXIDE
ENDOSULFAN I
DIELDRIN
4,4-DDE
ENDRIN
ENDOSULFAN II
4,4-DDD
TOXAPHENE
ENDOSULFAN SULFATE
4,4-DDT
METHOXYCHLOR
ENDRIN KETONE
ALPHA-CHLORDANE
GAMMA-CHLORDANE
AROCHLOR-1016
AROCHLOR-1021
AROCHLOR-1232
AROCHLOR-1242
AROCHLOR-1248
AROCHLOR-1254
AROCHLOR-1260

TARGET ANALYTE LIST - METAL ELEMENTS

ALUMINUM
ANTIMONY
ARSENIC
BARIUM
BERYLLIUM
CADMIUM
CALCIUM
CHROMIUM
COBALT
COPPER
IRON
LEAD
MAGNESIUM
MANGANESE
MERCURY
NICKEL
POTASSIUM
SELENIUM
SILVER
SODIUM
THALLIUM
VANADIUM
ZINC

OTHER INORGANIC ELEMENTS

CYANIDE

Appendix C

Additional Toxicological Information

Radioactive Contaminants

Uranium. Pure metallic uranium dust is known to be a very strong carcinogenic agent (1). However, pure uranium metal is very reactive chemically so it either oxidizes in air, preventing further oxidation, or ignites spontaneously at room temperature. The size of the granular structure normally determines the outcome; large chunks tarnish, and very small pieces burn. Water also reacts slowly with uranium.

There are a number of uranium oxides of concern at a mill site, as shown in Table C1 (2). UO_2 is uranium dioxide, a component of the various minerals in the raw ore. U_3O_8 is uranium octaoxide, UO_3 is uranium trioxide, and $UO_4 \bullet 2H_2O$ is uranium peroxide.

Table C1. Uranium Oxides

Oxide	Color	Method of Formation
UO_2	Brown	Reduction of UO_3 by H_2
U_3O_8	Black	Oxidation of UO_2
UO_3	Orange	Ignition of $UO_2(NO_3)_2$
$UO_4 \bullet 2H_2O$	Yellow	Precipitation by H_2O_2 from solutions of UO_2^{2+}

Uranium octaoxide is an insoluble radioactive metal oxide. It is odorless and has an olive-green to black color and solid or orthorhombic (trimetric) crystal structure. In milling, exposure to U_3O_8 dust may cause redness and swelling of the eyes and eye damage, with cataract formation occurring anywhere from 6 months to several years after a single exposure. Other short-term chemical acute health effects due to inhalation include lack of appetite, nausea, vomiting, diarrhea, dehydration, weakness, drowsiness, incoordination, twitching, sterility, blood disorders, kidney damage, convulsions, and shock. "Chronic inhalation may affect the lungs and tracheobronchial lymph nodes and may be associated with increased cancer of the lungs, bone, lymphatic, and hemopoietic tissue. The major organ for uranium toxicity is the kidneys"(3).

Typically, uranium compounds taken into the body are more chemically toxic than radioactively toxic. Animal studies have shown that uranium primarily affects two parts of the kidneys, the glomerulus and the proximal tubules (4). The result is a decrease in filtration rate by the glomerulus and a disruption of solute reabsorption by the tubules. Uranium is loosely bound in the kidneys. It clears within a few weeks, and repair processes start. Chronic repeated exposures typical of exposures uranium millers and miners encounter may affect the repair process. Deaths from nephritis and sclerosis have been reported for both uranium millers and miners (5,6). Nephritis is an acute or chronic inflammation of the kidney; a sclerosis is a hardening of the kidney tissue.

Some animal studies also indicate that uranium administered orally (7), by inhalation (8), or subcutaneously (9) may cause minor liver conditions. These include congestion with blood, exaggerated growth of the hepatocyte cells, and blood circulation changes.

Radium and Thorium. Radium and thorium present complications. Because of these complications, we will discuss both elements. Radium has three isotopes. They are radium-228, radium-226, and radium-224. Thorium has four: thorium-234, thorium-232, thorium-230, and thorium-228. The movement of the thorium and radium radionuclides inside the body is different. Radium and thorium exhibit different behaviors because of the various transmutation[2] possibilities, i.e., the transition of one isotope to another depends on radiation characteristics, half-lives, decay energies, etc.

The focus here will depend on the radionuclides' retention in the bone. There are two classes of "bone seekers": surface seekers and volume seekers. Thorium tends to accumulate on bone surfaces; while radium tends to locate within the volume of the bone. Bone surface seekers are in the immediate vicinity of blood vessels. Thorium, since it is a bone surface seeker, may cause leukemia. The decay products of thorium may remain in the bone, transfer to other portions of the body, or exit the body entirely.

Radon. The United States Environmental Protection Agency (EPA) has listed radon as the second leading cause of lung cancer in the United States (11). One cannot see, smell, or taste it. Good ventilation is necessary to prevent radon accumulation indoors, but outdoors radon is usually found in very low concentrations and generally should not present a health risk. However, since radon is produced from uranium and thorium, there are fairly large amounts of radon releases near uranium processing sites.

Uranium and thorium are naturally occurring radioactive materials present in all soils. Each decays through a sequence or decay chain of radionuclides that includes radon. The isotopes of radon that are the most abundant in soil are radon-220 and radon-222. Since radon is a nonreactive noble gas, it can pass through the soil and escape into the atmosphere. Radon-222 achieves a higher air concentration, which causes it to be a larger public health hazard. The decay products of radon are electrically charged, so they attract and attach to particles floating in the air. The radioactive contamination in the air arises mainly from the radon-222

[2]In physics, a transmutation is any process in which a nuclide is transformed into a different nuclide, usually one of a different element.

parent, its daughters that are attached to dust particles, and its unattached daughters (12). The radon daughters, being heavy metals, react with proteins and can potentially be trapped in the lungs of those breathing radon gas (13).

There are a number of health problems related to radon-220 and radon-222. The lungs retain a large amount of radon decay products produced in them. Radon decay causes radiation exposure of the mucosa of the nose, pharynx, and tracheobronchial tree, and that exposure can lead eventually to cancer. Measurements of the radon concentration in the sinus and mastoid air spaces show that radon and its decay products contribute a significant portion of the total alpha dose to the sinus and mastoid epithelium (10). The healthy human respiratory tract is lined with ciliated cells (cilia are like motorized hairs) and other cells that produce a layer of thick mucus. The beating of the cilia create upward currents in the mucus, forming a mucociliary escalator that carries entrapped hazardous particulate substances upward to where they can be swallowed and eliminated by the digestive tract. In people who smoke and, to a lesser extent, people who have respiratory tract damage from particulate-born acid air pollutants such as sulfurous and sulfuric acid, the cells responsible for this elimination mechanism are damaged. Radon daughters can remain trapped in their lungs for a much longer time (14).

The noble gases radon-220 and radon-222 can diffuse into the bloodstream, where they deposit in the fatty tissues. Cancer and genetic effects are among the long-term delayed effects. However, cancer is most frequently observed in the hematopoietic system, thyroid, bone, and skin (15), with leukemia occurring as the most likely form of malignancy.

Studies of miners (especially of uranium miners) have shown an incidence of lung diseases, including lung cancer, that increases with the concentration and duration of radon exposure (13). These studies associating radon and radon daughters with lung cancer are confounded by the presence of other radionuclides and the silicon dust the miners inhale, and they are also confounded by higher smoking rates among miners than in the general population (13). Efforts to extend the association with cancer reported for the high radon-222 levels (100 to 10,000 picocuries per liter [pCi/L]) to environmental levels (1 to 10 pCi/L) have met with mixed results. Here in the United States, counties with high lung cancer mortality rates ($\geq$ 8 in 100,000) have lower reported indoor radon levels (0.4 to 2 pCi/L) than the radon levels (0.9 to 4 pCi/L) in counties with low lung cancer mortality rates ($\leq$ 4 in 100,000); lung cancer deaths decrease with increasing exposure to radon (16, 17). A group of Swedish researchers examined a wider range of indoor radon levels (from less than 1.4 to more than 10.8 pCi/L) and found no significant association with the relative risk of lung cancer in those who never smoked (18). But the relative risk for those who smoked at least 10 cigarettes per day and were exposed to more than 10.8 pCi/L was three times that of the smokers exposed to less than 4 pCi/L, and more than 30 times the risk of the general population exposed to less than 4 pCi/L (18).

Nonradioactive Contaminants in Soil and Sediment

Beryllium. Soil and sediment off site contain 1 milligram (mg) beryllium per kilogram (kg) soil, which is below the reference dose media evaluation guide (RMEG) of 10 parts per million (ppm). An RMEG is a soil environmental media evaluation guide (EMEG) based on EPA's oral reference dose for absence of noncancer effects. Moreover, ingestion of up to 25 mg/kg/day beryllium has failed to produce adverse noncancer effects in animals (19). A 10-pound child would have to consume 250 kg of the soil each day to ingest the maximum amount of beryllium shown not to have these adverse effects. A significant association between beryllium ingestion and cancer has not been shown, probably because absorption from the gut is poor (19, 20). Dermal absorption is also poor, but beryllium is absorbed upon inhalation (20). When inhaled, its primary hazard is to the point of entry -- the lung (19, 20). Inhaled beryllium has been associated with lung cancer in humans and animals. It is classified B2, a probable human carcinogen, with a unit inhalation risk of 2.4×10^{-3} $(\mu g/m^3)^{-1}$ (19). Assuming a 70-kg human inhales 20 cubic meters/day, the inhalation slope factor is 8.4 mg/kg/day. EPA staff members have drafted a method for determining preliminary remediation goals for carcinogens and noncarcinogens in soil based on route of exposure and land use (21). For a soil contaminant that could present a cancer risk by inhalation and/or ingestion, the following formula expresses the soil concentration (in mg contaminant per kg soil, or ppm) associated with a one-in-a-million risk of cancer:

$$PRG = \frac{TR \text{ X } AT \text{ X } 365 \text{ days/yr}}{EF\text{X}\{(SF_o\text{X}10^{-6}\text{kg/mg}\text{X}IF_{soil/adj}) + (SF_i\text{X}IR_{age\text{-}adj}\text{X}[1/VF+1/PEF])\}}$$

where PRG is the contaminant concentration in the soil associated with TR, the target risk (10^{-6}) for AT years average exposure at 365 days/year with an exposure frequency (EF) of 350 days/year to a soil contaminant having an oral slope factor of SF_o, an inhalation slope factor SF_i, and a soil-to-air volatilization factor of VF. The age-adjusted soil ingestion factor, $IF_{soil/adj}$, is assumed to be 114 mg-yr/kg-day, the age-adjusted inhalation rate, $IR_{age\text{-}adj}$, is assumed to be 14.6 m^3-yr/kg-day, and the particulate emission factor, PEF, is assumed to be $4.63\text{X}10^9$ m^3/kg (21).

For beryllium, assumed to be present chiefly as the oxides, the particulate contribution will be very much greater than that from volatilization, causing the 1/VF term to drop out. Because beryllium causes cancer by inhalation only at the port of entry (lung) and is poorly absorbed by ingestion with no significant reported associated carcinogenicity, the SF_o term also drops out. Thus, the soil concentration of beryllium associated with a one-in-a-million inhalation risk of cancer for residents who are in this area 350 days/year, 24 hours/day, for their entire lifetimes would be almost 3,000 ppm; the 1 ppm present off site therefore would present no increased risk of lung cancer to the people living in the area.

Lead. Children near the Monticello Mill Tailings Site could play in soil containing as much as 22 ppm lead. These concentrations are close to background and below even the most conservative standards likely to be considered in the near future (22). The exact relationship between the lead concentration in soil and that in children's blood is in dispute among scientists. According to one theory, the average concentration of lead in their blood is unlikely to be increased by as much as 0.1 (μg) lead per deciliter (dl) of blood, although the relationship would depend on many factors, such as the chemical form of the lead, the soil particle size, and the nutritional state of the children (22). In one case, this increase was calculated using the relationship reported between soil and blood lead concentrations observed in Helena Valley in Montana and Silver Valley in Idaho (22). The following equation was derived:

$$\text{natural log (blood lead in } \mu\text{g/dl)} = 0.879 + 0.241 \text{ X natural log (soil lead in ppm)}$$

Some factors (soil particle size, chemical species of lead, nonsoil lead sources, population demographics such as age and distribution of wealth, nutritional status, etc.) upon which a soil-lead relationship depends are site specific. By varying assumptions about these and other factors, it is possible to form different conclusions about the potential for lead-induced harm.

Young children are at risk from lead ingestion during the years (ages 2-4 years) they are prone to pica behavior (ingestion of nonnutritive substances, such as soil). Ingestion of small amounts of lead by children is associated with depressed intelligence quotient (IQ) scores, slow growth, and hearing deficits (23). Exposure to larger amounts of lead could harm the fetuses of pregnant women, leading to premature delivery, low birthweight, or miscarriage. Moreover, lead has caused tumors in laboratory animals, suggesting it could cause human cancer (23). Lead is classified by the EPA as B2 (probable human carcinogen), although the available data are not sufficient for quantitative assessment (19). Middle-aged men may become hypertensive from small increases in their blood lead levels (23).

EPA scientists point out that the health effects of lead, especially those on "children's neurobehavioral development, may occur at blood lead levels so low as to be essentially without a threshold" and consider it inappropriate to derive a reference dose (RfD) for oral exposure to lead (19). Because a population's blood lead concentration is directly related to the local soil lead concentration (22), it seems inadvisable to use soil comparison values or standards. Under certain conditions, however, a soil standard may be used. If, as in the case of residents living near the Monticello Mill Tailings Site, there are no lead exposures from additional pathways, young children are probably protected by keeping barren soil near them below 100 ppm, and adults are probably protected from increases in their blood lead levels by keeping soil lead concentrations below 120 to 333 ppm (22). These concentrations are well above the maximum soil concentration found near Monticello.

Thallium. Thallium is no longer used as a rat poison, because the oral dose sufficient to kill half of treated rats is three times greater than that which would have the same proportion of lethality in humans (14). EPA verified an oral RfD of 0.00009 mg thallium (as the sulfate)/kg/day (19). This value resulted from application of an uncertainty factor of 3,000 to the highest oral no-observed-adverse-effects-level (a NOAEL of 0.25 mg thallium sulfate/kg/day) administered to rats for 90 days in the key study (19). All treated rats in this study, down to the lowest dose of 0.01 mg/kg/day, showed hair loss, excessive eye tearing and bulging eyeballs, but EPA did not consider these effects adverse (19). The uncertainty factor of 3,000 included factors of 10 for extrapolation from subchronic to lifetime exposure, 10 to allow for sensitive subpopulations, and 3 to account for lack of reproductive and lifetime toxicity data (19). Moreover, it is not clear that the effects in the study would not be considered adverse to human health. Thallium has been used as a depilatory (hair remover) by some people, but involuntary loss of all hair from the head and body might not be welcomed by all people (14). Finally, reproductive and developmental effects do exist in the thallium toxicity database (19, 24). A strain of rats different from that used in the key study exhibited testicular injury at 0.7 mg thallium/kg/day for 60 days, with no NOAEL identified (19). Pups born to pregnant rats treated with 0.08 mg or more thallium/kg/day exhibited poor learning capacity, with no NOAEL identified, suggesting neurological vulnerability in the developing or young animal (24). For all these reasons, use of the RfD to estimate a soil RfD-based medium evaluation guide would not be unreasonably conservative. If a 10-kg child prone to pica behavior ingested 5 grams (about a teaspoon) of soil per day contaminated by 0.2 ppm thallium, the resulting dose would be the RfD (25). The sample quantitation limit applied to off-site soil is 10 times this RMEG (26). More sensitive analytical methods are available to protect the exposed public (24).

