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ENVIRONMENTAL ASSESSMENT

OF

REMEDIAL ACTION AT THE SLICK ROCK

URANIUM MILL TAILINGS SITES

SLICK ROCK, COLORADO

APRIL, 1987

U.S. DEPARTMENT OF ENERGY

UMTRA PROJECT OFFICE

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ENVIRONMENTAL ASSESSMENT OF REMEDIAL ACTION AT THE SLICK ROCK URANIUM MILL TAILINGS SITES SLICK ROCK, COLORADO

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ABSTRACT

This document assesses and compares the environmental impacts of various alternatives for remedial action at the two Slick Rock uranium mill tailings sites which are 0.9 and 1.6 miles northwest of the unincorporated town of Slick Rock, Colorado. The Slick Rock sites consist of the Union Carbide tailings pile which covers 17 acres with an additional 131 acres of adjacent contaminated land and the North Continent pile which covers approximately two acres with 44.4 acres of surrounding lands also contaminated. Seepage from the tailings piles have contaminated the ground water in the alluvium beneath the piles. The Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), Public Law 95-604, authorized the U.S. Department of Energy to clean up the sites to reduce the potential health impacts associated with the residual radioactive materials. The U.S. Environmental Protection Agency promulgated standards for the remedial action (40 CFR Part 192). Remedial action must be performed in accordance with these standards and with the concurrence of the Nuclear Regulatory Commission and the State of Colorado. The proposed action is to stabilize the tailings partially below-grade approximately six hundred feet from the existing Union Carbide pile. All of the tailings from both piles and associated contaminated materials would be consolidated and contoured into one pile. A radon barrier would be constructed over the pile and various erosion control measures would be taken to assure the long-term stability of the pile. The no action and disposal at the Section 36 site alternatives are also assessed in this document.

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1.0 SUMMARY

1.1 PROJECT SUMMARY

The Slick Rock tailings sites consist of two tailings piles in San Miguel County, Colorado (Figure 1.1). The Union Carbide (UC) tailings site is approximately one mile downstream of the North Continent (NC) tailings site. The tailings sites are next to the Dolores River and are surrounded by steep juniper covered hillsides and cliffs of the Dolores River Canyon. The tailings sites are at approximately 5500 feet above mean sea level (MSL), while the surrounding hillsides reach 6500 feet above MSL.

The tailings piles are in a semiarid environment with a mean annual precipitation of approximately nine inches. The dominant land use in the area is grazing; a gas sweetener plant is next to the UC pile. In the past, mining was common in the area and there are now numerous abandoned mines and mining roads in the area. The area is sparsely populated: 17 people live in a trailer park near the UC pile, and another six people live within 1.6 miles of the UC site.

The Union Carbide Corporation presently owns both the UC and NC sites. The UC site began operation in 1957 and ore was received from mines in the area. Upgraded material from the UC site was trucked to the Union Carbide mill in Rifle, Colorado. The NC site dates back to 1931

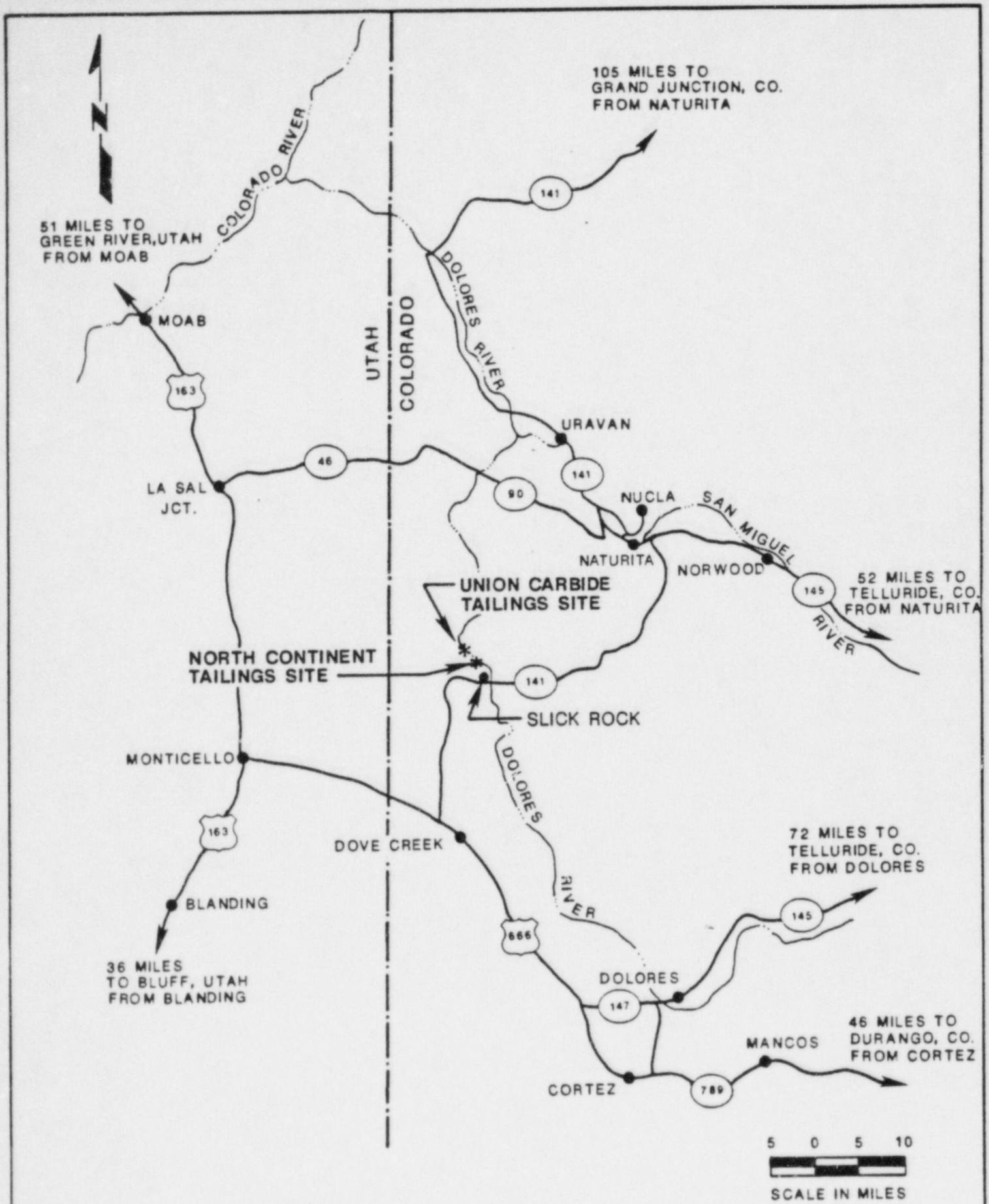


FIGURE 1.1
LOCATION OF THE SLICK ROCK TAILINGS SITES
NEAR SLICK ROCK, COLORADO

when Shattuck Chemical Company was the owner. The Federal Government acquired control of the site through the Union Mines Development Corporation with the specific purpose of supplying uranium and vanadium for the Manhattan Project. Union Carbide became the owner of the site in 1957. Except for some concrete foundations, the mill buildings have been removed from the UC site, while all structures including foundations have been removed from the NC site. Both tailings piles were covered with approximately six inches of soil and are at least partially revegetated.

The UC tailings site consists of the tailings pile, mill site, and windblown/waterborne contaminated areas (Figure 1.2). In addition, a small area (1.5 acres) within the UC designated site is the site of a radium mill operated by Madame Curie around the turn of the century. The tailings cover approximately 17 acres and the surrounding contaminated land in the mill building area covers some 41 acres. An additional 89.7 acres are contaminated mostly downstream of the site in the riparian habitat. There are approximately 565,100 cubic yards of contaminated material at the UC site; 344,000 cubic yards of tailings with the remainder being contaminated material below the tailings pile, in the mill yard area, and windblown/waterborne areas. Seepage from the tailings pile has contaminated the ground water in the alluvium beneath the pile.

The NC tailings site consists of the tailings pile and windblown contaminated area (Figure 1.3). The tailings pile is difficult to

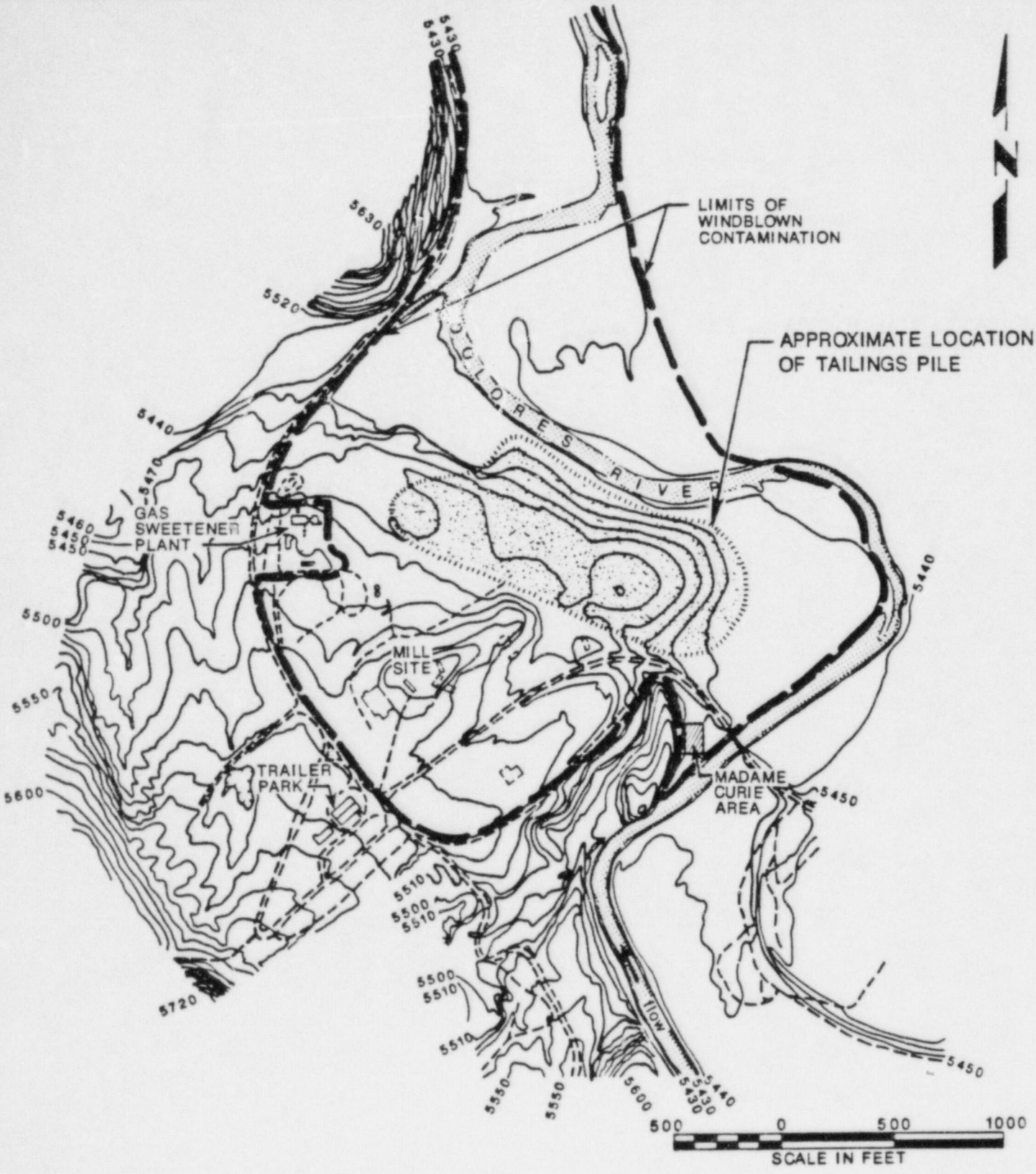


FIGURE 1.2
PRESENT CONDITIONS
UC TAILINGS SITE AT SLICK ROCK, COLORADO

Figure 1.3 Present conditions, NC tailings site at Slick Rock, Colorado

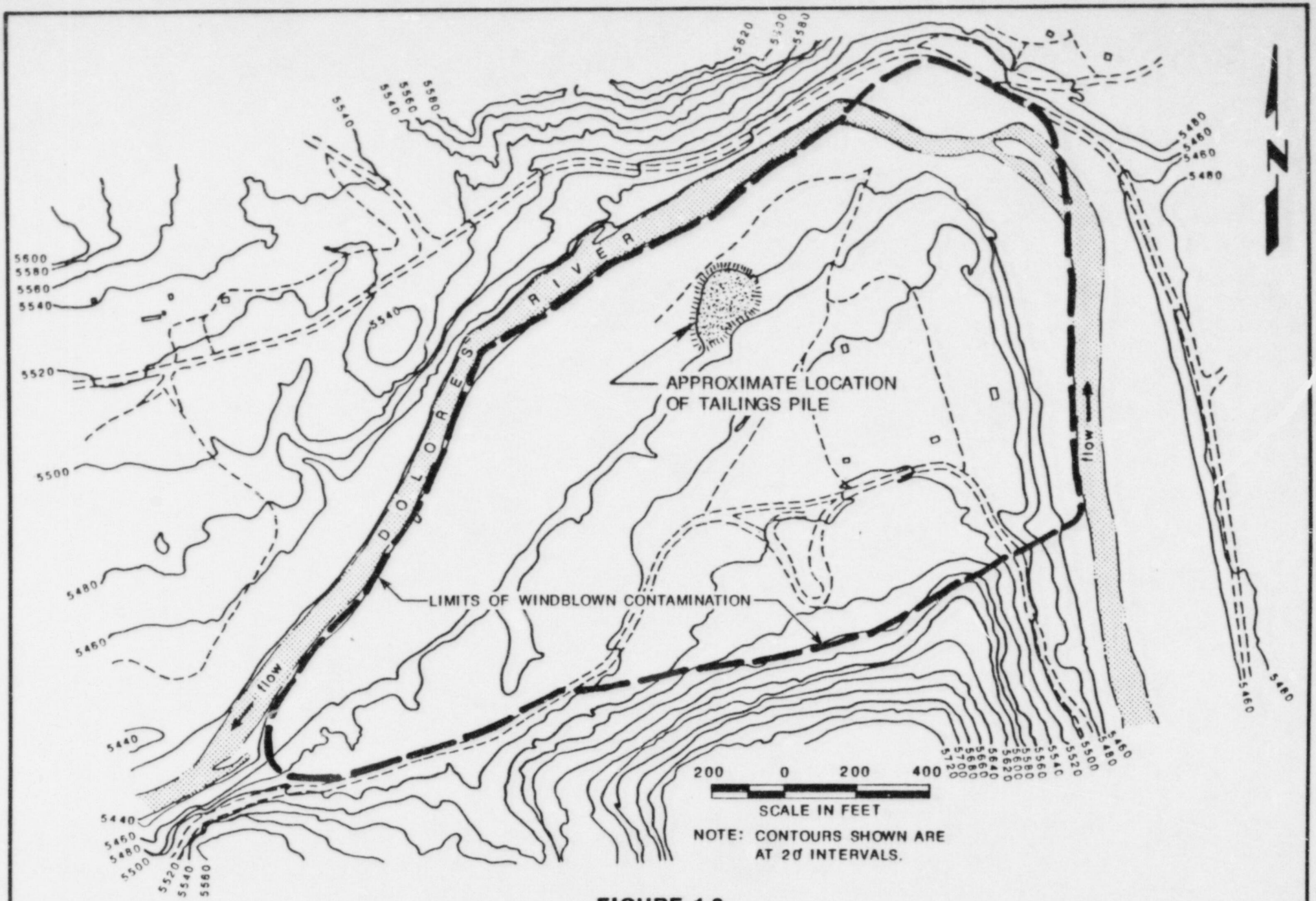


FIGURE 1.3
PRESENT CONDITIONS
NC TAILINGS SITE AT SLICK ROCK, COLORADO

differentiate from the surrounding contaminated land; approximately 46 acres are contaminated with 14 of these acres being in the Dolores River riparian zone. There are approximately 97,000 cy of contaminated materials at the NC site. Seepage from the tailings pile has contaminated the ground water in the alluvium beneath the pile.