Nonradioactive Contaminants in Groundwater

Arsenic. Arsenic occurs in the environment in both inorganic and organic forms. In the absence of specific information about the form of arsenic in the soil and groundwater, public health would be better protected by assuming that all arsenic found on-site in groundwater and soil is in the much more toxic inorganic form. Chronic human ingestion of as little as 0.01 to 0.06 mg/kg/day (e.g., 350 to 2,000 ppb in drinking water) of inorganic, but not organic, arsenic has been associated with evidence of impaired circulation in the extremities, such as significantly increased incidence of blackfoot disease and symptoms similar to Raynaud syndrome (27). Other noncancer effects of low-level human oral exposure to the inorganic form included abdominal pain, diarrhea, liver damage (hepatomegaly and portal hypertension), skin lesions (melanosis and keratosis), and mild peripheral neuropathy (27). No effects were seen consequent to oral intake of as much as 0.006 mg inorganic arsenic/kg/day (e.g., 21 ppb in drinking water) (27). Human ingestion of 0.009 to 0.04 mg inorganic arsenic/kg/day (e.g., 315 to 1,400 ppb in drinking water) for 12 to 60 years has been associated with increased incidence of cancer of the skin, lung, and liver (27). Although EPA declined to verify an oral slope factor for inorganic arsenic, that agency did derive a unit risk in water of 0.00005/μg/L (19). Because EPA assumes chemical carcinogenesis to be without a threshold, the derived value suggests lifetime exposure to drinking water containing as little as 0.2 ppb inorganic arsenic might result in a low increased cancer rate in the exposed public. Because of pharmacokinetic considerations, ingestion of less than 250 μg/day (0.004 mg/kg/day) does not affect blood arsenic concentration -- i.e., an adverse effect on the public health from arsenic ingestion would be unlikely from concentrations of inorganic arsenic less than 120 ppb in drinking water (28).

Drinking water used by residents near the mill site is either supplied by the city from surface water taken upstream of the mill site, or taken from wells that tap the Burro Canyon Aquifer. These water sources have not exceeded 50 ppb (29). Since 1984, the alluvial aquifer has not exceeded 131 ppb off site (29). This value is unlikely to affect the public health adversely for two reasons. First, there is no evidence that any wells that have been supplying potable water tap the alluvial aquifer, although it is possible that some wells might do so now or in the future in the absence of institutional controls, such as ordinances to prevent screening this aquifer. Second, there is little likelihood that this maximum value has been reached with sufficient frequency to result in an average chronic intake in excess of 120 ppb for any individual.

Vanadium. Vanadium is a nonradioactive chemical element that makes up about 0.02% of the earth's crust. After refining, it is a light gray, shapeable, flexible metal that is hardened and embrittled after reaction with oxygen, nitrogen, or hydrogen. Vanadium is found in air, soil, food, plants, and animals. Although some evidence suggests that vanadium may be an essential trace element for mammals, this issue has not been resolved. In the mill operated at Monticello, the vanadium and its compounds were extracted as vanadium pentoxide (V_2O_5). Vanadium pentoxide (red cake) is an odorless, yellow to rust-brown crystalline powder. Vanadium pentoxide and vanadates are the vanadium compounds most likely released from the Monticello Mill Tailings Site onto nearby properties.

Occupational exposure to vanadium-containing dusts is encountered in the mining of vanadium-bearing ores. Most of the vanadium-bearing ores in the United States come from Arkansas, Colorado, Utah, and Idaho. In milling, exposure to vanadium-containing dust can occur on and near the production sites. These dusts can contain numerous vanadium compounds, particularly vanadium pentoxide and, to a lesser extent, the vanadates. Numerous exposures to vanadium compounds have occurred during the cleaning of oil-fired burners, where the dust is generated from the residual oil ash of high-vanadium content oil.

Much of the information on the public health effects of vanadium and its compounds on humans has come from reports of accidental exposures of workers in vanadium processing and manufacturing plants and in boiler cleaning operations. However, some questions posed by these studies have prompted research involving controlled exposures of humans. Table C2 (30) summarizes the health effects of vanadium compounds on humans involved in those controlled exposure experiments. Most of the symptoms and signs indicated in Table C2 are short-term or acute health effects.

Epidemiologic studies of workers exposed for a long time indicate that exposures to vanadium cause health effects similar to those of the short-term studies described above. The acute effects of irritation were reversible after exposure ended. However, more severe chronic or delayed effects, i.e., emphysema and pneumonia, were reported, but the available data make these reports less than reliable. Table C3 (30) summarizes the epidemiologic studies conducted in populations exposed to vanadium compounds, mostly vanadium pentoxide.

Occupational exposure to vanadium and vanadium compounds, especially vanadium pentoxide, produces mainly irritation of the eyes and the upper respiratory tract, often accompanied by productive cough, wheezing, rales, chest pains, difficulty in breathing, bronchitis, questionable pneumonia, and rhinitis (31,32,33,34,35,36,37,38,39,40). There have been occurrences of green-to-black discoloration of the tongue, metallic taste, nausea, and diarrhea (38, 39, 40). Several studies have reported skin irritation (31,32,41,42,43,44). General fatigue, weakness, headache, and tremors of the hands have also been reported (32,33,39,40,45), but their relationship to vanadium exposure has not been demonstrated. Earlier investigations (40, 46) that suggested systemic poisoning effects from vanadium have not been confirmed by later and more detailed studies (32,36,38,39,42).

The most likely routes of exposure that would result in environmental doses of vanadium and its compounds for the residents of Monticello are inhalation, skin contact, eye contact, and ingestion. Doses of vanadium and its compounds can cause short-term acute effects and long-term chronic or delayed effects. The occurrences of these effects depend on the amount of the vanadium and its compounds that are delivered to the body, i.e., the body dose. If the dose is not large enough, there would be no adverse health effects. The residents of Monticello likely were exposed to vanadium pentoxide through the airborne particulate releases from the mill site and resuspension of the released materials. The Occupational Safety and Health Administration (OSHA), the National Toxicology Program, and the International Agency for Research on Cancer do not list vanadium pentoxide as a carcinogen (47). The primary short-term effect (47) that could be caused by inhalation is respiratory irritation, which exacerbates respiratory diseases such as asthma. Low doses may cause other signs and symptoms (48, 49), such as runny nose, sneezing, coughing, asthma, headache, lack of appetite, dizziness, nervousness, and sleeplessness. High doses may cause signs and symptoms (48) such as weight loss, nausea, vomiting, stomach pain, bloody spit, blood in the urine, difficulty breathing, asthma, headache, anemia, dizziness, nervousness, sleeplessness, and for very high doses, even lung damage. Possible long-term effects from exposure (47, 49) are high blood pressure, lung effects, blood disorders, and liver and kidney damage.

Skin contact may cause dermal irritation, including rash and itching. Eye contact may cause eye irritation, including tearing and blurred vision. These signs and symptoms would apply to both short- and long-term effects (47).

Ingestion may cause the following symptoms at low doses: runny nose, metallic taste, blood disorders, high blood pressure, and kidney effects. The following effects may be caused at high doses: nausea, vomiting, diarrhea, stomach pain, and difficulty breathing. The effects that may be caused at very high doses are paralysis, convulsions, and even kidney damage. These signs and symptoms are for short-term effects (47, 49); there is no information available on significant long-term adverse health effects (47). Animal studies indicate that vanadium may be an essential requirement of the diet and that it contributes to glucose balance in animals (49). Vanadium is being investigated as a treatment for diabetes (48,50,51,52).

Table C4 shows occupational exposure limits established for vanadium pentoxide. Table C5 lists the environmental exposure limit and dose limits for the general public established for vanadium and its compounds.

The occupational limits are provided for informational purposes only. These limits are for use in the practice of industrial hygiene as guidelines or recommendations in control of potential health hazards and **are not** for use in the evaluation or control of community air pollution exposures. Although the OSHA permissible exposure limit is 0.05 $mg(V_2O_5)/m^3$ time weighted average (TWA), a material safety data sheet (46) indicates that direct skin contact with air concentrations of about 0.03 $mg(V)/m^3$ may result in dermal irritation, eczema with intense itching and discharge, generalized rashes such as hives, and possible sensitization resulting in contact dermatitis during acute exposures. During chronic exposures at these concentrations, repeated or prolonged contact may result in allergic eczema, sensitization, and dermatitis. Direct eye contact with air concentrations of greater than or equal to 0.018 $mg(V)/m^3$ may result in eye irritation, profuse tearing, blurred vision, and a burning sensation of the conjunctiva during acute exposures. During chronic exposures at these concentrations, repeated or prolonged exposures may cause inflammation of the conjunctiva.

The signs and symptoms discussed above can also be caused by physical, radioactive, and chemical toxicants other than vanadium and its compounds. Only a medical diagnosis can determine the cause of reported signs and symptoms. Any residents of Monticello who develop any of these signs or symptoms and suspect that they may be caused by exposure to vanadium-containing or radioactive dusts should consult their physicians.

Table C2. Human Research Results on the Health Effects of Vanadium Compounds

SUBSTANCE	DURATION and EXPOSURE ROUTE	CONCENTRATION OF VANADIUM (mg/m³)	REPORTED EFFECTS	REFERENCE
V_2O_5 (vanadium pentoxide)	Unknown Respiratory	1-48	Respiratory irritation with bronchopneumonia, heart palpitations	53
V_2O_5	2-5 days Respiratory	10-32	Respiratory irritation, tremors, discolored tongue	54
V_2O_5	8 hours Respiratory	0.6	Coughing	55
V_2O_5	5 minutes Respiratory	0.6	Coughing, rales	55
V_2O_5	8 hours Respiratory	0.1	Coughing	55
V_2O_5	8 hours Respiratory	0.06	Coughing	55
V_2O_5, $NaVO_3$ (ammonium metavanadate)	Unknown Respiratory	0.3-1.2	Eye, respiratory irritation	37
V_2O_5, NH_4VO_3	Unknown Respiratory	0.04-0.4	Respiratory irritation, discolored tongue	56
V_2O_5, V_2O_3 (vanadium trioxide)	1-5 years Respiratory	Unknown	Asthma in 3 of 120 workers	57
$Ca_3(VO_4)_2$ (calcium vanadate)	1.5 days Respiratory	Unknown	Bronchitis, fever, headache, gastrointestinal (GI) distress	45
V-Al alloy (vanadium aluminum)	Unknown Respiratory	Unknown	Respiratory irritation, discolored tongue	58
VC (vanadium carbide)	Unknown Respiratory	Unknown	Little effect	38
FeV (ferrovanadium)	Unknown Respiratory	Unknown	Eye, respiratory irritation	38
V (vanadium metal)	Unknown Respiratory	Unknown	Respiratory irritation	38
$(CHOH)(CO_2NH_4)$ (ammonium vanadyl tartrate)	45-68 days Oral	25 mg, 1-4/day	GI discomfort, discolored tongue, increased steroid excretion	59
$(CHOH)_2(CO_2NH_4)_2$ (diammonium vanadotartrate)	6 months Oral	25mg/day,2 wk; 125mg/day, 22 wk	GI discomfort, pharyngitis, tongue ulceration and discoloration	60

Table C3. Summary of Epidemiologic Studies with Vanadium				
SUBSTANCE	DURATION and EXPOSURE ROUTE	CONCENTRATION of VANADIUM (mg/m^3)	REPORTED EFFECTS	REFERENCE
Vanadium ore	<3 years Respiratory	0.1-2.212	Eye, respiratory irritation	39
V_2O_5 (vanadium pentoxide), vanadates	2.5 years (mean) Respiratory	0.01-0.52	Respiratory irritation, discolored tongue	38
V_2O_5	0.5-16 years 6 years (mean) Respiratory	Unknown	Cough, pulmonary effects with chest pain	40
V_2O_5	2-13 years 6.6 years (mean) Respiratory	Unknown	Eye, respiratory irritation, chest pain, bronchitis, emphysema	61
V_2O_5	2-3 years Respiratory	Unknown	Eye and respiratory irritation, bronchitis	61

Table C4. Occupational Exposure Limits for Vanadium Pentoxide		
ESTABLISHED BY	CONCENTRATION	FORM
Occupational Safety and Health Administration	0.05 $mg(V_2O_5)/m^3$ time-weighted average (TWA)	Respirable dust and fume
National Institute for Occupational Safety and Health	0.05 $mg(V)/m^3$ 15-minute ceiling	Total particulate
American Conference of Governmental Industrial Hygienists	0.05 $mg(V_2O_5)/m^3$ TWA	Respirable dust and fume

Table C5. Vanadium Exposure/Dose Limits for the General Public		
Established By	Type Limit	Limit
ATSDR[a]	MRL (Airborne Exposure)	0.0002 mg V/m^3
ATSDR[a]	MRL (Oral Dose)	0.003 mg V/kg/day
USEPA[b]	RfD (Oral Dose)	0.009 mg V/kg/day

NOTE: Table C5 includes the following footnotes and abbreviations:

[a]Agency for Toxic Substances and Disease Registry. Toxicological profile for vanadium. Atlanta: U.S. Department of Health and Human Services, Public Health Service; 1992.
[b]Environmental Protection Agency. "Integrated Risk Information System," [online database]. January 6, 1994. Washington, DC: Environmental Protection Agency; 1994.

MRL = minimal risk level
RfD = reference dose
mg = milligram
V/m^3 = vanadium per cubic meter
V/kg/day = vanadium per kilogram per day

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Appendix D

Other Community Concerns Evaluation

1. What is ATSDR, and what are the agency's responsibilities?

The Agency for Toxic Substances and Disease Registry (ATSDR) is part of the U.S. Department of Health and Human Services. ATSDR's mission is to prevent exposure and adverse human health effects and diminished quality of life associated with exposure to hazardous substances from waste sites, unplanned releases, and other sources of pollution present in the environment. ATSDR has no regulatory authority, but the agency does recommend public health actions that address potential adverse health effects resulting from environmental releases from hazardous waste sites.

ATSDR's staff is responsible for preparing public health assessments according to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund). As mandated by that law, staff members conduct public health assessments of hazardous waste sites listed or proposed for listing on the National Priorities List (NPL) of the U.S. Environmental Protection Agency (EPA). ATSDR also responds to requests (petitions) to conduct public health assessments.

Three primary sources of information are used in a public health assessment: environmental data, community health concerns, and health outcome data. ATSDR scientists do not routinely perform environmental sampling. The environmental data used in public health assessments come from the Department of Energy (DOE), the EPA, state and local environmental and health agencies, and other groups or individuals. In addition, ATSDR health assessors conduct site visits to make firsthand observations of current conditions at the site, land use, public accessibility, and demographic characteristics of the nearby community.

Health assessors gather community members' health concerns to determine whether people who live or work near the site are experiencing specific health effects. Information from the public also helps ATSDR assessors determine how people might have been or might be exposed to hazardous substances in the environment. Throughout the public health assessment process, ATSDR staff members talk with people living or working at or near the site about site-related health concerns. Other sources of community health concerns are records from the site's public affairs office, EPA's community relations representative, and state and local health and environmental agencies.

Health outcome documents identify health effects that occur in populations. Data from those documents, which come from sources such as state tumor registry databases, birth defects databases, vital statistics records, or other records, may provide information about the general health of the community living near a site. Other, more specific information, such as hospital and medical records and records from site-specific health studies, may be used. Demographic data that provide information on population characteristics (e.g., age, sex, and socioeconomic status) are useful in the analysis of health outcome data.

ATSDR health assessors identify actual and perceived site-related health effects and the level of public health hazard posed by the site. They then make recommendations for the agency to DOE, EPA, and relevant state and local agencies, as appropriate, on preventing or alleviating human exposures to site-related contaminants. When indicated, ATSDR assessors identify a need for any follow-up health activities such as epidemiologic studies, registries, or community health education. Finally, ATSDR staff members provide a mechanism to reevaluate health issues as site conditions change (e.g., after site remediation or changes in land use) or when new information becomes available.

The public health assessment includes a public health action plan (PHAP). The PHAP contains a description of actions ATSDR representatives and other parties will take at and in the vicinity of the site. The purpose of the PHAP is to provide a plan of action for preventing and mitigating adverse human health effects resulting from exposure to hazardous substances in the environment. ATSDR staff members monitor the implementation of the plan annually. Public health actions may include but are not limited to restricting site access, sampling, surveillance, registries, health studies, environmental health education, and applied substance-specific research.

Public health assessments are distributed in three phases: an initial release (red cover), a public comment release (brown cover), and a final release (blue cover). The initial release document, which is prepared as part of the process of gathering and analyzing data and drawing conclusions and recommendations from the information evaluated in a public health assessment, goes for review and comment to the DOE component involved, EPA, and state and local environmental and health agencies. This release gives agencies the opportunity to comment on the completeness of information they have provided and the clarity of the presentation. The initial release comment period lasts 45 days. After the initial release, the ATSDR staff prepares the document for distribution to the general public. The public is notified of the document's availability at repositories (e.g., libraries and city halls) in the site area through advertisements and public notices in newspapers. The public comment period lasts 45 days. After public comments, ATSDR staff members address all public comments and revise or append the document as appropriate. The final public health assessment is then released; that document includes written responses to all public comments.