The principal potential hazard associated with the tailings results from the production of radon, a radioactive decay product of the radium contained in the tailings. Radon, a radioactive gas, can diffuse through the pile and be released into the atmosphere where it and its radioactive decay products (radon daughters) may be inhaled by humans. Increased exposure to radon and its decay products over a long period of time will increase the probability that health effects (i.e., cancers) may develop in persons living and working near the tailings. Exposure to gamma radiation, the inhalation of airborne radioactive particulates, the ingestion of contaminated foodstuffs produced in the area around the tailings, and the ingestion of surface and ground waters contaminated by the tailings also pose potential hazards. If the tailings and associated contaminated materials are not properly stabilized, erosion by wind or water or human removal of contaminated materials could spread the contamination over a much wider area and increase the potential for public health hazards.

The Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), Public Law 95-604 (PL95-604), authorized the U.S. Department of Energy (DOE) to perform remedial action at the Slick Rock tailings sites (as well as at many other sites) to reduce the potential public health

impacts from the residual radioactivity remaining in the piles. The U.S. Environmental Protection Agency (EPA) promulgated standards (40 CFR Part 192) in March, 1983, for this remedial action.

The proposed remedial action for the Slick Rock tailings is stabilization on site. The tailings and windblown/waterborne contaminated soils from the piles would be consolidated at a site within the UC designated site (Figure 1.4). The resulting pile would have 20 percent sideslopes (five horizontal to one vertical) and a gently sloping (two to four percent) top. The pile would then be covered with a layer of compacted earth to inhibit radon emanation and water infiltration. The top and sides of the pile would be covered with a layer of sand and rock to protect the pile against erosion, penetration by animals, and inadvertent human intrusion. The top of the stabilized pile would average 41 feet above the surrounding terrain. The pile perimeter would be graded to prevent surface runoff from concentrating on or around the pile. Areas disturbed by remedial action (including the UC and NC pile areas) would be restored and released for any use consistent with existing land use controls.

The no action alternative would consist of taking no remedial action at the tailings sites. The tailings would remain in their present locations and conditions and would continue to be susceptible to erosion and unauthorized removal and use by man.

Disposal of the tailings at the Section 36 alternate disposal site in Disappointment Valley (Figure 1.5) would involve moving the

Figure 1.4 Proposed pile configuration, stabilization on site, Slick Rock, Colorado

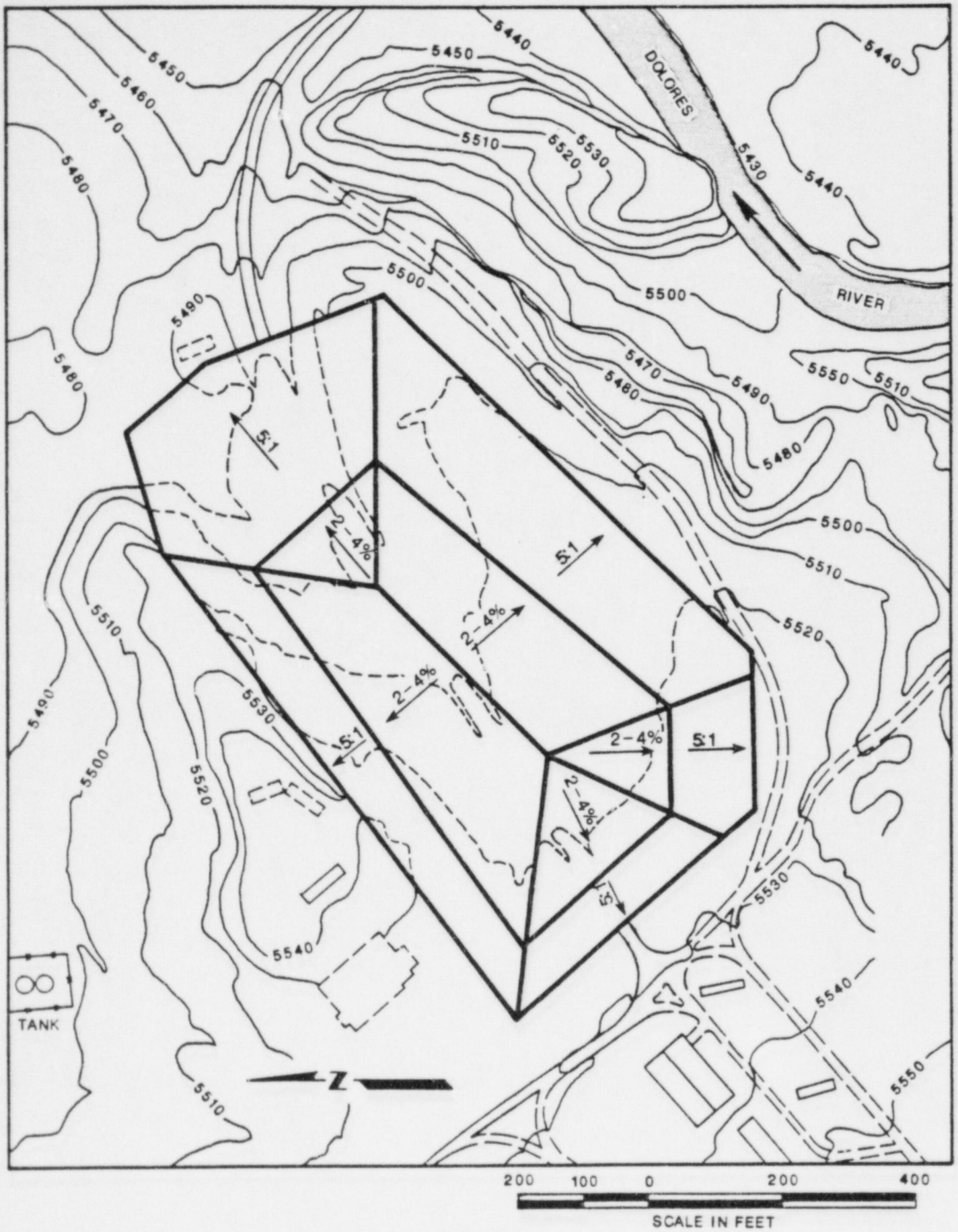
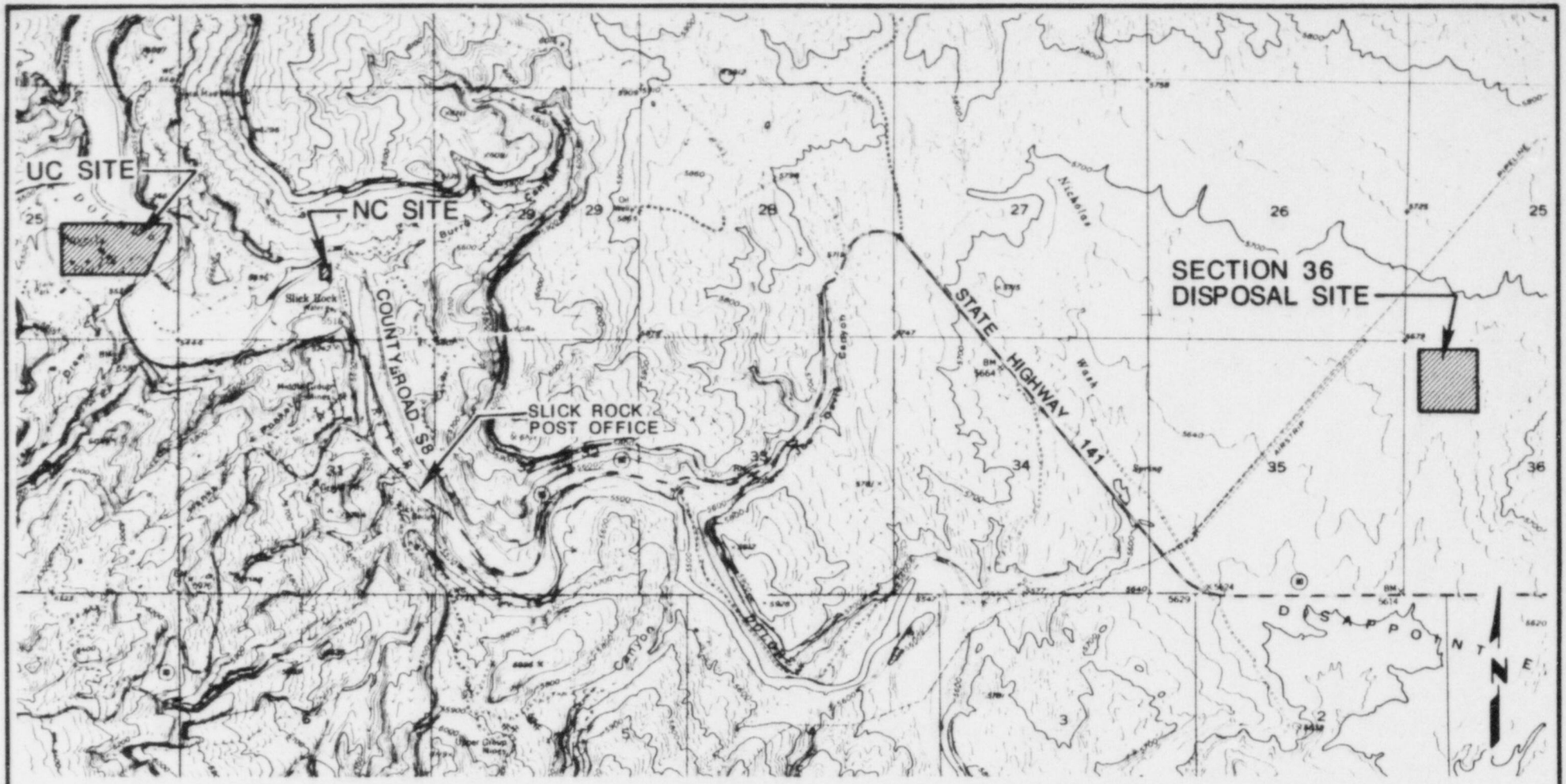


FIGURE 1.4
PROPOSED PILE CONFIGURATION, STABILIZATION ON SITE, SLICK ROCK, COLORADO

Figure 1.5 Location of the Section 36 alternate disposal site at the Slick Rock, Colorado, sites



MODIFIED FROM HAMM CANYON, COLO., AND
HORSE RANGE MESA, COLO., 7.5' USGS TOPO MAPS.

FIGURE 1.5
LOCATION OF THE SECTION 36 ALTERNATE DISPOSAL SITE
FOR THE SLICK ROCK, COLORADO SITES

contaminated materials approximately five air miles east of the existing UC site. This site is on lands administered by the U.S. Bureau of Land Management (BLM). Land directly adjacent to this site was evaluated for tailings disposal by Pioneer-Uravan and was licensed by the state for tailings disposal. The existing tailings sites would be restored and released for any use consistent with existing land use controls.

1.2 IMPACT SUMMARY

This section contains a quantitative listing of the environmental impacts of the proposed action (Table 1.1) and a brief discussion of the major differences between the proposed action and the other alternatives. These impacts are based on the use of conservative impact assessment methods and represent a realistic upper limit of the severity of the potential impacts for stabilization on site. For the purpose of evaluating impacts and for conceptual design, specific borrow sites were identified; however, other borrow sites may be identified during the final design process and used for remedial action. The impacts identified for these borrow sites are also conservative and represent a realistic upper limit on the severity of the impacts that may occur.

No action alternative

Selection of the no action alternative would not be consistent with the intent of Congress in UMTRCA (PL95-604) and would not result in compliance with the EPA standards (40 CFR Part 192). This alternative

Table 1.1 Environmental impacts of the proposed action at the Slick Rock, Colorado, tailings sites

Environmental component	Impacts
Remedial action worker health	0.00092 excess radon daughter health effects; 0.00037 excess gamma health effects.
Public health	0.000046 excess radon daughter health effects; 0.00020 excess gamma health effects.
Mineral resources	No mineral resources at any of the sites would be impacted by remedial action.
Soils	Approximately 662,000 cubic yards removed in contaminated area, 87,000 cubic yards at borrow sites, and 26,000 cubic yards for road construction.
Water resources	Gradual reduction in existing ground-water contamination; no impacts on surface waters and existing water use.
Water consumption	Approximately 5,384,000 gallons consumed.
Air quality (nonradiological, 24-hour maximum)	Total suspended particulate level above 24-hour standard likely at disposal site and North Continent site.
Wildlife	Diverse, productive wildlife communities in approximately 96 acres of riparian habitat would be impacted.
Vegetation	Approximately 236 acres of vegetation would be cleared; 41 percent are located in the riparian zone.
Threatened and endangered (T&E) species	No impact on T&E species. Two candidate species may occur at the Disappointment Valley borrow site.
Historic and cultural resources	No eligible archaeological sites would be impacted. One eligible historic site may be impacted.
Noise	Elevated noise levels would impact 23 people living near the Slick Rock sites.

Table 1.1 Environmental impacts of the proposed action at the Slick Rock, Colorado tailings sites (Continued)

Land use	236 acres of land would be disturbed, most of which is presently grazed by livestock. This use would be eliminated until the area was revegetated.
Population	None.
Employment	None.
Social services	None.
Transportation networks	CR-S8 would have a large increase in traffic (five to six vehicles per day to as many as 225 trips per day).
Energy resources	Estimated fuel and electricity consumptions are 333,000 gallons and 156,000 kilowatt-hours, respectively.
Construction costs ($)[a]	5,383,000.

[a] This estimate does not include the costs of: (1) property acquisition; (2) engineering design; (3) construction management; (4) overall project management; (5) long-term surveillance and maintenance.

would result in the continued dispersion of the tailings over a wide area by wind and water erosion, continued livestock and wildlife feeding in the contaminated areas, and the ground water beneath the tailings would continue to be contaminated. Also, the tailings would not be protected against unauthorized removal by humans. Finally, continued erosion and use of the tailings could cause radiological contamination of other areas and could result in greater public health impacts than those calculated for this alternative.

Section 36 alternative disposal site

Tailings relocation to the Section 36 site would result in stabilization of the tailings at an undeveloped location, but would generally involve greater short-term impacts and costs than the proposed action.

The major differences between disposal at the Section 36 site and stabilization on site are:

- The Section 36 alternative would have a greater impact on nonradiological air quality, transportation networks, consumption of water and energy, and wildlife habitat.

- The construction costs for stabilization at Section 36 would be approximately 37 percent more than stabilization on site.

2.0 REMEDIAL ACTION ALTERNATIVES

2.1 THE NEED FOR REMEDIAL ACTION

2.1.1 Background

In response to public concern over the potential public health hazards related to uranium mill tailings and the associated contaminated materials left abandoned or otherwise uncontrolled at inactive processing sites throughout the United States, Congress passed the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), Public Law 95-604 (PL95-604), which was enacted into law on November 8, 1978. In the UMTRCA, Congress acknowledged the potential health hazards associated with uranium mill tailings and identified 24 sites that were in need of remedial action. The two Slick Rock tailings piles constitute two of these sites.

Title I of the UMTRCA authorized the U.S. Department of Energy (DOE) to enter into cooperative agreements with affected states or Indian tribes to clean up those inactive sites contaminated with uranium mill tailings and required the Secretary of the DOE to designate sites to be cleaned up. Title I also required the U.S. Environmental Protection Agency (EPA) to promulgate standards for these sites and defined the role of the U.S. Nuclear Regulatory Commission (NRC).

Effective October 19, 1981, the DOE and the State of Colorado entered into a cooperative agreement under the UMTRCA. The cooperative agreement set forth the terms and conditions for the DOE and state cooperative remedial action efforts including the DOE's development of a Remedial Action Plan (in concurrence with the State of Colorado), the DOE's preparation of an appropriate environmental document, real estate responsibilities, and other concerns.

The EPA published an Environmental Impact Statement (EIS) (EPA, 1982) on the development and impacts of the standards (40 CFR Part 192) and issued final standards (48 FR 590-604) which became effective on March 7, 1983. In developing these standards, EPA determined "that the primary objective for control of tailings should be isolation and stabilization to prevent their misuse by man and dispersal by natural forces" and that "a secondary objective should be to reduce the radon emissions from the piles." A third objective should be "the elimination of significant exposure to gamma radiation from tailings piles." The EPA standards are summarized in Table 2.1; more detailed discussions of the EPA standards are provided in Appendix A, EPA standards, of the Environmental Assessment of Remedial Action at the Shiprock Uranium Mill Tailings Site, Shiprock, New Mexico (DOE, 1984a) and the Plan for Implementing EPA Standards for UMTRA Sites (DOE, 1984b).