A public health assessment is an ongoing process. ATSDR staff members revise final documents if new information about the environment, community health concerns, and health outcome data become available and are found to modify previous conclusions and recommendations.

2. **Is the aquifer located beneath White Mesa Mill contaminated?**

Staff members of EPA Region VIII, the Nuclear Regulatory Commission, and Energy Fuels are investigating the concern that the aquifer located beneath the White Mesa Mill Site may be contaminated by UMETCO activities.

3. **Can you provide additional information about the granary, golf course, and cemetery?**

Uranium mill tailings were found at the golf course and cemetery during the radioactive surveys performed throughout Monticello, and both tailings and ore were found at the granary. The tailings appear to have been introduced as a fill material for depressions or top dressing to improve surface quality. The radioactive surveys used the same type of equipment and methods described below to locate, quantify, and determine the extent of contamination. Contaminated sites were then scheduled for remediation. A summary of the survey equipment and methods appears below, followed by a discussion of remediation efforts and their status for each site.

Scientists used a gamma scanner, a soil contamination monitor, soil collection and analysis equipment, and a bore hole logging device to assess radioactive levels. The gamma scanner determined the aerial extent of the contamination; the soil contamination monitor estimated the radium-226 concentration and refined the contamination boundaries; the soil collection equipment was used to obtain a column of soil for measuring the depth profile of the contamination; and the bore hole logger provided a rapid estimate of that profile. Table D1 summarizes the ambient levels of gamma radiation and soil radioactivity concentration present in the particular portion of Monticello and the increase above those levels that would cause a property to be included in the remediation program.

Table D1. Property Inclusion Limits				
Property Type	Gamma Radiation (μR/hr)		Radium-226 in Soil (pCi/g)	
	Background Level	Limit	Background Concentration	Limit Above Background
Granary	17	Bkg + 30%	1	5/15
Golf Course	14.6	Bkg + 30%	1	5/15
Cemetery	14.6	Bkg + 30%	1	5/15

μR/hr = microroentgen per hour
pCi/g = picocuries per gram
Bkg = background
5/15 = 5 pCi/g in the top 15-centimeter (cm) layer of soil and 15 pCi/g in each subsequent 15-cm layer

The gamma scanner used to locate and define the perimeter of contaminated areas consisted of a 1-1/2" x 1-1/2" sodium iodide detector and a digital rate meter that measures in counts per second. It was checked against a pressurized ion chamber to determine the count rate to dose rate conversion factor. The detector was mounted on a hospital crutch to make it easy to quickly move the detector and reproducible space the detector 3" off the ground. Any reading more than 30% greater than the background level indicated potential contamination and was noted on a property map. The resulting map provided a rough footprint of elevated areas.

Analysts used the Delta Scintillometer soil contamination monitor to estimate the radium concentration in the top 15 centimeters (cm) of soil and define the perimeter of contaminated areas precisely. The monitor measures total counts during a counting interval. It is a one-piece instrument, manufactured by Rust Geotech, that consists of a 2" x 2" sodium iodide detector surrounded by a lead prefilter a few millimeters thick, a count-up and count-down digital scaler with timer, and a 3" x 3" x 1/4" tungsten shield. It was placed in contact with the ground and allowed to collect counts for 2 minutes. The tungsten shield was inserted below the detector to shield the detector from any contamination directly below it and allowed to count backward for 2 minutes. The resulting counts measured contamination directly below the detector. The factor for converting the unit's count rate readings to soil activity concentration was determined on a DOE calibration pad at the Grand Junction, Colorado, airport, where the radium-226 concentration is well documented.

Investigators used either a corer to collect a vertical sample or a bore hole logging device to measure radiation levels at depths under the surface as a basis for determining the depth profile of contamination. The corer is a hollow tube pounded into the ground and then removed to extract a vertical plug of soil, which is subsequently sectioned every two inches and analyzed through the use of a multichannel analyzer. The bore hole logger was a 3" x 3" sodium iodide detector connected to a scaler and adjusted to see gamma ray energies above 500 kiloelectron volts. The process involved digging a hole with a gasoline-powered 4"-diameter auger, and lowering the detector into the hole. Readings were taken at 3-inch intervals from the surface to a maximum depth of 6 feet, although the practical depth was normally limited to 3 feet by the rough and rocky terrain. A correction was made for activity in soil sections above and below the section of interest. Soil concentrations at more than 5 picocuries per gram (pCi/g) in the top 15 cm of soil and more than 15 pCi/g in deeper layers were considered contaminated.

Each area was mapped to show its area size and depth in inches. The tailings were excavated to the prescribed depth through the use of earthmoving equipment, or hand tools near fence posts, and moved to the East Tailings Pile for temporary storage. The excavated areas were then backfilled with clean soil with a concentration below 1 pCi/g and reseeded or resodded.

After remedial action, each excavation area was gridded into roughly 10' x 10' areas and soil samples and Delta Scintillation surveys were taken. Soil aliquots from 9 to 12 areas were blended to represent 100 meters of surface and analyzed in an opposed crystal system (OCS). The OCS is a lead shield containing two 3" x 3" sodium iodide detectors facing each other. The sample was packaged in a metal can, then placed between the detectors and, after 500 seconds, analyzed for the 609 keV peak of 214-Bi, a radium-226 decay product. This method can analyze a nonuniform sample more accurately than a single crystal system can. Any area where the average radium-226 concentration exceeds 5 pCi/g in the top 15-cm of soil or 15 pCi/g in each subsequent 15-cm layer, averaged over 100 square meters, was selected for remediation.

4. Why are uranium mill workers not covered by a federal compensation act when uranium mine workers are?

Address concerns about the expansion of the Uranium Mine Workers Compensation Act to cover mill workers to the following individuals:

Lynda Taylor
Southwest Research and Information Center
P.O. Box 4524
Albuquerque, NM 87106
(505) 262-1862

Christine Benally
Office of Navajo Uranium Workers
P.O. Box 6035
Shiprock, NM 87420
(505) 368-1260

Address further questions about the scope of the Uranium Mine Workers Compensation Act to the appropriate congressional representatives.

5. **How can the residents find more information about the Nevada Test Site and the Utah downwinders study?**

The Utah downwinders study was conducted by representatives of the U.S. Department of Energy's Nevada Operations Office, which is the office responsible for the Nevada Test Site. Concerned residents may request information about the Nevada Test Site and/or about how the downwinders study from the following individual:

Mr. Chris L. West, Director
Office of Intergovernmental and External Affairs
U.S. Department of Energy
Nevada Operations Office
P.O. Box 98518
Las Vegas, NV 89193-8518

Appendix E

Uranium Mill Workers Exposures and Long-Term Health Effects

Compiled by Ken Silver, Boston University

Former workers of the Monticello Mill and area mines have raised questions regarding their long-term risks of chronic, work-related diseases. These concerns are well-founded. Since the 1940s, federal and state authorities, as well as some employers, have conducted periodic evaluations of working conditions and mine and mill workers' health status. The Monticello Mill itself and some area mines have been included in a number of these evaluations. The implications of these historical studies for former workers are discussed in the sections below. Overall, these studies provide an important documentary record of working conditions and health problems in the industry during the time period that is of concern to Monticello residents.

One serious drawback to relying on old government studies is that exposure levels specific to the Monticello Mill are not always available. Most studies provide summary results from several mills, instead of a mill-by-mill breakdown. However, in general terms, Harris et al (1959) states that the older mills that were originally built for the extraction of vanadium "had no great emphasis on dust control." The 1958 industrial hygiene evaluation of the Monticello Mill conducted by National Lead Company (Beverly and McArthur, 1958), which is discussed below, suggests that this generalization was an apt description of the Monticello Mill, which was built for the extraction of vanadium in 1942.

Mill workers are thought to have had relatively little exposure to radon gas and its decay products, because of the open, airy construction of mills in that era and the opportunities for off-gassing by ores in the early steps of transport and processing. Crusher houses were the only mill areas ever considered to pose a radon hazard. Exposures to silica dust, mixed radioactive dusts, metallic components, and acids were commonplace in milling operations. Beginning with the earliest investigations of Wolf (1948) and Holaday et al (1951, 1952), several themes are apparent:

- o dry operations, including the handling of finished product, were associated with the highest exposures
- o vanadium exposure in certain operations produced upper respiratory tract irritation, resulting in a dry hack, or cough
- o vanadium exposure produced a green coating on mucous membranes, tongue and teeth,
- o workers in certain operations absorbed uranium
- o a high potential for silica exposure existed in certain mills

These investigators also struck several themes regarding industrial hygiene controls that were to be echoed by subsequent reports and studies:

o local exhaust ventilation, if made available, could bring under control many of the hazards in the dustiest operations
o better housekeeping was needed to reduce dust throughout the plants
o vacuuming should replace dry sweeping and compressed air for cleanup
o respirators may be useful as an interim measure, until engineering controls were instituted, or in transient high-exposure situations

An industrial hygiene survey of the Monticello Mill performed by National Lead Company in 1958 (Beverly and McArthur, 1958) reiterated many of these themes. Marked variability in levels of dust was found among different areas of the plant. Levels of airborne radioactive dust exceeded the maximum permissible concentration (at that time 5×10^{-11} μc/ml) by 2- to 78-fold in air samples obtained in the following areas of the plant: ore sample plant, sample preparation area, crushing area, and yellow cake drying area. Workers in some dusty areas were found to have elevated urinary levels of uranium, but the results were highly variable among individuals with similar external exposures. Exposure to external radiation was highest in areas where yellow cake was handled. The authors recommended major improvements in equipment, such as new dust collectors for the plant crusher building as well as the yellow cake drying and drumming area. After some equipment changes were instituted in July 1958, further air sampling in October of that year revealed mixed results: big decreases were seen in some areas, with modest reductions in others. In a few cases, such as the yellow cake dryer, exposures actually increased.

The most extensive evaluation of the uranium milling industry was conducted by Harris et al (1959). Harris's team from the Atomic Energy Commission's Health and Safety Laboratory in New York inspected 12 mills from the standpoint of worker health hazards, but also took into consideration environmental health hazards. The industrial hygiene survey conducted by Beverly and McArthur (1958) mentions Harris's group as having monitored the Monticello Mill for radiation in April 1957. Therefore, it is safe to assume that the Monticello Mill is one of the 12 mills reported in the Harris et al (1959) study as mills "A through L." But which one? We do not know.

Nevertheless, the Harris et al (1959) report provides an important glimpse into working conditions and health hazards in this industry during the late 1950s. Between one-fourth and one-third of workers were estimated to be exposed to airborne radioactive dust above the Atomic Energy Commission's maximum permissible concentration of 5×10^{-11} μc/ml. The highest exposures were in initial ore handling and final concentrate packaging. Manual handling of dry yellow cake produced "extremely high" levels of airborne radioactive dust. Workers in adjacent operations were also at risk, as the aforementioned dusty operations were capable of contaminating surrounding work areas. The degree of silica hazard was dependent to a large degree on the percent free silica in the ore, which ranged from 5% to 50% among the 12 mills studied. Vanadium levels were found to be high in the final processing areas. Confirming concerns first raised by Miller et al (1956), Harris' group also noted potential hazards associated with the handling of acids, alkalis, and other chemicals employed in milling operations.

By the end of the 1950s, a large database had accumulated on worker exposure to airborne contaminants in the uranium milling industry (Kusnetz, 1959). The crushing area of the mill was frequently associated with excessive airborne concentrations of silica, radium, and vanadium. In the final product area of the mill, uranium exposures were especially problematic, but vanadium could also pose a hazard. By the early 1970s, when responsibility for following up the health experience of uranium millers had passed to the National Institute for Occupational Safety and Health, Archer et al (1973) detected excess deaths due to lymphatic and hematopoietic cancers. A decade later, Waxweiler et al (1983) confirmed this finding, and also suggested that nonmalignant respiratory disease and chronic kidney disease are elevated among former uranium mill workers. With funding from the U.S. Army, NIOSH is now embarking on a further follow-up study of the long-term health experience of uranium mill workers.

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Los Alamos Scientific Laboratory, Health Division. H-Division progress report, August 20, 1950, to September 20, 1950. Los Alamos: Los Alamos Scientific Laboratory, 1950; p. 23.

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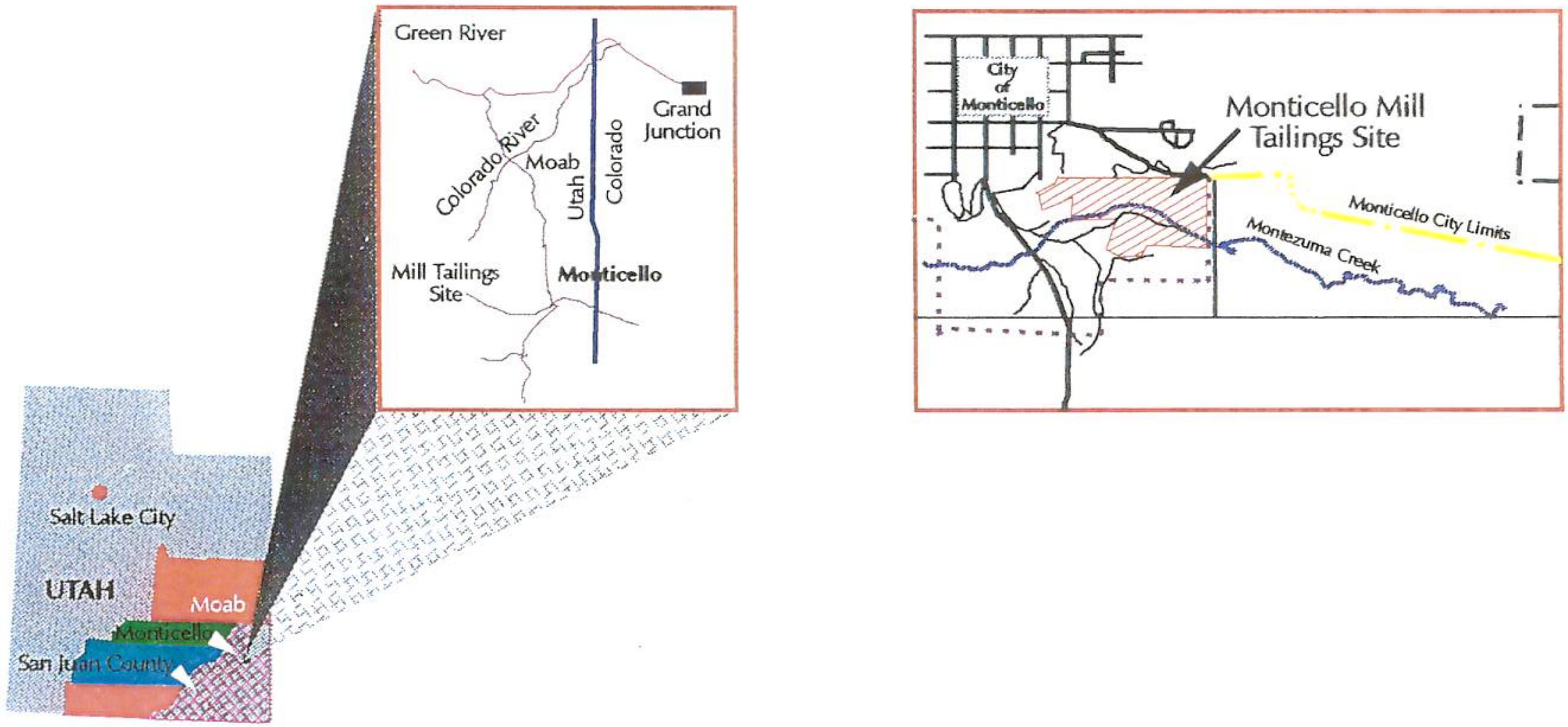
Appendix F

Figures

Figure 1
Location



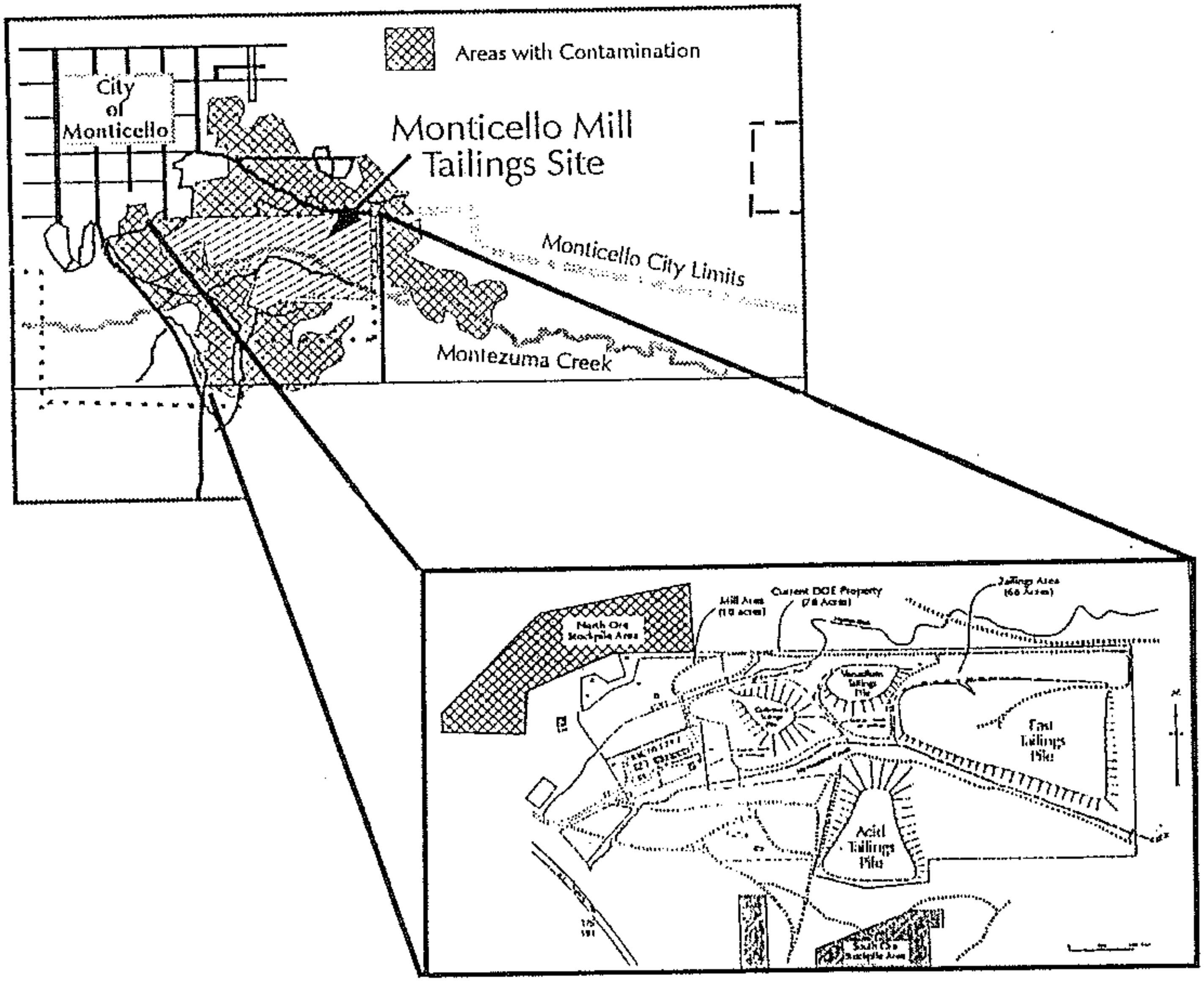

Areas with Contamination
City of Monticello
Monticello Mill Tailings Site
Monticello City Limits
Montezuma Creek
North Ore Stockpile Area
Mill Area (10 acres)
Current DOE Property (78 Acres)
Tailings Area (66 Acres)
East Tailings Pile
Acid Tailings Pile
South Ore Stockpile Area

Figure 2

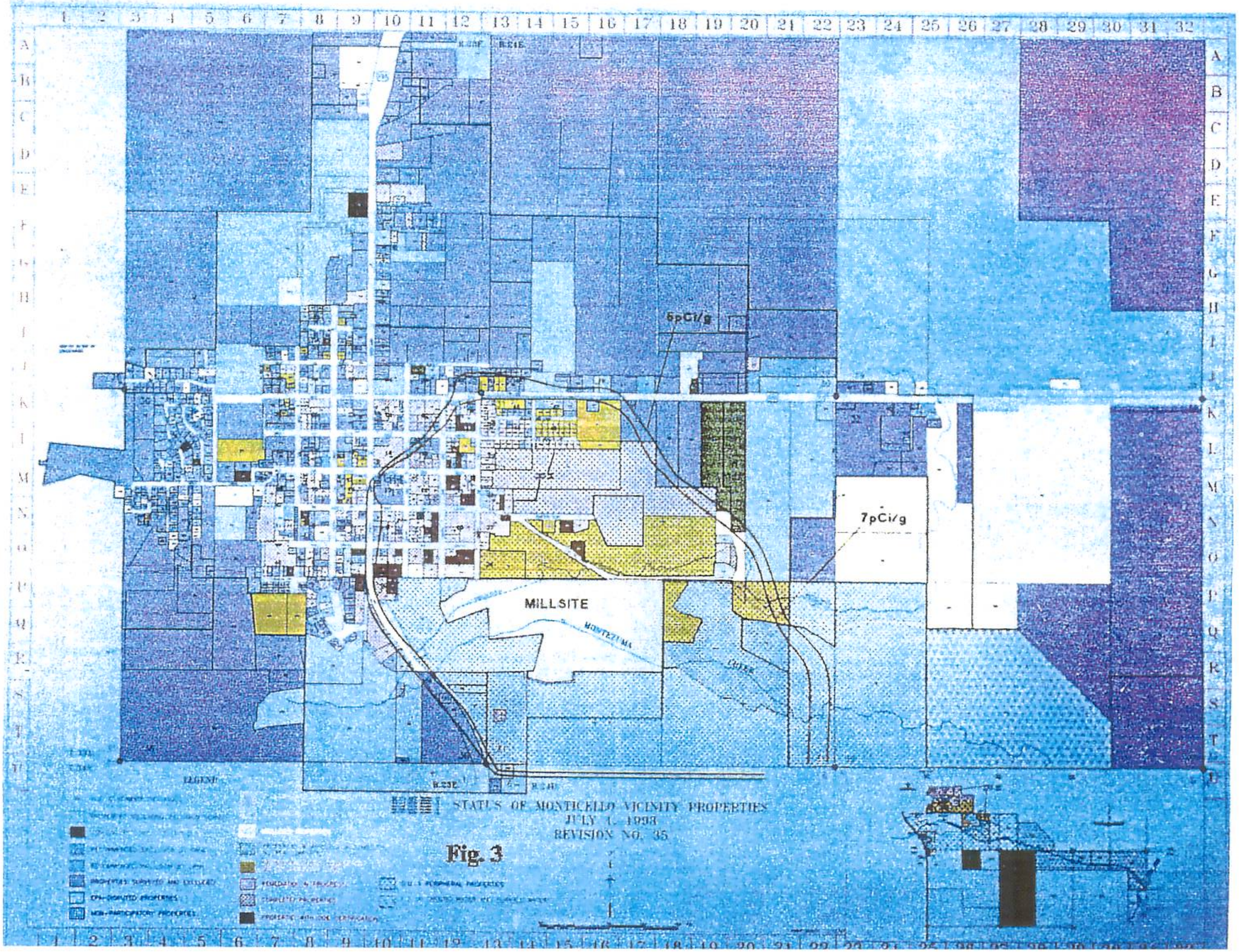

5pCi/g
7pCi/g
MILLSITE
MONTEZUMA
CREEK
LEGEND
STATUS OF MONTICELLO VICINITY PROPERTIES
JULY 1, 1998
REVISION NO. 35

Fig. 3

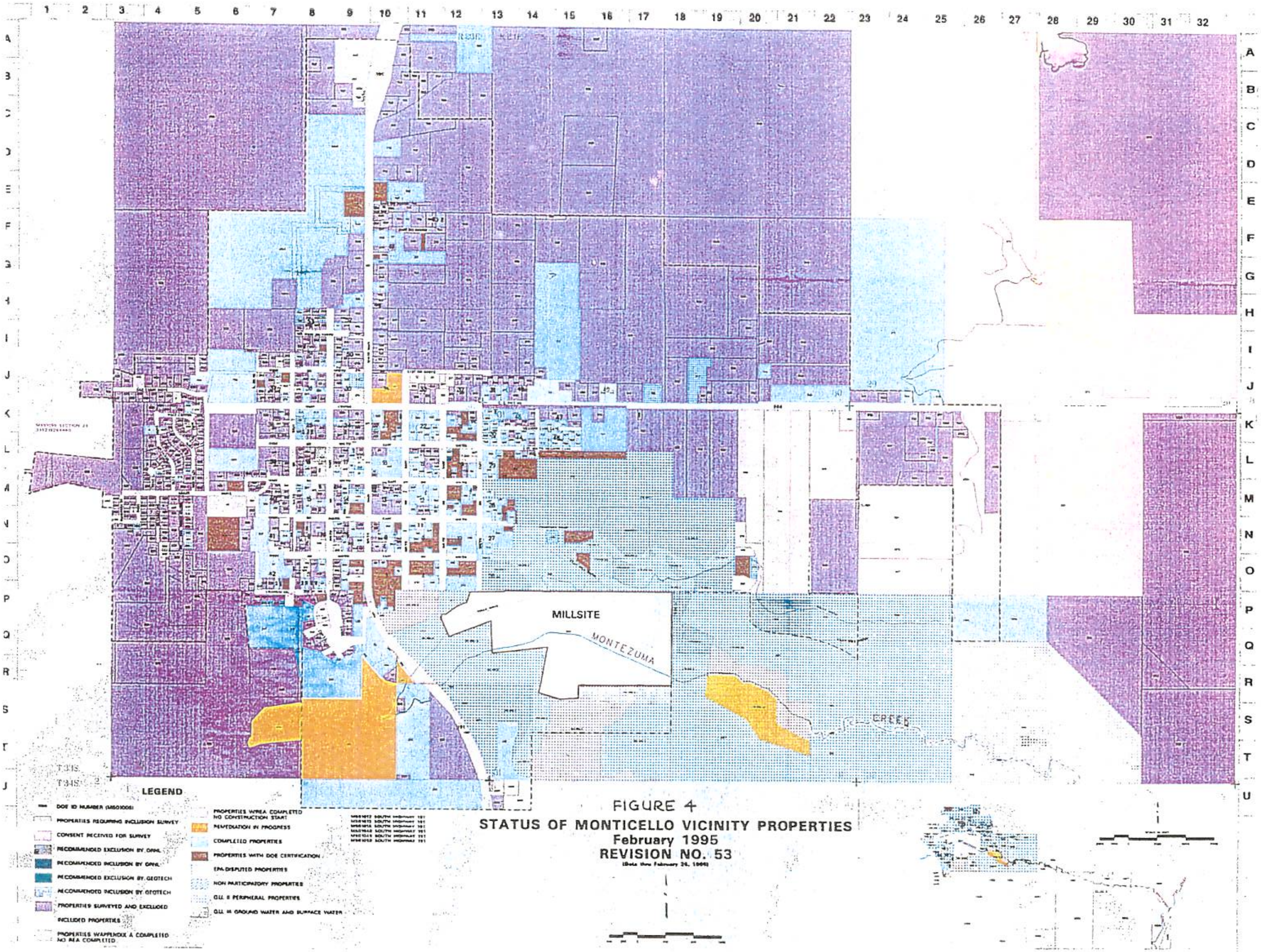


FIGURE 4
STATUS OF MONTICELLO VICINITY PROPERTIES
February 1995
REVISION NO. 53

FIGURE 5: Population Density

Monticello Mill Tailings Site

Demographic Statistics Source: U.S. 1990 Census

Total Number of Persons Living Within One Mile of the Monticello Site is 1,952

LEGEND

- No People
- 1 - 100 *
- 101 - 500 *
- 501 - 1000 *
- > 1000 *

* Persons Per Square Mile

ATSDR GIS Spatial Analysis Activity

FIGURE 6: Children 5 Years and Younger

Monticello Mill Tailings Site

Demographic Statistics Source: U.S. 1990 Census

Total Number of Children 5 Years and Younger Living Within One Mile of the Monticello Site is 221.

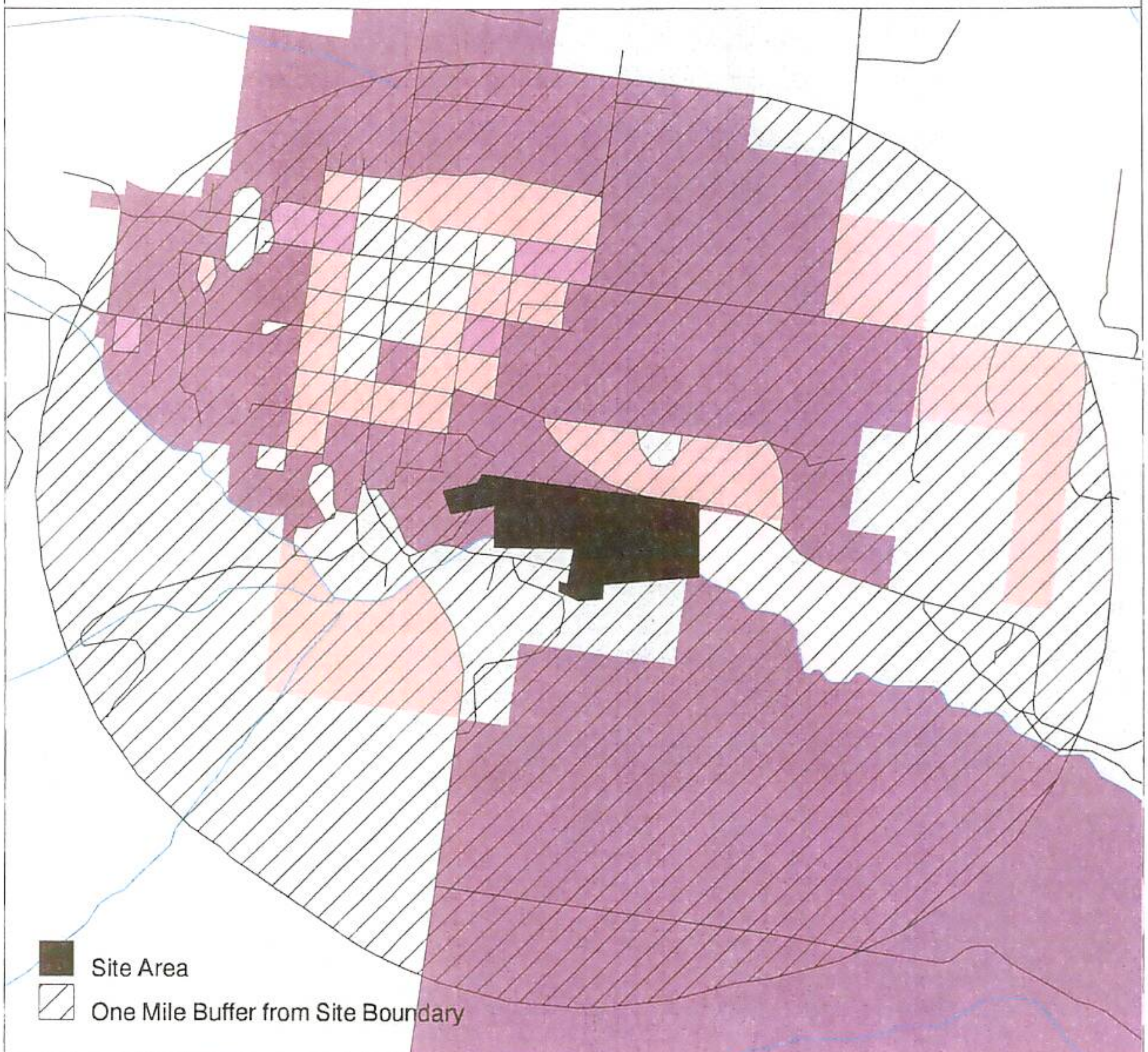
LEGEND

- No Children
- 1 - 3 Children
- 4 - 5 Children
- 6 - 10 Children
- > 10 Children

ATSDR GIS Spatial Analysis Activity

FIGURE 7: Adults Age 30 - 59

Monticello Mill Tailings Site



Demographic Statistics Source: U.S. 1990 Census

Total Number of Adults Age 30 - 59 Living Within One Mile of the Monticello Site is 630.