PART 192 - HEALTH AND ENVIRONMENTAL PROTECTION STANDARDS FOR URANIUM MILL TAILINGS

SUBPART A - Standards for the Control of Residual Radioactive Materials from Inactive Processing Sites

192.02 Standards

Control shall be designed to:

(a) Be effective for up to one thousand years, to the extent reasonably achievable, and, in any case, for at least 200 years, and,

(b) Provide reasonable assurance that releases of radon-222 from residual radioactive material to the atmosphere will not:

(1) Exceed an average release rate of 20 picocuries per square meter per second, or
(2) Increase the annual average concentration of radon-222 in air at or above any location outside the disposal site by more than one-half picocurie per liter.

SUBPART B - Standards for Cleanup of Land and Buildings Contaminated with Residual Radioactive Materials from Inactive Uranium Processing Sites

192.12 Standards

Remedial actions shall be conducted so as to provide reasonable assurance that, as a result of residual radioactive materials from any designated processing site:

(a) The concentration of radium-226 in land averaged over any area of 100 square meters shall not exceed the background level by more than -

(1) 5 pCi/g, averaged over the first 15 cm of soil below the surface, and
(2) 15 pCi/g, averaged over 15 cm thick layers of soil more than 15 cm below the surface.

(b) In any occupied or habitable building -

(1) The objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL. In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL, and
(2) The level of gamma radiation shall not exceed the background level by more than 20 microroentgens per hour.

SUBPART C - Implementation (condensed)

192.20 Guidance for Implementation

Remedial action will be performed with the "concurrence of the Nuclear Regulatory Commission and the full participation of any state that pays part of the cost" and in consultation as appropriate with other government agencies.

192.21 Criteria for Applying Supplemental Standards

The implementing agencies may apply standards in lieu of the standards of Subparts A or B if certain circumstances exist, as defined in 192.21.

192.22 Supplemental Standards

"Federal agencies implementing Subparts A and B may in lieu thereof proceed pursuant to this section with respect to generic or individual situations meeting the eligibility requirements of 192.21."

(a) ". . .the implementing agencies shall select and perform remedial actions that come as close to meeting the otherwise applicable standards as is reasonable under the circumstances."

(b) ". . .remedial actions shall, in addition to satisfying the standards of Subparts A and B, reduce other residual radioactivity to levels that are as low as is reasonably achievable."

(c) "The implementing agencies may make general determinations concerning remedial actions under this Section that will apply to all locations with specified characteristics, or they may make a determination for a specific location. When remedial actions are proposed under this Section for a specific location, the Department of Energy shall inform any private owners and occupants of the affected location and solicit their comments. The Department of Energy shall provide any such comments to the other implementing agencies [and] shall also periodically inform the Environmental Protection Agency of both general and individual determinations under the provisions of this section."

Ref: Federal Register, Volume 48, No. 3, January 5, 1983, 40 CFR Part 192.

TABLE 2.1

EPA HEALTH AND ENVIRONMENTAL STANDARDS FOR URANIUM MILL TAILINGS

Table 2.1 EPA health and environmental standards for uranium mill tailings

On September 3, 1985, the United States Tenth Circuit Court of Appeals remanded the EPA Water Protection Standards, 40 CFR Part 192.20(a)(2)-(3). When the EPA issues revisions to these standards, the DOE will reevaluate the ground-water issues at the Slick Rock tailings sites to assure that revised standards are met. Performing remedial actions to stabilize the tailings prior to EPA issuing new standards will not affect the measures that are ultimately required to meet the revised EPA water protection standards. The DOE has characterized conditions at the Slick Rock sites and does not anticipate that any substantial changes to the remedial action will be required. However, after the EPA reissues the water protection standards, the DOE will determine the need for institutional controls, aquifer restoration, or other controls and take such appropriate action so as to comply with the reissued standards. Section B.2.2 of Appendix B, Hydrology, identifies how the DOE will approach this issue until water protection standards are reissued.

The tailings are the residue of uranium ore processing operations and are finely ground rock, much like sand. The principal potential hazard associated with the tailings results from the production of radon, a radioactive gas, from the radioactive decay of the radium contained within the tailings. Radon can move through the tailings into the air. Increased exposure to radon and its decay products over a long period of time will increase the probability that health effects (i.e., cancers) may develop in persons living and working near the tailings.

Exposure to gamma radiation, the inhalation and ingestion of airborne radioactive particulates, the ingestion of contaminated food produced in the areas around the tailings, and the ingestion of surface and ground waters contaminated by the tailings pose lesser potential health hazards. If the tailings and the associated contaminated materials are not properly stabilized, natural processes such as wind and water erosion or removal of the materials by man could spread the contamination and increase the potential public health hazards.

All remedial actions performed under the UMTRCA must be performed in accordance with the EPA standards and with the concurrence of the NRC. The NRC has not and does not intend to issue regulations applicable to the remedial actions at the inactive uranium processing sites, but will issue a general license for all sites and will concur in a site-specific surveillance and maintenance plan of the disposal site. The NRC concurrence in the site-specific surveillance and maintenance plan will render the site licensed. The final plan will contain the site-specific surveillance and maintenance program, legal description of the site, site ownership, subsurface mineral ownership, and reporting and recordkeeping requirements.

2.1.2 The remedial action process

The remedial action process for the Slick Rock sites began with site characterization and will conclude with long-term

surveillance and maintenance. Preliminary radiological investigations and engineering assessments have been completed and published. Currently, related studies that address the site-specific engineering concepts, surveillance and maintenance requirements, and licensing are under preparation.

2.1.3 The Slick Rock tailings sites

The Slick Rock tailings sites are in San Miguel County, Colorado, approximately 100 miles south of the city of Grand Junction, Colorado. The closest town is Slick Rock (unincorporated) which is approximately three road miles southeast of the UC site and one mile southeast of the NC site. Slick Rock consists of two buildings which include a restaurant and post office. A population of 23 people lives within a 1.6-mile radius of the sites.

The tailings sites are partially within the floodplain of the Dolores River. The Dolores River canyon is bounded by steep slopes and cliffs in the tailings area. The tailings sites are approximately 5500 feet above mean sea level (MSL) while the surrounding hills reach 6500 feet above MSL. The climate of the area is semiarid with an average precipitation of nine inches per year. The area has warm summers and cold winters. Wildlife habitat in the area is domirated by steep juniper covered hills with a relatively thin band of riparian vegetation growing along the river. Grazing is the major land use in the area while a gas sweetener plant is located near the sites.

The Slick Rock sites consist of two tailings piles, associated contaminated ore storage and mill areas, and windblown/waterborne contaminated areas. The Union Carbide (UC) tailings pile is immediately south of the Dolores River. Due to the sharp bend in the Dolores River at the UC pile, the distance from the pile to the river ranges from 15 to 150 feet. The UC pile covers approximately 17 acres while the mill/ore storage and pond areas south of the pile cover some 41.3 acres. The total area contaminated at the UC site is approximately 148 acres.

The mill at the UC site became operational in September, 1957. Ore containing uranium and vanadium was mined in the Slick Rock area and trucked to the mill. This material was upgraded at the mill and then trucked to Union Carbide's mill in Rifle, Colorado (FBDU, 1981). A total of 565,100 cubic yards (cy) of contaminated materials are at the UC site: 344,000 cy of tailings; 36,000 cy of subpile contamination; 72,100 cy of contamination in the mill/ore storage/pond area; and 113,000 cy of windblown/waterborne contamination. The waterborne contamination extends approximately one mile downstream from the UC pile. It is not known how the contaminated material was transported down the Dolores River.

Operations at the UC mill ceased in December, 1961, and the pile was then stabilized in accordance with the State of Colorado regulations. This involved covering the pile with six inches of

soil and revegetating; the pile is approximately 20 percent revegetated at this time (FBDU, 1981). All of the mill buildings have been removed from the site; only the concrete foundations remain.

The North Continent (NC) site is located next to the Dolores River approximately one mile east of the UC site. The original owner of the site was Shattuck Chemical Company; North Continent Mines Inc., acquired the site in 1934. A Federal Government-established corporation (Union Mines Development Corporation) became the owner of the site in 1945 for the specific purpose of producing uranium and vanadium for the Manhattan Project in World War II (FBDU, 1981). Union Carbide (the present owner) became the owner in 1957. Uranium and vanadium bearing ore was mined near Slick Rock and shipped to the mill by trucks and mule teams. An estimated 97,000 cy of contaminated materials covering 46.4 acres are at the NC site.