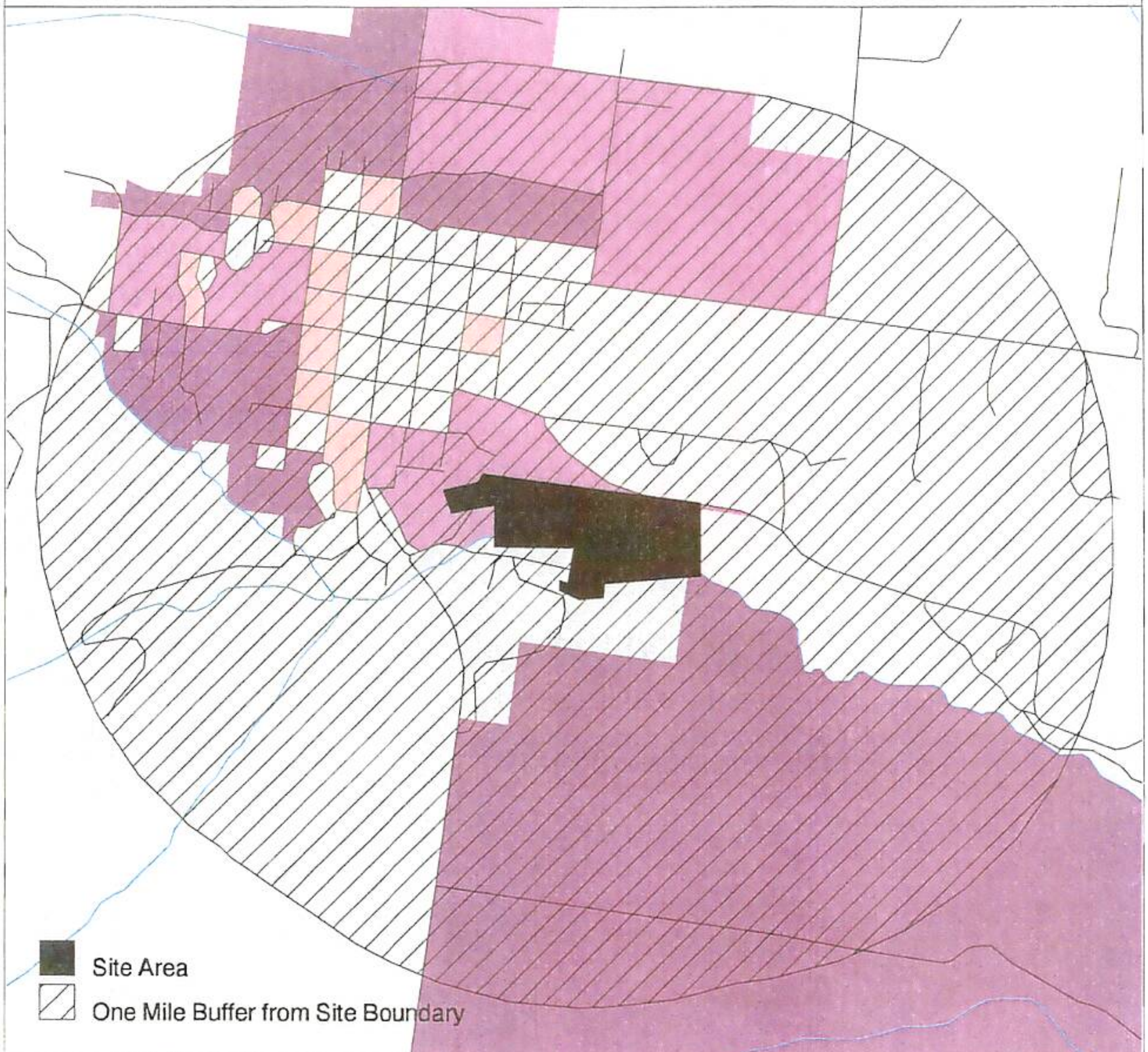
LEGEND

- No Adults
- 1 - 5 Adults
- 5 - 10 Adults
- 10 - 15 Adults
- > 15 Adults

ATSDR GIS Spatial Analysis Activity

FIGURE 8: Adults 60 Years and Older

Monticello Mill Tailings Site



Demographic Statistics Source: U.S. 1990 Census

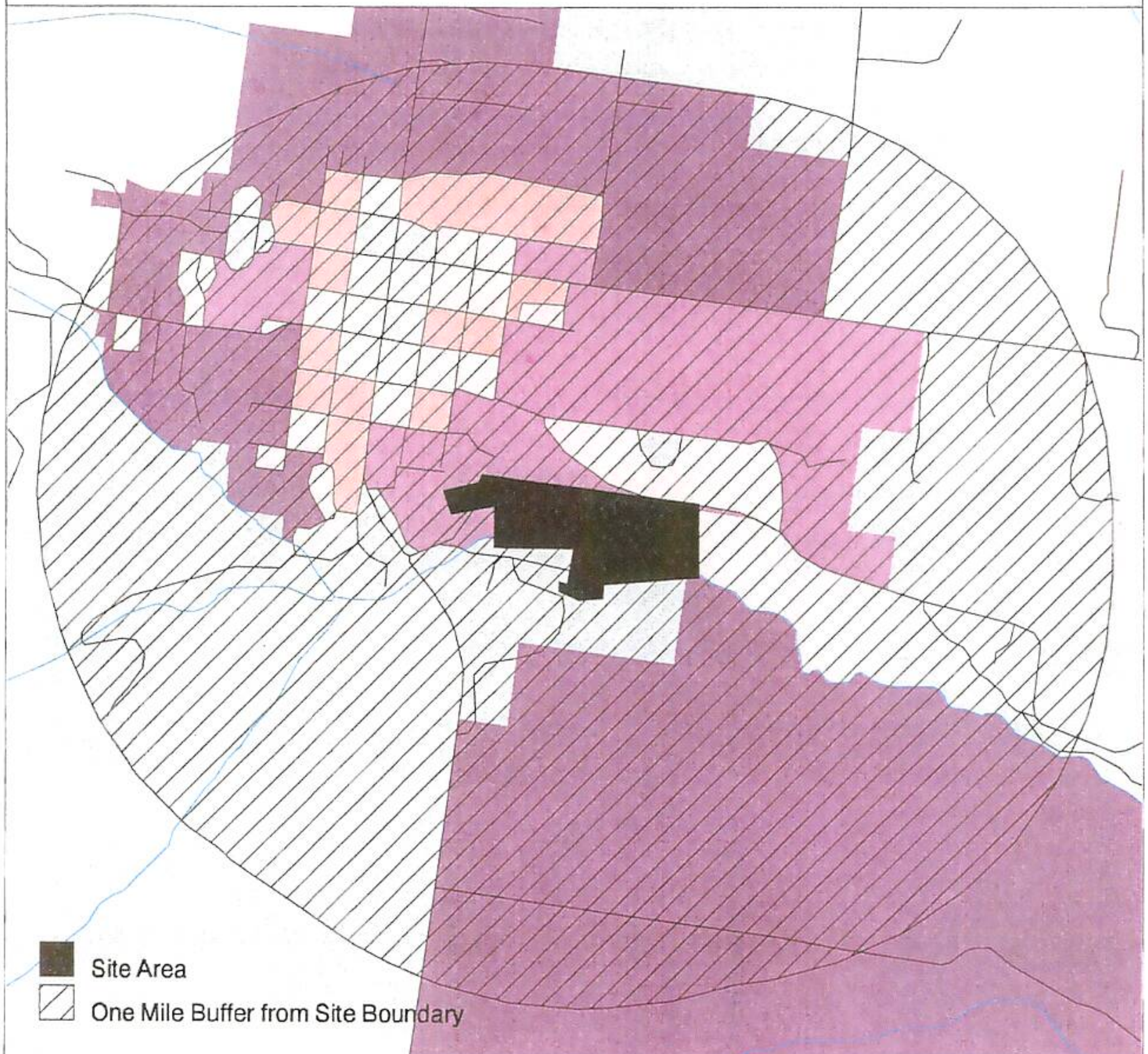
Total Number of Adults 60 Years and Older Living Within One Mile of the Monticello Site is 287.

LEGEND

- No Adults
- 1 - 5 Adults
- 5 - 10 Adults
- 10 - 15 Adults
- > 15 Adults

ATSDR GIS Spatial Analysis Activity

FIGURE 9: Females Age 15 - 44
Monticello Mill Tailings Site



Demographic Statistics Source: U.S. 1990 Census

Total Number of Females Age 15 - 44 Living Within One Mile of the Monticello Site is 359.