After operations ceased at the NC site, the pile was stabilized in accordance with the State of Colorado regulations in effect in the early 1960s (six inches topsoil, reseeding, and fertilizing). All man-made structures (including foundations) which included the mill and a small town have been removed from the site.

2.1.4 The purpose of this document

This environmental assessment (EA) is prepared pursuant to the National Environmental Policy Act (NEPA) which requires Federal agencies to assess the impacts that their actions may have on the environment. The EA examines the short-term and long-term effects of the DOE's proposed remedial action at the Slick Rock tailings sites. Alternatives to the proposed action are also examined.

The DOE will use the information and analyses presented here to determine whether the proposed action would have a significant impact on the environment. If the impacts are determined to be significant, an EIS will be prepared. If the impacts are not judged to be significant, the DOE will issue a "Finding of No Significant Impact" and implement the proposed action. These procedures and documents are defined in regulations issued by the Council on Environmental Quality (CEQ) in 40 CFR, Parts 1500 through 1508.

Remedial action may include the cleanup of vicinity properties associated with the tailings sites. Vicinity properties are properties outside a designated tailings site boundary that were contaminated by the dispersion of tailings by wind or water erosion or by removal by man before the potential hazards of the tailings were known. The windblown/waterborne contaminated areas at the Slick Rock sites are not considered

vicinity properties. Further, surveys indicated that there are no vicinity properties associated with the Slick Rock tailings sites. The potential environmental impacts of remedial actions at vicinity properties were previously assessed in a programmatic environmental report (DOE, 1985). Impacts to any vicinity properties associated with the Slick Rock tailings sites that may be located prior to remedial action are expected to be similiar to those assessed in the programmatic environmental report and, therefore, are not considered in this EA.

This EA is divided into the following sections: Section 2.0, which describes the proposed action and its alternatives; Section 3.0, which describes the present condition of the environment; and Section 4.0, which assesses the environmental impacts of the proposed action and the alternatives. Further details of the studies on which this document is based are contained in the attached appendices and the referenced supporting documents.

2.2 THE PROPOSED ACTION - STABILIZATION ON SITE

The proposed action for the Slick Rock tailings sites is to stabilize the tailings piles within the UC designated site boundary. The tailings from the UC and NC piles along with contaminated materials from the ore storage/mill areas, and windblown/waterborne areas would be consolidated and covered with compacted earth to inhibit radon emanation

and water infiltration. A sand and rock erosion protection barrier would be placed over the pile to inhibit wind and water erosion and discourage animal and human intrusion.

The design for stabilization on site will comply with the EPA standards, and the major design features are summarized below. Details of the design and its objectives are provided in Appendix A, Conceptual Designs, and in the draft Remedial Action Plan and Site Conceptual Design for Stabilization of the Inactive Uranium Mill Tailings Sites at Slick Rock, Colorado (DOE, 1987).

Description of final conditions

The pile would be roughly rectangular in shape, and would have a maximum length of 1050 feet and a maximum width of 620 feet (see Figure 1.4). The tailings would be covered with lesser contaminated material from the mill area and windblown/waterborne areas, then a layer of compacted earth to inhibit radon emanation and water infiltration, and finally, a layer of sand and rock for erosion protection. The stabilized tailings pile would have maximum sideslopes of 20 percent and topslopes of two to four percent. The average height of the pile above the surrounding terrain would be approximately 41 feet (Figure 2.1).

The sand and rock erosion protection barrier would tie into a rock erosion protection apron which would encircle the stabilized tailings

Figure 2.1 Typical cross section for stabilization on site at the Slick Rock sites, Slick Rock, Colorado

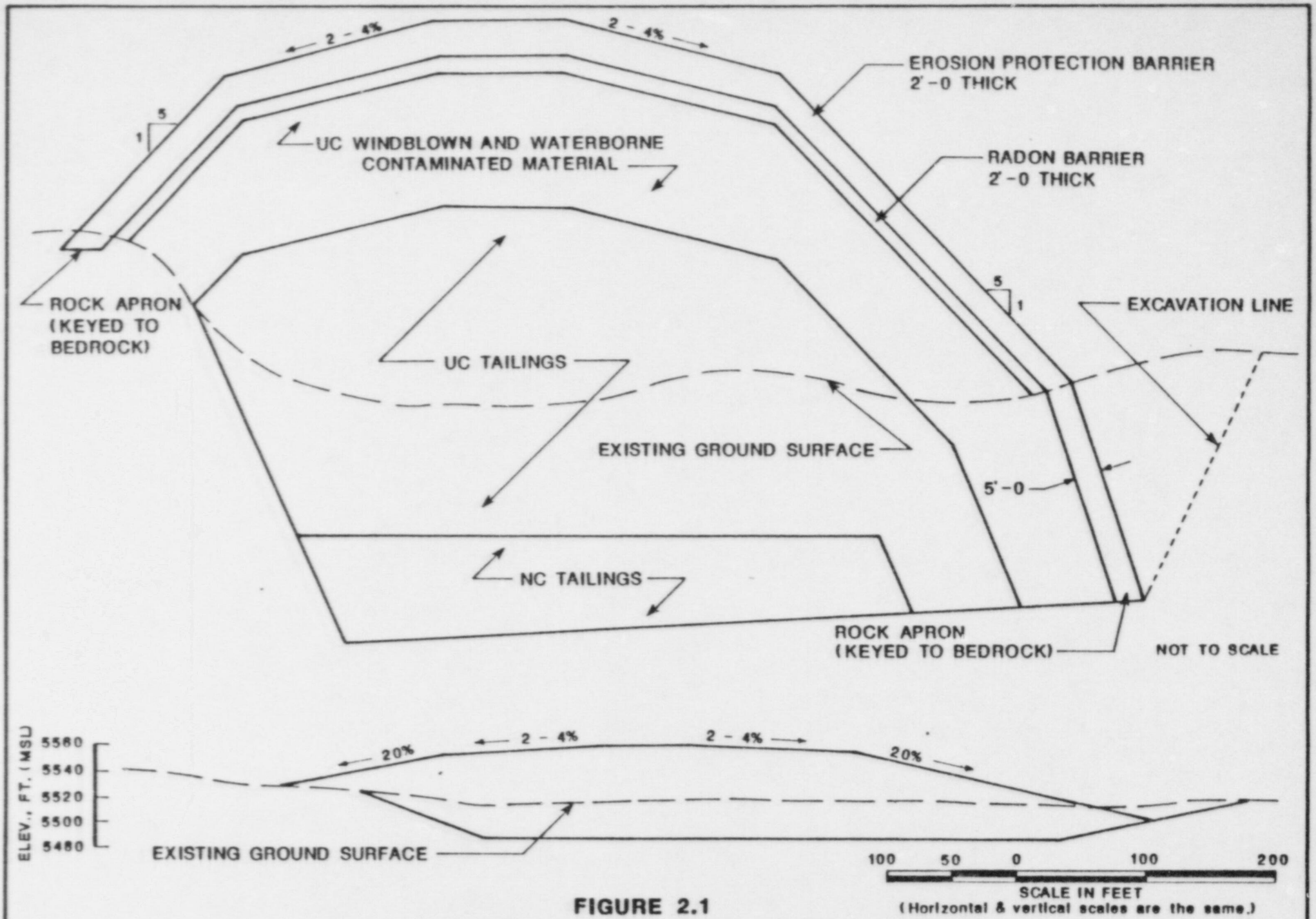


FIGURE 2.1
TYPICAL CROSS SECTION, STABILIZATION ON SITE
SLICK ROCK, COLORADO

pile except on the north end where the pile would tie into a bedrock outcrop. The perimeter of the disposal site would be marked with warning signs and fenced if required.

The stabilized tailings pile would occupy an area of 13 acres while the restricted area would add an additional two acres. After remedial action, all disturbed areas including the tailings piles and windblown/waterborne contaminated areas would be restored in accordance with applicable permits or approvals.