LEGEND

- No Females
- 1 - 5 Females
- 5 - 10 Females
- 10 - 15 Females
- > 15 Females

ATSDR GIS Spatial Analysis Activity

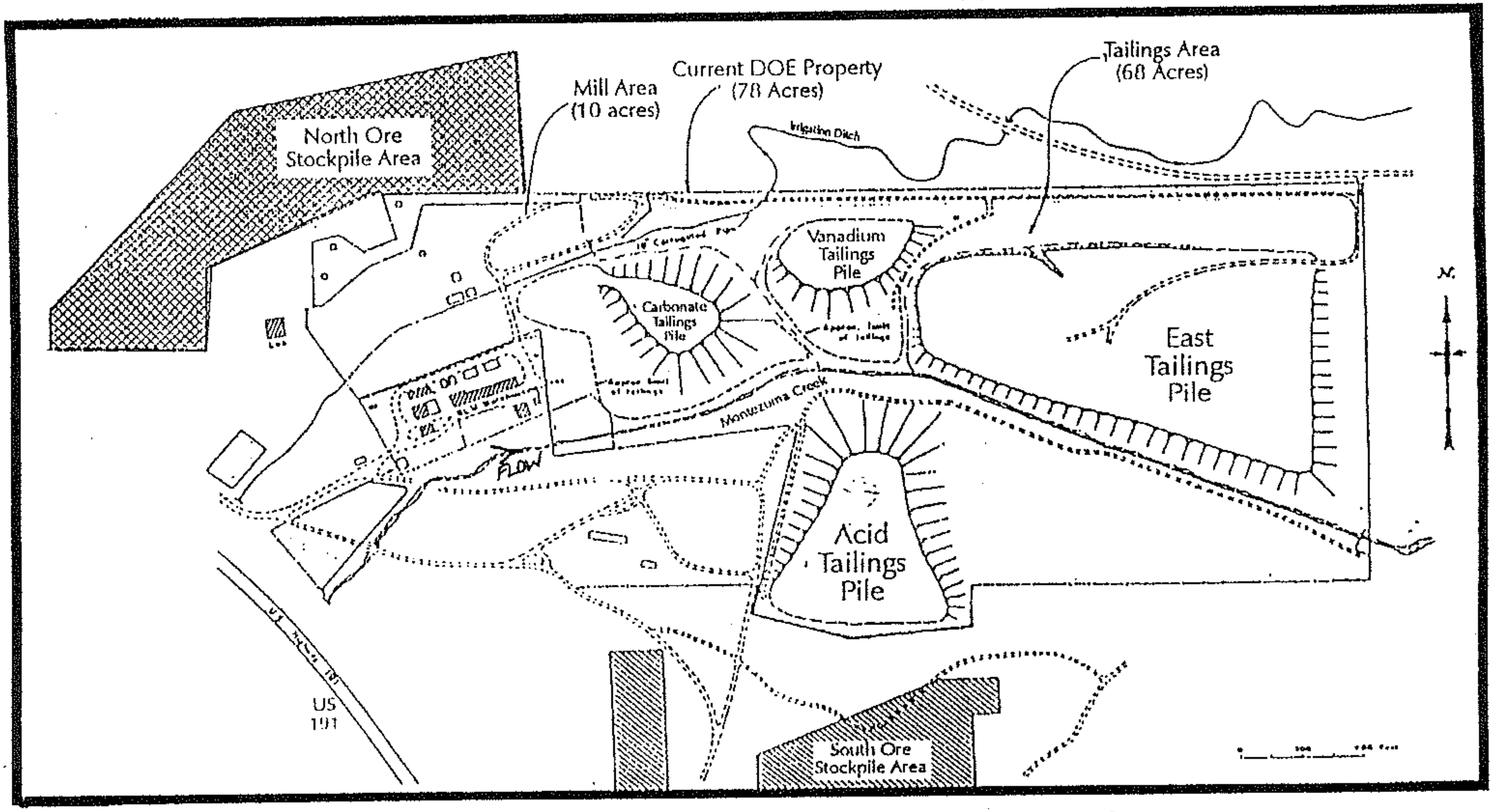


Fig 10. Locations of Tailings Piles

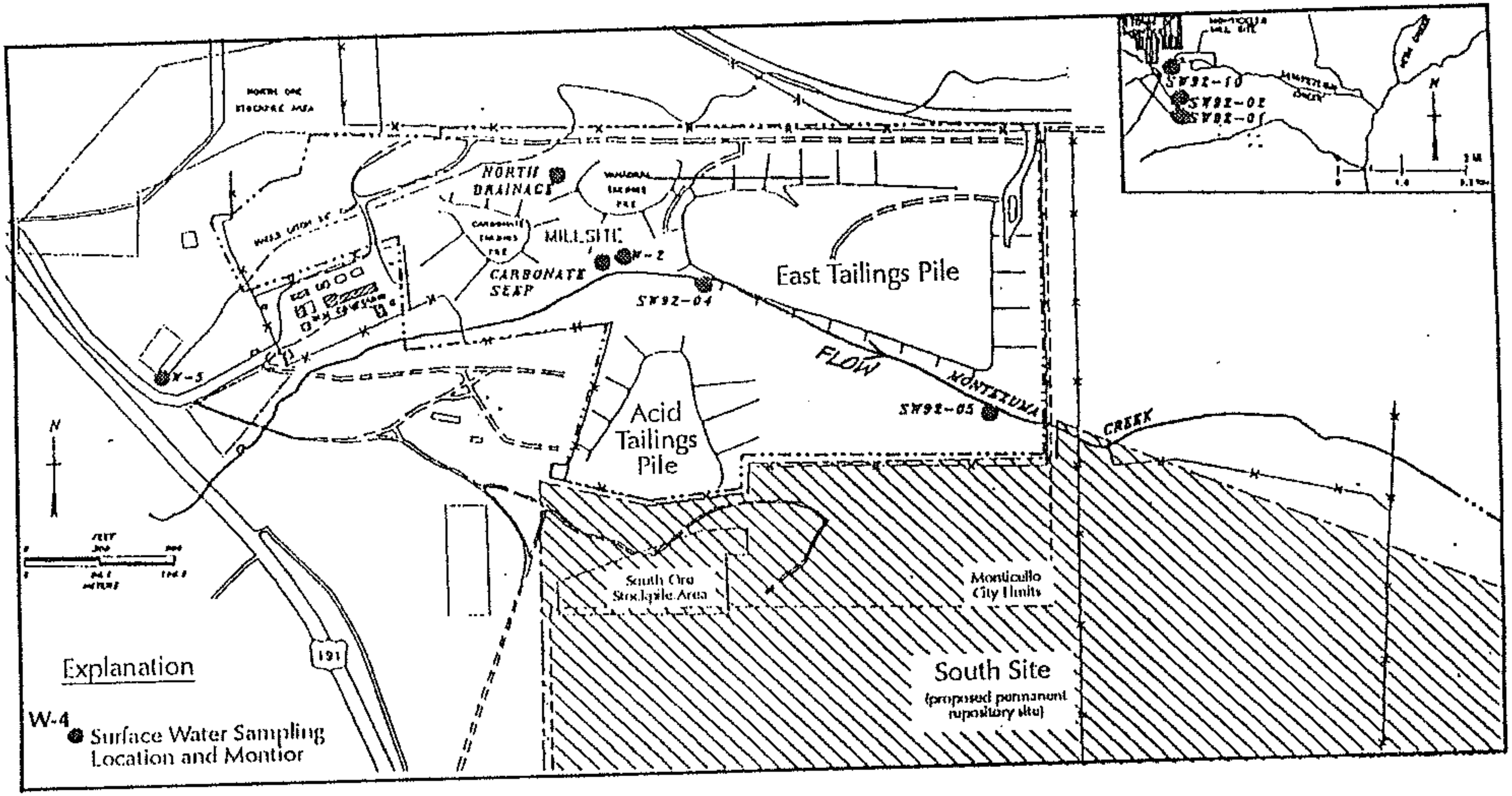


Fig 11. Upgradient and On-Site Surface Water Sampling Locations

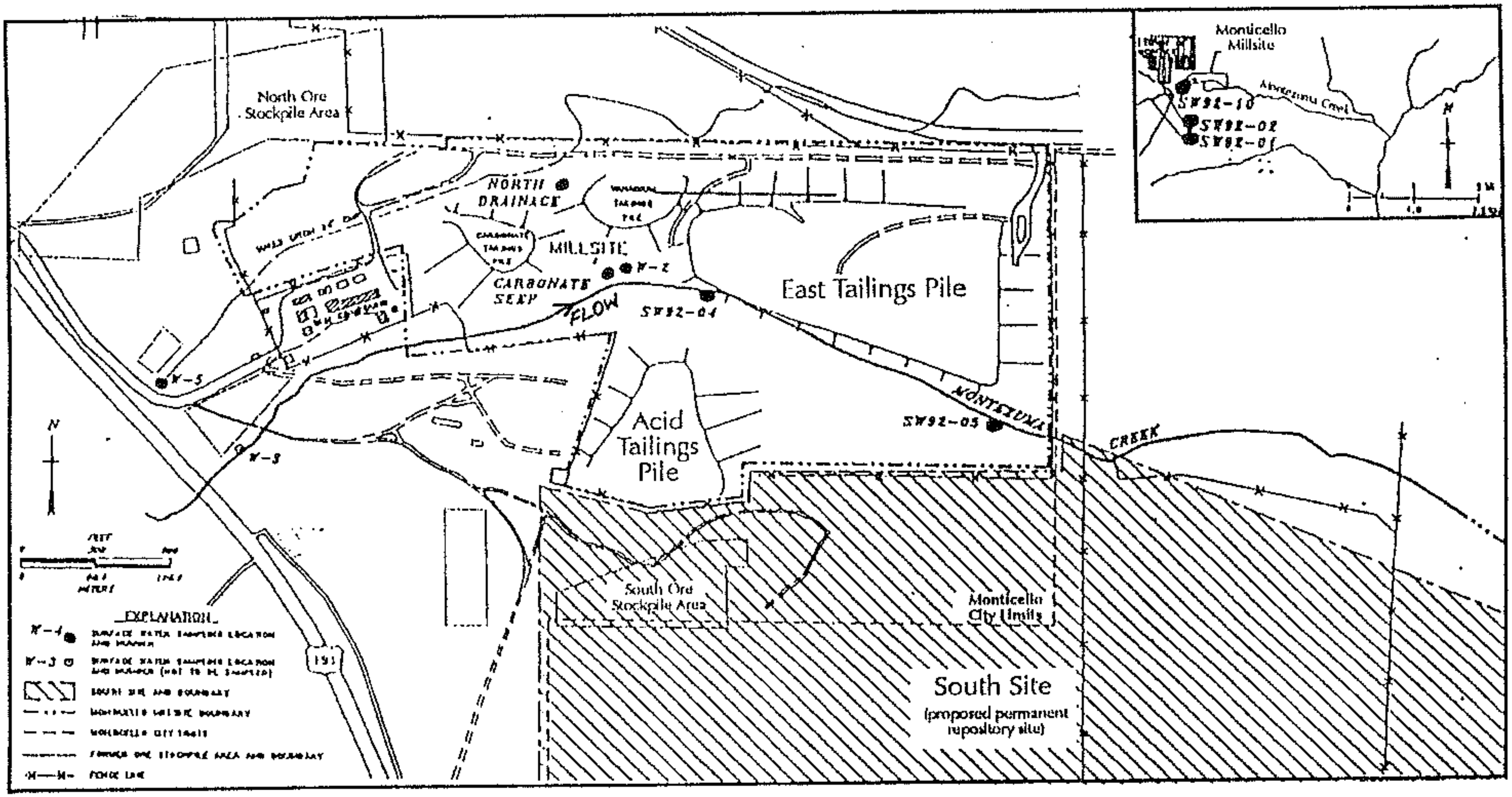


Fig 12a. Downgradient Surface Water Sampling Locations

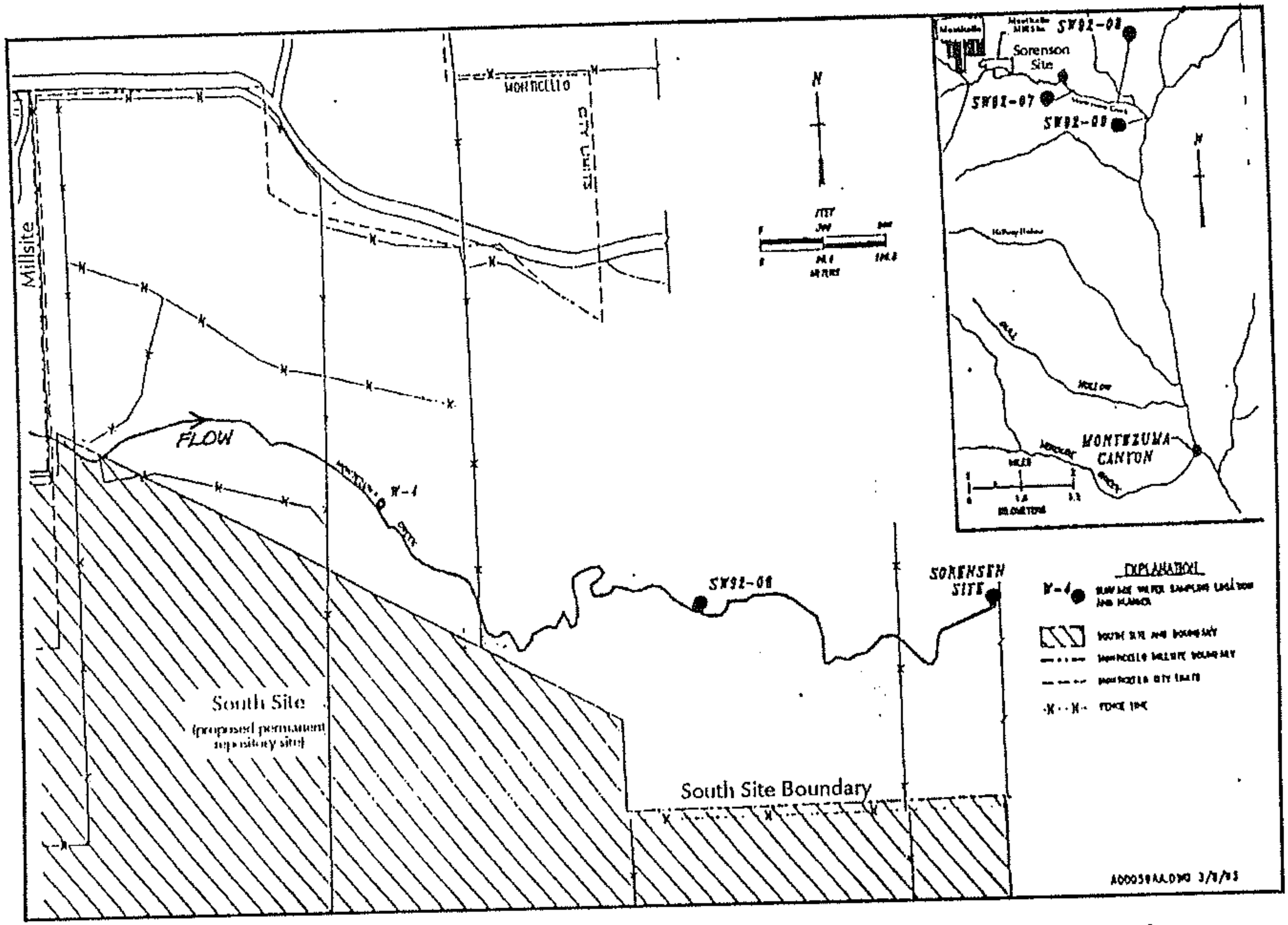


Fig 12b. Downgradient Surface Water Sampling Locations

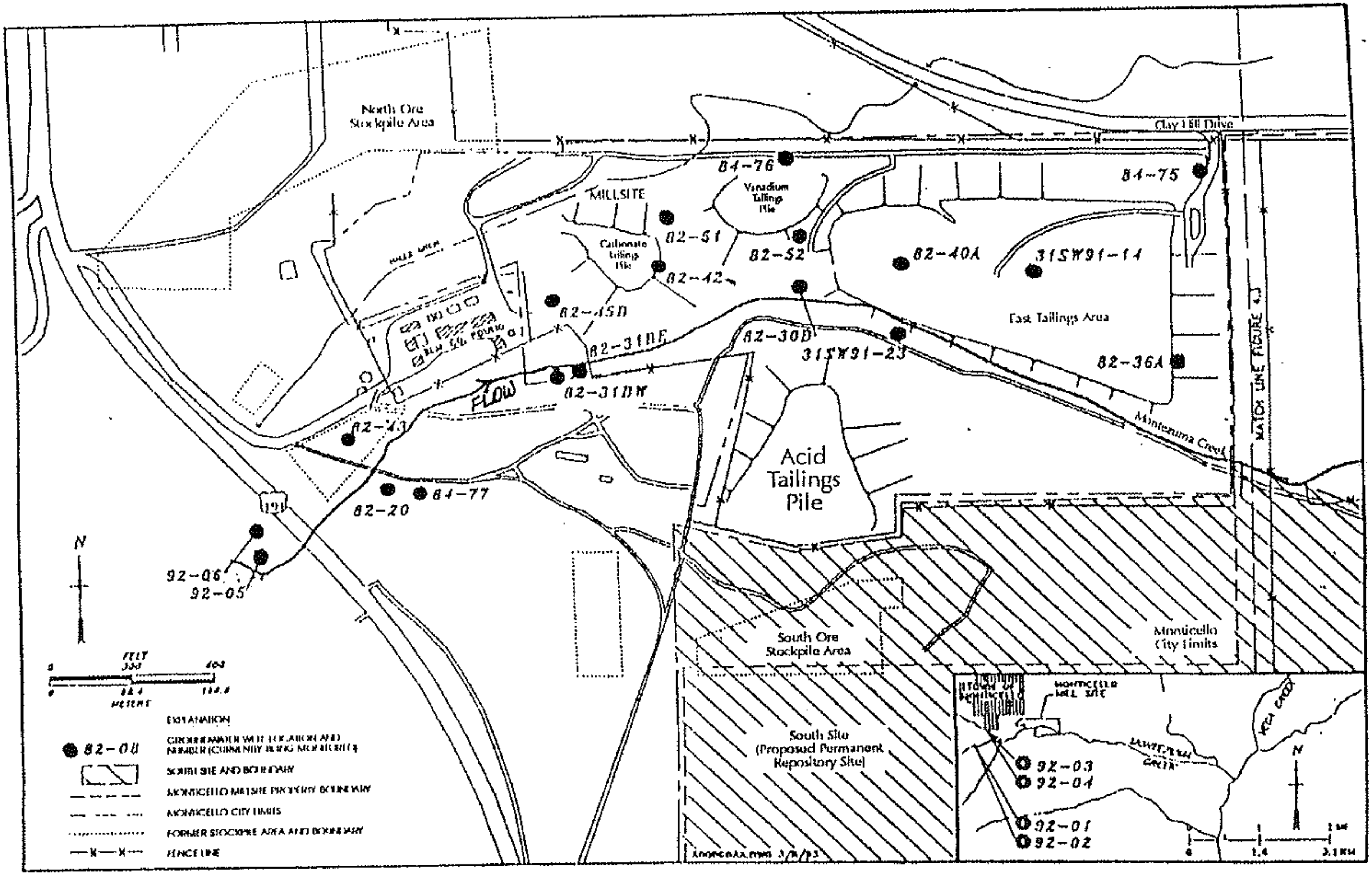


Fig 13. Upgradient and On-Site Monitoring Well Locations

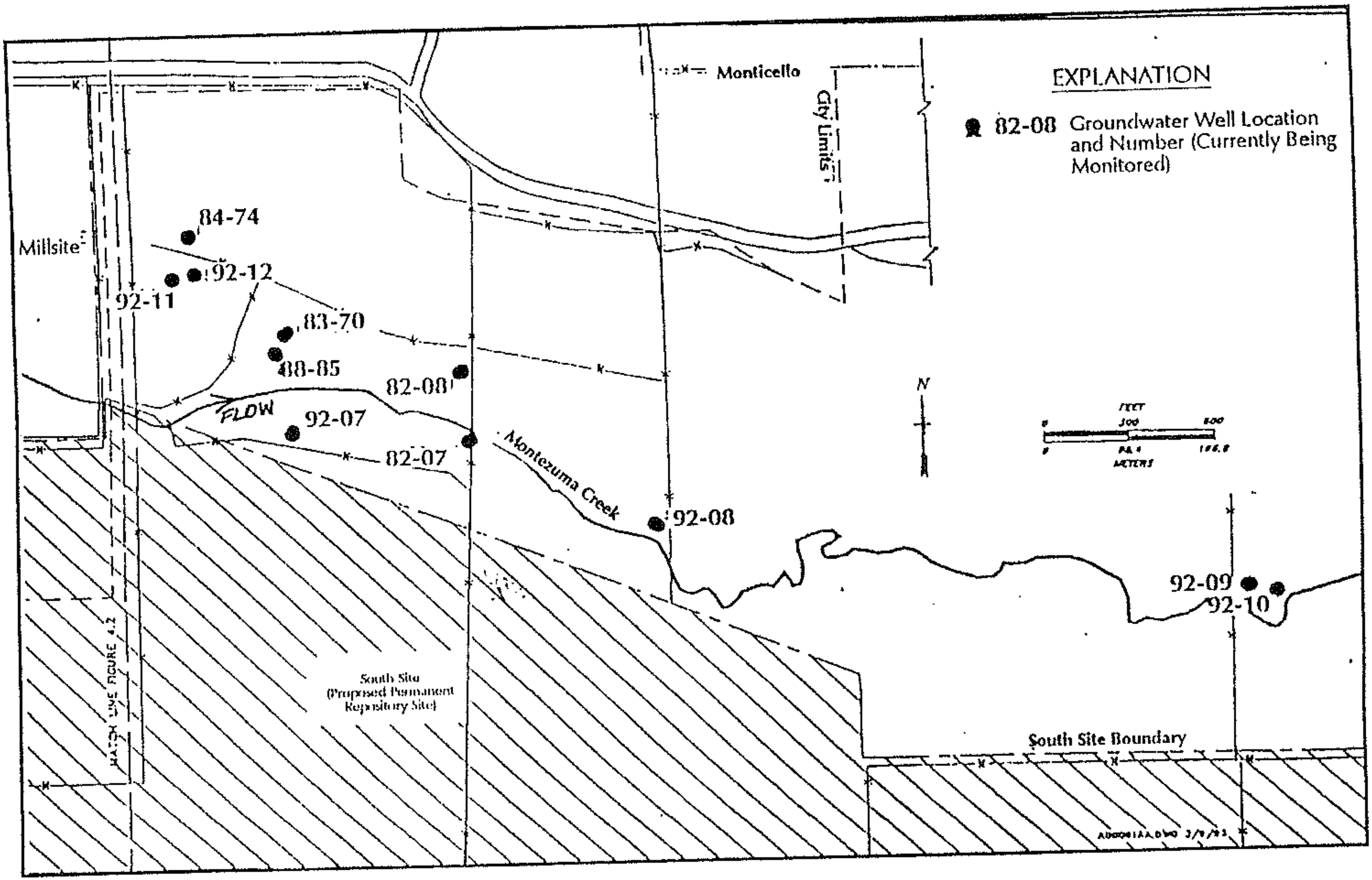


Fig 14. Downgradient Monitoring Well Locations

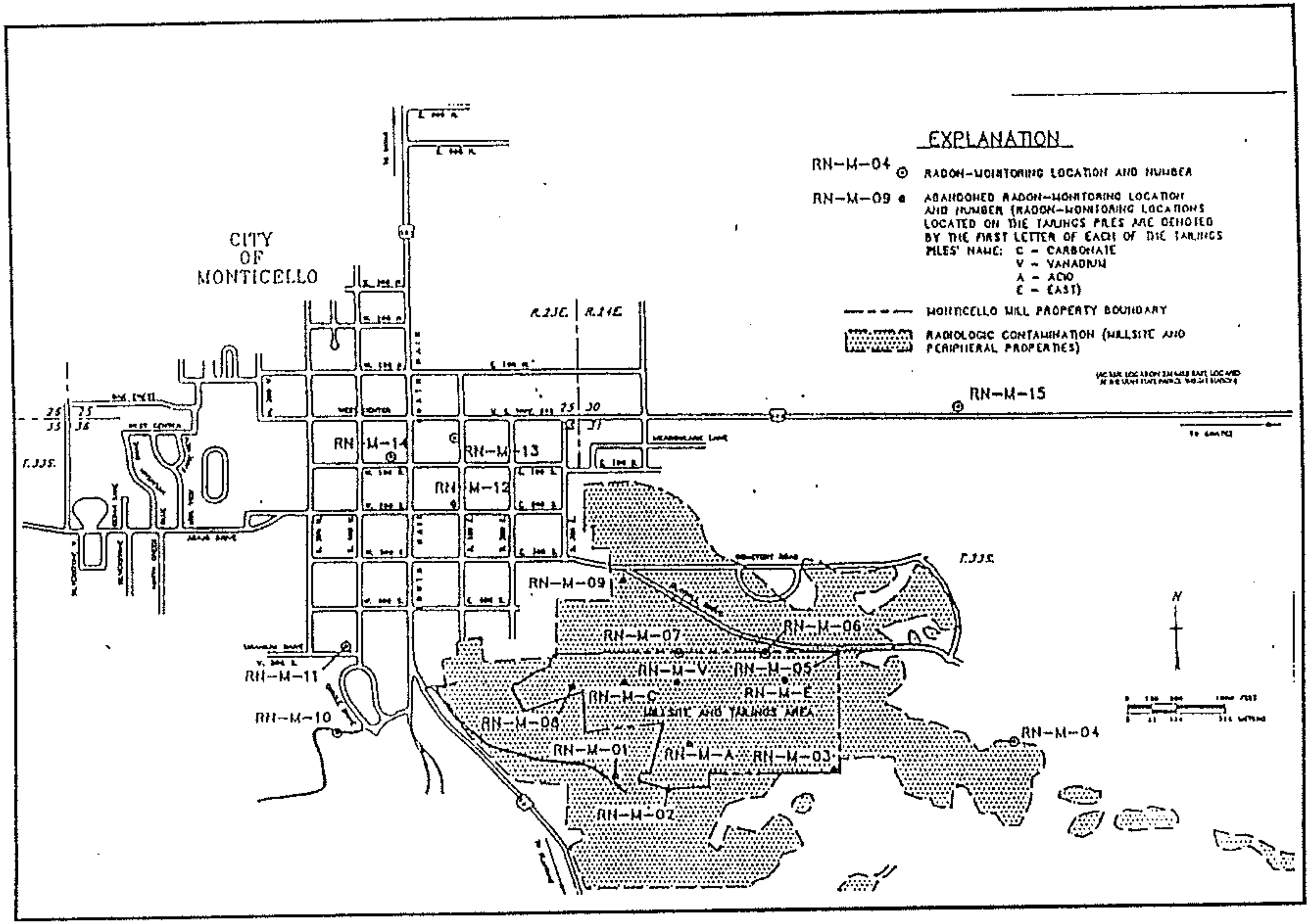


Fig 15. Atmospheric Radon Monitoring Locations at or Near the Monticello Millsite