Major construction activities

The remedial action would be performed using conventional construction practices and techniques that comply with applicable regulations (Appendix E, Permits, Licenses, Approvals) and that would ensure the safe and environmentally sound stabilization of the tailings and other contaminated materials in accordance with the EPA standards. The major construction activities for stabilization on site would be site preparation, demolition of existing mill building foundations, construction of drainage control measures, construction and upgrading of haulage roads to the NC and borrow sites, consolidation of the tailings and windblown/waterborne contaminated soils onto the excavation, excavation of borrow materials, placement of cover materials onto the tailings pile, and restoration of the borrow sites and surrounding land, including the UC and NC tailings sites and the windblown/waterborne areas.

Borrow sites

Construction of the stabilized tailings pile would require the use of borrow materials (earth, gravel, and rock). The Disappointment Valley borrow site would be the source of earthen radon barrier material and is in Disappointment Valley approximately five air miles from the UC site. The Dolores River borrow site would be the source of erosion protection materials and is in a terrace above the Dolores River between the UC and NC sites (Figure 2.2).

It should be noted that the borrow sites included in this EA were selected as the source of the necessary borrow materials for impacts analysis purposes. Although the borrow sites to be used for the remedial action will be selected during the final design, the impacts identified for borrow sites included in this EA are conservative and represent a realistic upper limit on the severity of the impacts that may occur.

Construction estimates

Estimates of personnel requirements, energy and water consumption, volumes of materials, and costs for stabilization on site are contained in Section A.2.5 of Appendix A, Conceptual Designs.

Figure 2.2 Location of the proposed Disappointment Valley and Dolores River borrow sites for the Slick Rock, Colorado tailings sites

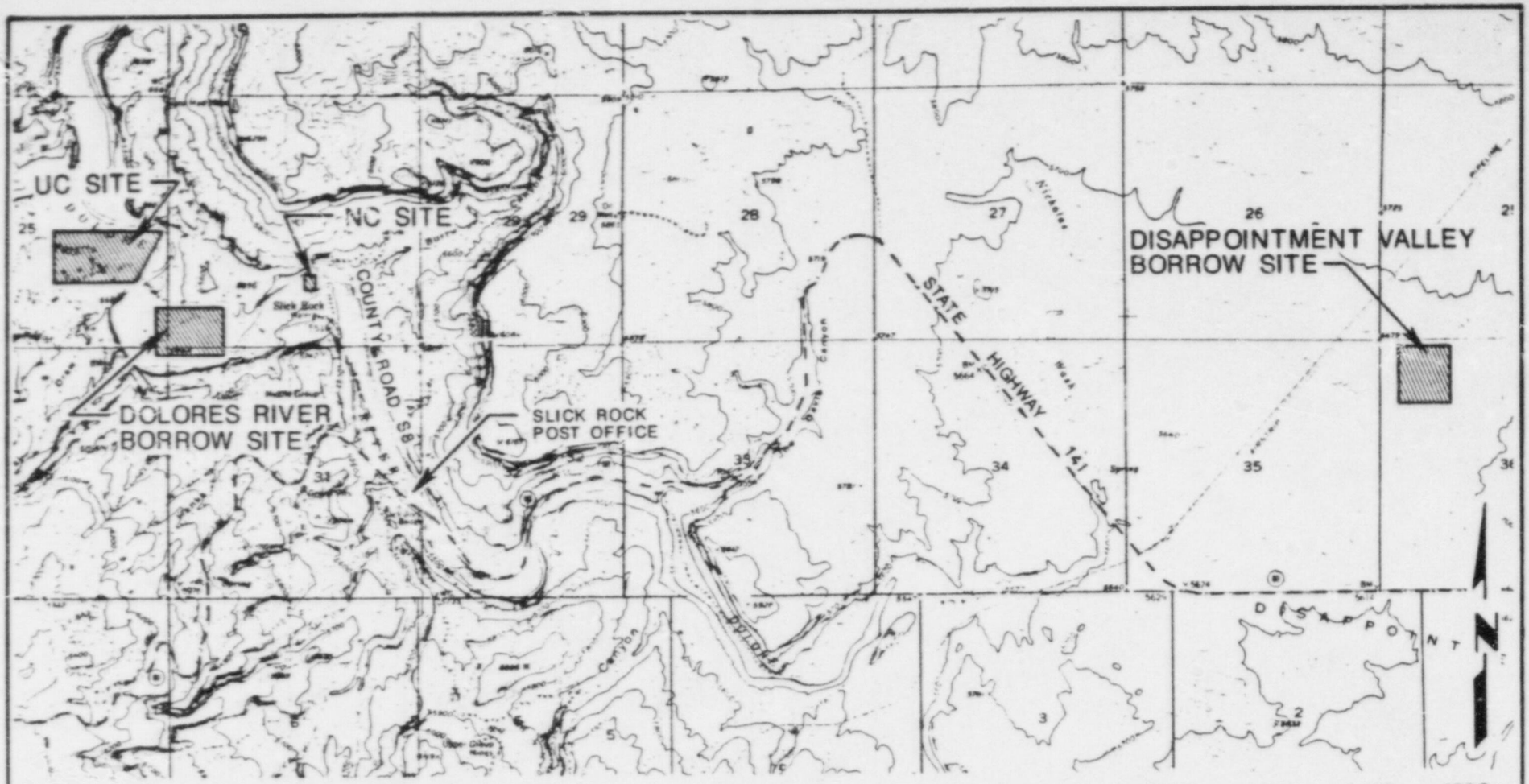


FIGURE 2.2
LOCATION OF PROPOSED DISAPPOINTMENT VALLEY AND DOLORES RIVER BORROW SITES FOR THE SLICK ROCK, COLORADO TAILINGS SITES

2.3 OTHER ALTERNATIVES

2.3.1 No action

This alternative consists of taking no steps toward remedial action at the tailings sites or areas of windblown/waterborne contamination. The tailings piles would remain in their present condition and would continue to be subject to dispersal by wind and water erosion, use by livestock and wildlife, and unauthorized removal by man. The selection of this alternative would not be consistent with the intent of Congress in the UMTRCA (PL95-604) and would not result in compliance with the EPA standards (40 CFR Part 192).

2.3.2 Disposal at the Section 36 site

The alternate disposal site is located in Section 36 of Disappointment Valley in the same area as the proposed Disappointment Valley borrow site. This site was proposed by the State of Colorado as an alternate disposal site during DOE's consultation with the state as part of the alternate site selection process. This process is described in greater detail in Section 2.4, below.

The design objectives for the disposal at the Section 36 site would be identical to those selected for stabilization on site. The tailings and associated contaminated materials would be moved

to the site and consolidated partially below grade and would be covered with compacted earth, sand, and rock. The engineering details and major construction activities for this alternative are contained in Section A.3 of Appendix A, Conceptual Designs.

The conceptual design for the alternate disposal site is based on existing published data. If this alternative were selected, additional site-specific data would be obtained before the final engineering design was prepared.

2.4 ALTERNATIVES ELIMINATED FROM DETAILED STUDY

Alternate disposal sites

A standardized approach for alternate site selection has been implemented for the UMTRA Project (DOE, 1986). For sites where it is likely the tailings would have to be relocated, a comprehensive and technically sound approach considering many factors would be used. For sites where stabilization in place is likely, a much less rigorous approach would be used. The proposed action at the Slick Rock sites is to relocate all the contaminated materials; therefore, the more comprehensive alternate site selection process was used.

The alternate site selection process consisted of four phases: (1) designation of a search region; (2) application of regional screening guidelines to eliminate areas within the search region that are

unsuitable for tailings disposal; (3) preliminary evaluation of potential areas; and (4) field inspection of potential areas.

An area within a five-mile radius around the UC site was designated as the search region. The alternate site selection team then applied geotechnical, hydrological, and environmental regional screening guidelines to eliminate unsuitable areas. This process eliminated sections of land that had unsuitable geologic characteristics such as steep slopes or erosive soils; hydrological characteristics such as water bodies or shallow aquifers; and environmental characteristics such as areas of human habitation or wetland areas.

The preliminary analysis of suitable areas remaining in the five-mile search zone after the application of the regional screening guidelines resulted in two areas being field checked and identified as possible alternate disposal sites (Figure 2.3). In addition, consultations with the State of Colorado resulted in the identification of a third possible alternate disposal site. This site (the Section 36 alternate disposal site) was just outside the five-mile radius search zone and is located in Disappointment Valley.