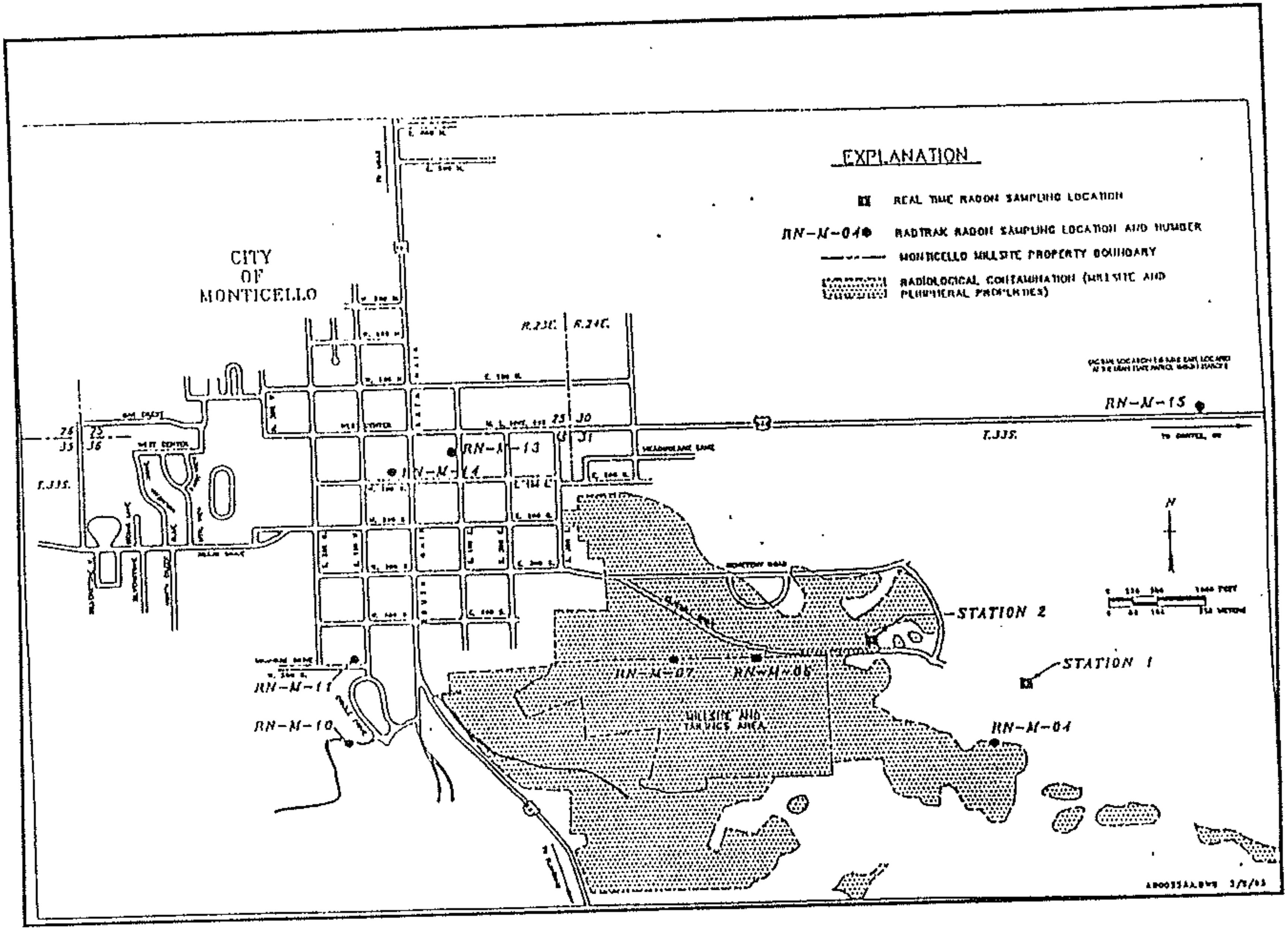


Fig 16. Atmospheric Radon Monitoring Locations At or Near the MMTS

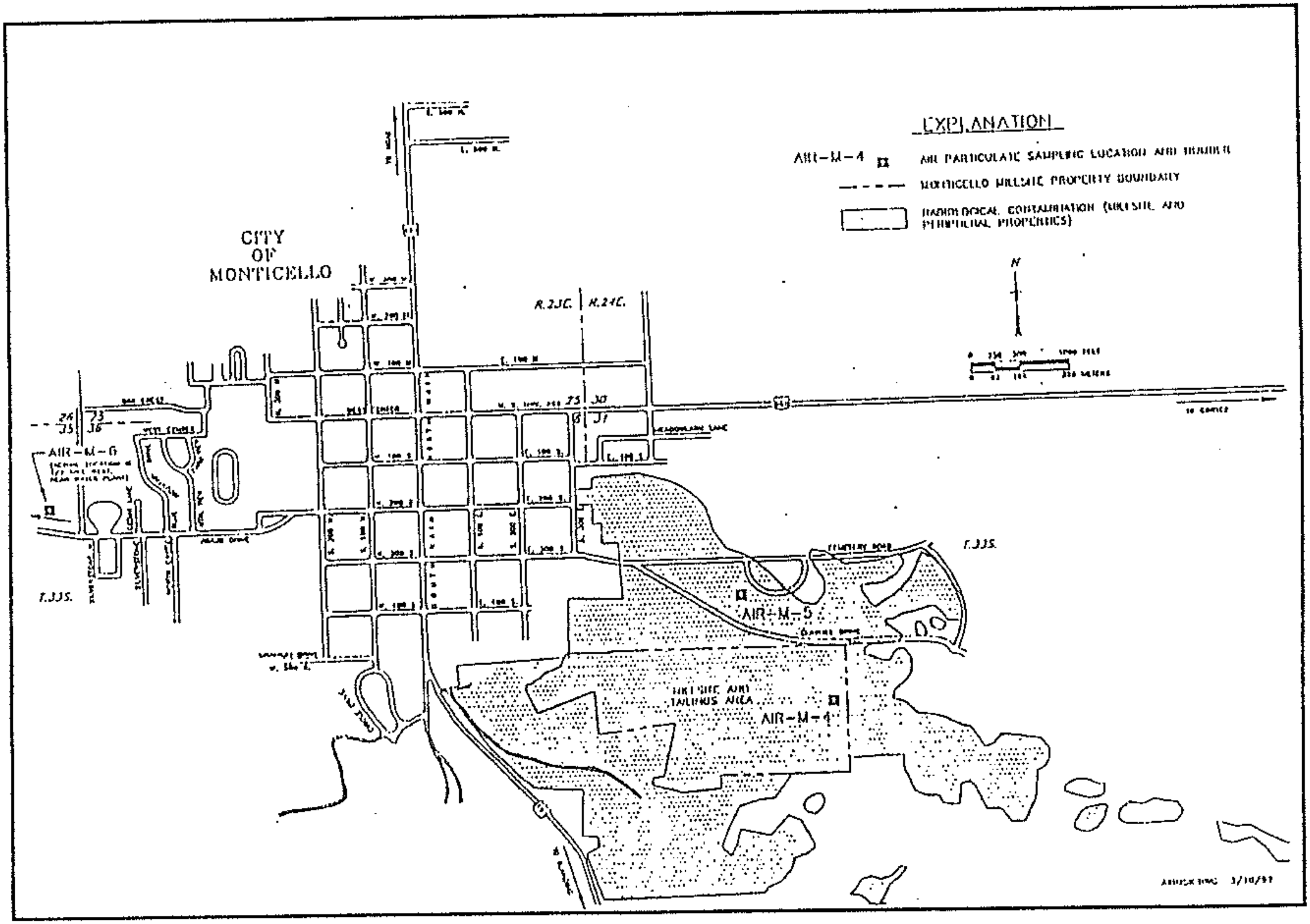


Fig 17. Air Particulate Sampling Locations At and Near the Monticello Mill Tailings Site

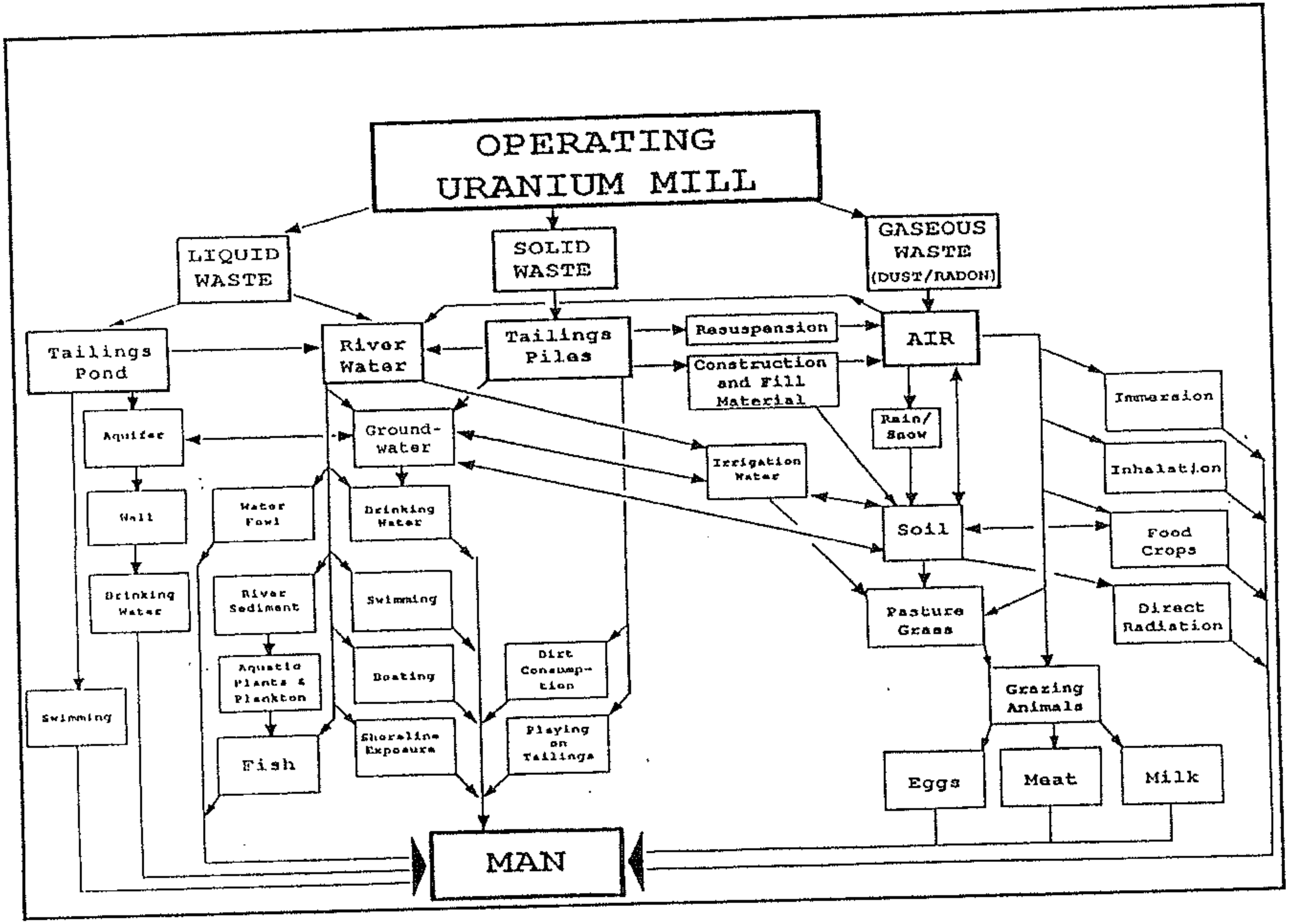

OPERATING URANIUM MILL
LIQUID WASTE
SOLID WASTE
GASEOUS WASTE (DUST/RADON)
Tailings Pond
River Water
Tailings Piles
Resuspension
Construction and Fill Material
AIR
Rain/ Snow
Immersion
Inhalation
Food Crops
Direct Radiation
Aquifer
Ground-water
Irrigation Water
Soil
Well
Water Fowl
Drinking Water
Drinking Water
River Sediment
Swimming
Pasture Grass
Aquatic Plants & Plankton
Boating
Dirt Consump-tion
Grazing Animals
Swimming
Fish
Shoreline Exposure
Playing on Tailings
Eggs
Meat
Milk
MAN

Figure 18.

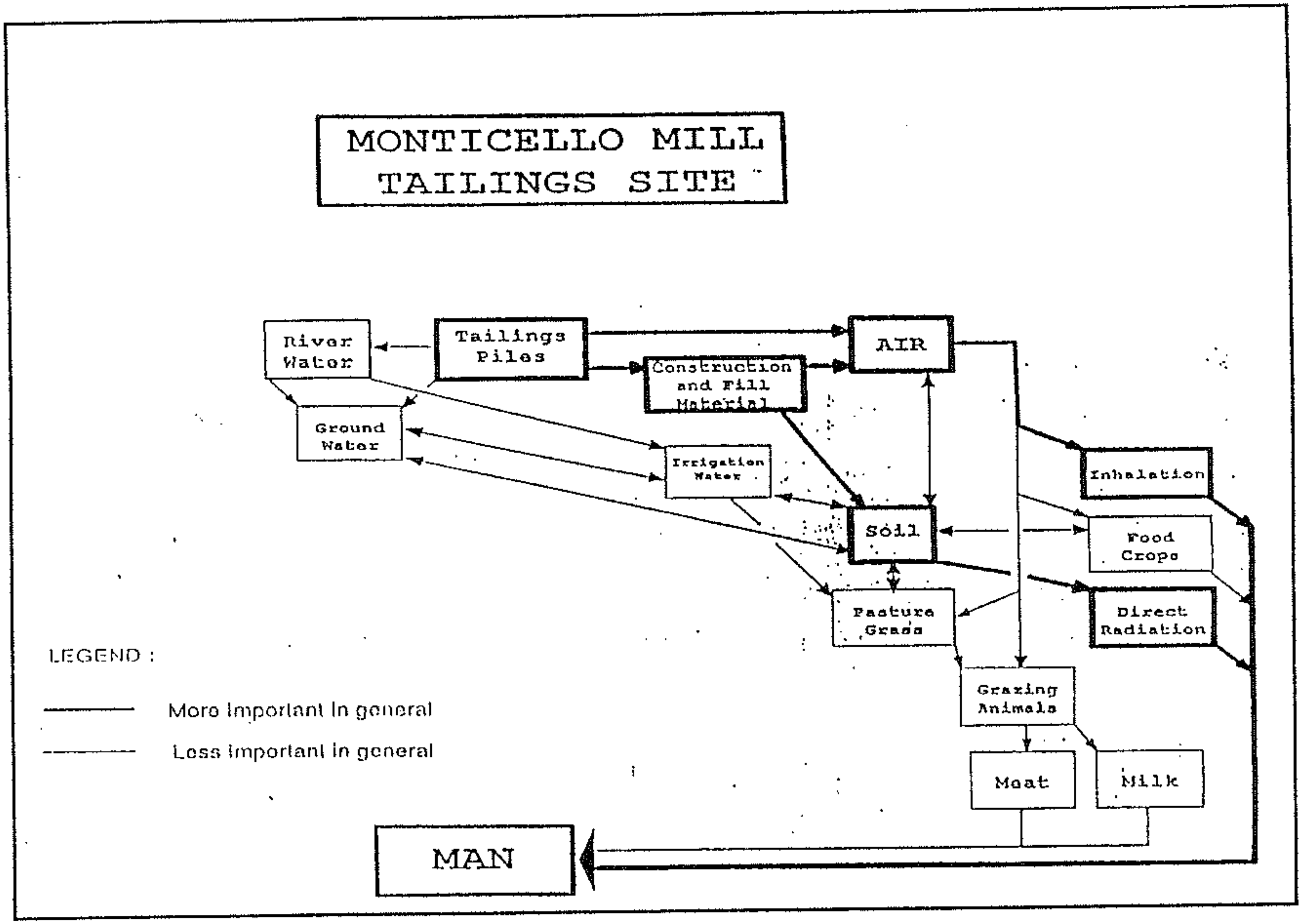


Figure 19. Existing Pathways at the Monticello Mill Tailings Site

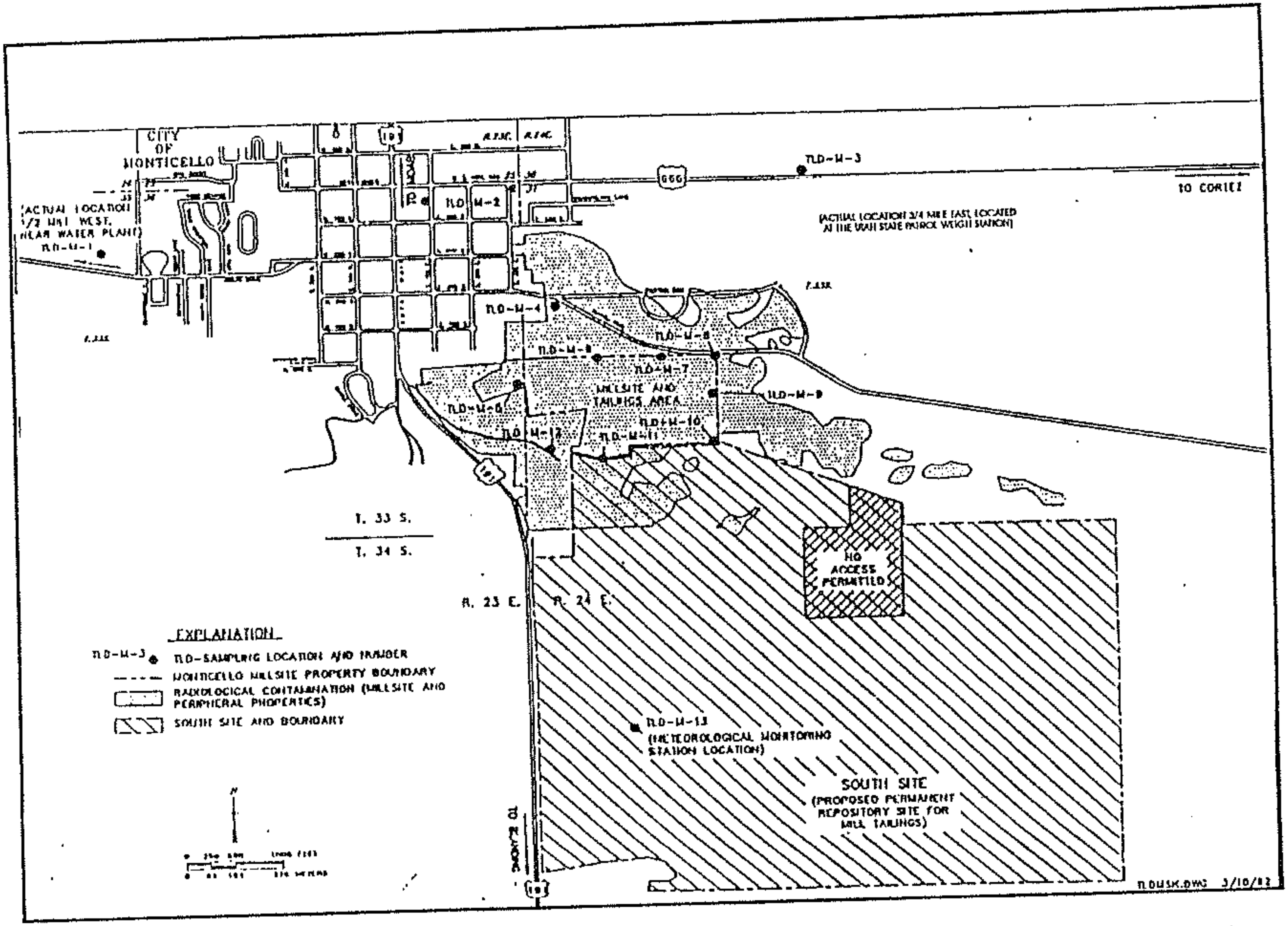


Fig 20. Direct Environmental Radiation Monitoring Locations At or Near the Monticello Millsite.

Appendix G

Comments to Public Comment Release

While I do not understand all I should when I remember how uranium was mined and milled, and knowing many people who did the work and are still alive, including myself, I wonder why it requires so many people to stand about watching one or two machine operators work. How can we assume that the radiation from soils in Monticello is a result of uranium contamination when we have learned that radon-222 is prevalent everywhere emanating from other sources than uranium or radium, or is the entire earth surface contaminated with enough of those two elements to cause the radon gas?

NO CHANGE. The document identifies that the radioactive elements uranium, radium, and radon are both naturally occurring in the environment and concentrated by milling operations. The document describes that radioactive material concentrations on the mill site and around Monticello were elevated above natural ambient levels; this elevation was attributed to the mill site's operations. See the Overview of Radiation and Sources of Contamination sections for further information.

The report would be more meaningful to the lay reader if the names of government agencies had been written out instead of using initials.

NO CHANGE. Throughout this public health assessment each time a new section is begun the complete name of every abbreviation is spelled out, with its initials in parentheses, to serve as a refresher to the reader. In addition, pages vi and vii located at the front of the public health assessment contain a complete list of all abbreviations.

There seems to be repetition in relationship to radiation from uranium workings, mining, milling, etc., in various discussions within the report.

NO CHANGE. Since it is the radiation given off by uranium that is important to human exposure during mining, milling, etc., the apparent repetition provides a more complete understanding of the human health aspects of this subject. In addition, this apparent repetition serves as a consistent reminder to the reader of the entire document as well as to those who review only selected sections.

Mailed by ATSDR plus second copy received from local DOE contractor, why do I need 2 copies? Is there a lack of communication somewhere?

NO CHANGE. Not a comment on the content of the public health assessment.

The Summary and Background (Land Use) section portions of the report state that Monticello is the largest town in San Juan County. The 1990 Census gives population of Monticello is 1806, population of Blanding as 3,162. If the compilers of the report can not be correct in such an easily researched thing as that, how can a lay person, knowing the error, take stock in other conclusions?

CHANGE. Wording changed to clarify that Monticello is the largest town in San Juan County in terms of area (Monticello total area = 2.74 square miles versus Blanding total area = 1.92 square miles), not population.

My father worked at the mill from 1953 until it closed. We lived for 4 years in the mill apartments, located by the tailings pond. My father worked with the yellow cake and after the mill closed down they moved to Salt Lake City, Utah. The doctor put him on oxygen since his lungs were contaminated with radiation. He passed away with silicosis. I have thyroid disease and cataracts, people tell me because I lived by the tailings ponds, is this true?

CHANGE. Silicosis is a debilitating lung disease caused by inhalation of crystalline silica dust, a nonradioactive substance released into the air during, e.g., mining and sandblasting activities. An estimated 2 million U.S. workers are at risk for silicosis (1).

One must come in direct contact with the tailings ponds (e.g., swimming) to have exposure. It is apparent from community responses that in the past children swam in the tailings ponds. However, ATSDR scientists do not have any environmental sampling data from those ponds; therefore, it is impossible to determine the concentrations of arsenic, molybdenum, selenium, and vanadium to which these children were exposed. Additional toxicological information follows to address thyroid disease and cataracts in relation to the four chemicals mentioned above.

If someone lived near the pond, but never swam in the water, or if they did swim in the pond, but never swallowed any of the water, the contaminants in the pond could not have caused their illnesses. The contaminants of concern in the pool that had the potential to cause illness were arsenic, molybdenum, selenium, and vanadium. ATSDR scientists searched the biomedical literature from 1966 to August 1997 and could not find any studies associating human ingestion of these substances with increased incidence of cataracts. ATSDR scientists considered whether pond water could cause illness if it entered the body through open scratches in the skin of swimmers. Although it was possible to cause cataracts by injecting large amounts of selenium under the skin of newborn rats, the cataracts cleared spontaneously a month after the injection (2), or could be prevented by simultaneous injection with arsenic, another pond contaminant (3). ATSDR scientists agree with another reviewer of this literature who concluded that "certain experimental models for . . . cataract have been useful for study of the cataractogenic process but are probably not important factors in the human disease. Little current evidence supports significant roles in human senile cataract for . . . excessive intake of selenium" (4).

There are many types of thyroid diseases. Some are caused by damage to the thyroid gland that prevents the gland from making the hormone T4, or by inability to make T3, the active *form of the hormone, either in the thyroid or in the liver. In either case, the effect would be hypothyroidism. The body would not receive enough stimulation from the hormone to generate all the energy it needs. A person might feel tired all the time and gain too much weight. A similar problem could result if body tissues and organs are genetically incapable of recognizing the active hormone. Thyroid hormones contain iodine, and a diet inadequate in iodine can cause the gland to become very large in an attempt to make more hormone with the scant iodine supply. This enlargement of the thyroid gland is called goiter. Overproduction of thyroid hormone can result if the pituitary signals the thyroid to produce too much hormone, and this hyperthyroidism can cause excess energy to be consumed. A person is continually nervous, active, and underweight. Other thyroid diseases include benign (noncancerous) or malignant (cancerous) thyroid growths, and thyroiditis (inflamed thyroid tissues).*

Very large amounts of arsenic (a pond contaminant) in rats' drinking water can cause toxic changes to their thyroid glands, but these changes can be prevented if selenium (another pond contaminant) is also present in the drinking water (5). In parts of Africa where the diet is deficient in both iodine and selenium, goiters were often found. If selenium supplements were given to treat that deficiency without first treating the lack of iodine, the thyroid became further impaired (6). This would not likely be a problem in Utah, where selenium is naturally abundant. Selenium is needed to make the enzymes in the thyroid and liver that convert T4 thyroid hormone to the active T3. It is not surprising that those with inadequate selenium in their diets (especially older people) may be hypothyroid, with high blood levels of T4 and low blood levels of T3 (7). Recently, people with excessive dietary selenium intake were found to have a similar imbalance of these two thyroid hormones (8). A study of rats given diets that were insufficient, adequate, or excessive in selenium showed the T4/T3 imbalance with both the low and high selenium diets, but not the normal selenium diet (9). We could find no information about whether normal T4/T3 balance was restored when the selenium intake was corrected. No information was found to indicate that any of the pond contaminants could cause hyperthyroidism, thyroid tumors (benign or malignant), or thyroiditis.

I think it all very stupid and a colossal waste of the taxpayers' money. Stop the stupidity! Get a job. Leave us alone.

NO CHANGE. Not a comment on the content of the public health assessment. According to the United States Code Annotated Title 42: there is hereby established within the Public Health Service an agency, to be known as the Agency for Toxic Substances and Disease Registry (ATSDR), which shall report directly to the Surgeon General of the United States. In addition to other entities, the administrator of ATSDR shall perform a health assessment for each facility on the National Priorities List established under section 9605 of this title.

Need to take care of dust while working at the mill site. I have radiation on one of my lungs. What can I do to get help?

NO CHANGE. Not a comment on the content of the public health assessment. For contact names regarding issues surrounding the federal compensation act, see Appendix D, Other Community Concerns Evaluation section, Number 4.

I don't understand, but my husband worked at the mill. He contracted leukemia and died 1 1/2 years later. His doctor said he felt that his cancer was working around chemicals and was work related.

NO CHANGE. Internal exposure to alpha radiation emitting radioactive materials, e.g., uranium and radium, have been related to bone cancer but not to leukemia. This is based primarily on studies of the radium dial painters and is likely due to the inability of alpha particles to penetrate through the bone and into the marrow where leukemia would originate. Radiation-induced leukemia has been related to large exposures from gamma radiation sources outside the body, e.g., Japanese atomic bomb survivors.

It doesn't show that mill workers' and citizens' cancer and other illnesses were caused by exposure to the effects of the operation of the mill.

CHANGE. The Conclusions have been changed to include the health outcome data findings (the increase in lung, prostate, and breast cancers) discussed in the Public Health Implications (Health Outcome Data Evaluation) section.

The information on deaths, diseases, etc., is obtained from Utah records. However, most people moved from Monticello after the mill closed, and many moved out of state. It doesn't seem to me the report could be accurate without the health history of those who moved.

NO CHANGE. Representatives of ATSDR identified and reviewed many sources of health outcome data for the Monticello area. Currently there are no resources that specifically take into account and identify former residents. Follow-up health studies are being considered by ATSDR scientists for the Monticello community. These studies will take into account people who have moved away from Monticello.

"It is no surprise that the agency failed to identify effects in this study. They have to limit the liability of the government, and they did just that."

NO CHANGE. Not a comment on the content of the public health assessment.

Will you please continue sending me these reports? My wife died of breast cancer and I'm concerned for my children.

Yes, we will continue to send the reports to people who request them.
CHANGE. Information regarding breast cancer is discussed in the Public Health Implications (Health Outcome Data Evaluation) section. The Conclusions have been changed to include the health outcome data findings discussed in the Public Health Implications (Health Outcome Data Evaluation) section.

The time line for danger is endless and the dangers are extreme! Cancer-related deaths are much too high for the population of the area. Your report is scary! The people in this area are in extreme danger!!!

NO CHANGE. Not a comment on the content of the public health assessment.

Health risk seems minimal-why continue study? The conclusions and actions did not seem to justify the expense of the project. Opening summary said not a great health risk. Why then is $230+ million being spent to clean up the area rather than to contain it on site?

NO CHANGE. Not a comment on the content of the public health assessment.

REFERENCES FOR APPENDIX OF COMMENTS TO PUBLIC COMMENT RELEASE

1. Centers for Disease Control and Prevention. Silicosis among workers involved in abrasive blasting--Cleveland, Ohio, 1995. Morbidity and Mortality Weekly Report 1997;46:744-747.

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