The alternate disposal site considered in this EA is the Section 36 site and is next to the Pioneer-Uravan site. The Pioneer-Uravan site received a license from the State of Colorado for tailings disposal. It was assumed that the hydrological and geotechnical conditions favorable

Figure 2.3 Location of preliminary alternate disposal sites for the Slick Rock, Colorado tailings sites

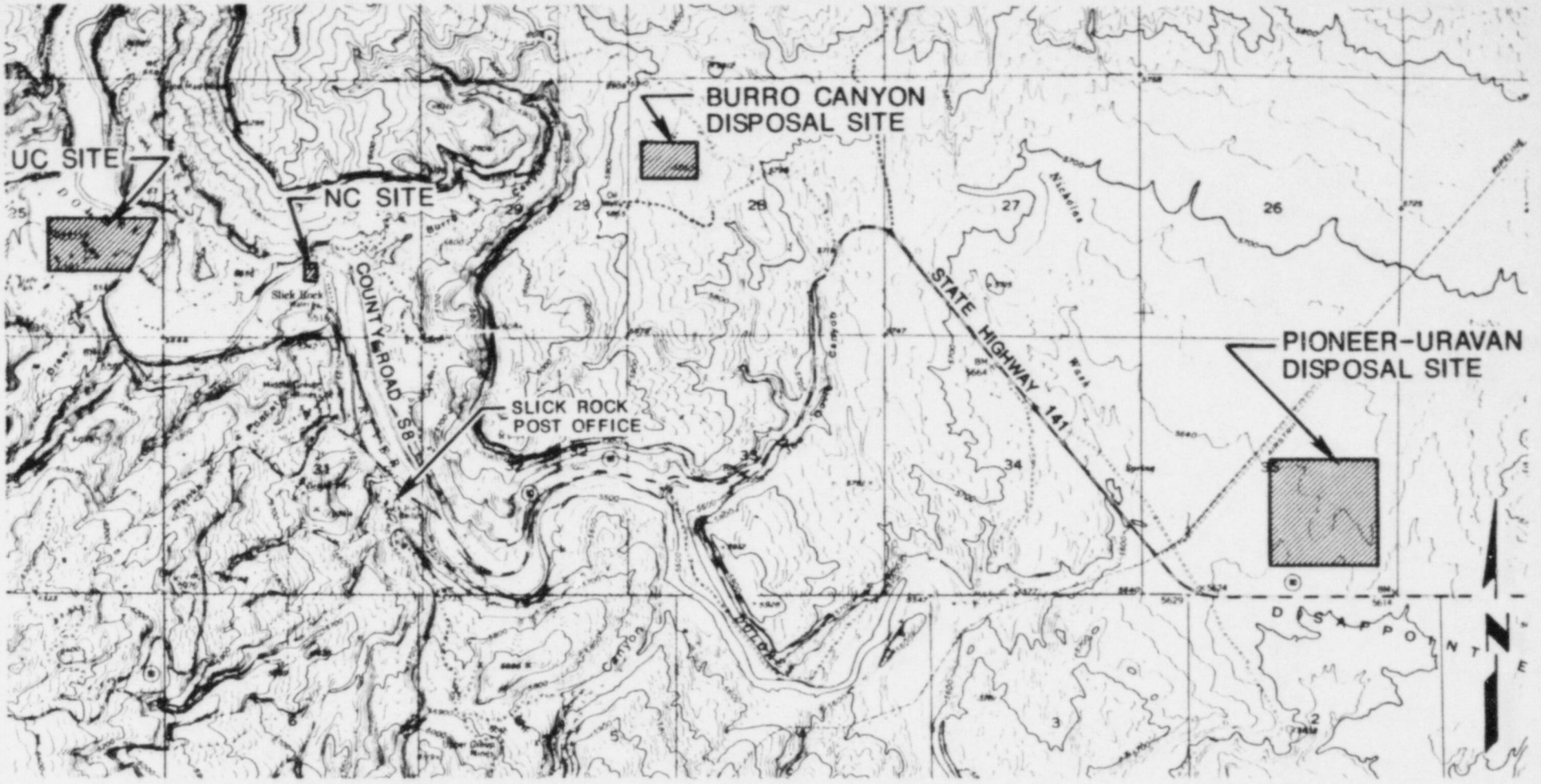


FIGURE 2.3
LOCATION OF PRELIMINARY ALTERNATE DISPOSAL SITES
FOR THE SLICK ROCK, COLORADO TAILINGS SITES

for tailings disposal at the Pioneer-Uravan site would occur at the Section 36 site. In addition, the Section 36 site is on land administered by the BLM which would eliminate possible problems regarding the aquisition of private land which could surface if the Pioneer-Uravan site were the alternate disposal site.

Reprocessing the tailings

The Slick Rock tailings contain low levels of uranium and vanadium and the feasibility of reprocessing the tailings for these metals was evaluated (FBDU, 1981). Two reprocessing methods were considered: heap leaching, and reprocessing at a new conventional mill. The uranium market as well as construction and labor costs were also considered in this analyses. It was determined that recovery of uranium would cost $830.00 to $870.00 per pound (1981 dollars), while the current market price for uranium is below $20.00 per pound.

Reprocessing would not reduce the tailings' radium content. Since radioactive decay of radium is the source of radon gas, the hazard from radon and radon daughters would not be reduced; hence, the reprocessed tailings would still require remedial action to meet the EPA standards. Reprocessing was therefore eliminated from further consideration.

REFERENCES FOR SECTION 2.0

DOE (U.S. Department of Energy), 1987. "Draft Remedial Action Plan and Site Conceptual Design for Stabilization of the Inactive Uranium Mill Tailings Sites at Slick Rock, Colorado," unpublished draft prepared by the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

DOE (U.S. Department of Energy), 1986. Alternate Site Selection Process for UMTRA Project Sites, UMTRA-DOE/AL-200129.0007R-2, prepared by the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

DOE (U. S. Department of Energy), 1985. Programmatic Environmental Report for Remedial Actions at UMTRA Project Vicinity Properties, UMTRA-DOE/AL-150327.0000, prepared by the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

DOE (U.S. Department of Energy), 1984a. Environmental Assessment of Remedial Action at the Shiprock Uranium Mill Tailings Site, Shiprock, New Mexico, DOE/EA-0232, prepared by the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

DOE (U.S. Department of Energy), 1984b. Plan for Implementing EPA Standards for UMTRA Sites, UMTRA-DOE/AL-163, prepared by the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

EPA (U.S. Environmental Protection Agency), 1982. Final Environmental Impact Statement for Remedial Action Standards for Inactive Uranium Processing Sites (40 CFR Part 192), EPA 520/4-82-013-1, Washington, D.C.

FBDU (Ford, Bacon, and Davis, Utah, Inc.), 1981. Engineering Assessment of Inactive Uranium Mill Tailings, Slick Rock Sites, Slick Rock, Colorado, DOE/UMT-0115, FBDU 360-07, UC 670, prepared by FBDU, Salt Lake City, Utah, for the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

3.0 AFFECTED ENVIRONMENT

3.1 WEATHER

The Slick Rock tailings sites are in a topographically complex area consisting of the Dolores River Valley and surrounding steep canyon walls and hill sides. The elevations range from 5500 feet above MSL in the river valley to 6500 feet above MSL on the hill tops. The region is located in a semiarid, continental climate with low precipitation and humidity, large temperature variations, and high evaporation. Elevation, exposure, and topographic channeling of winds affect the climate and dispersion potential at the sites.

Weather data are not available from the Slick Rock tailings sites area. The nearest weather station with long-term weather data (30 years plus) and at approximately the same elevation as the Slick Rock sites is in Montrose, Colorado, (elevation 5830 feet above MSL) approximately 65 miles from the sites. Ten years of weather data are also available from Paradox, Colorado, (elevation 5530 feet above MSL) approximately 19 miles north of Slick Rock. The temperature data from Montrose and Paradox are in close agreement (Tables 3.1 and 3.2) and are assumed to be representative of the temperature patterns at the Slick Rock sites. Using the Parodox data, the mean maximum temperature is 65°F and ranged from a low of 39°F in January to a high of 90°F in July. The yearly mean minimum temperature is 36°F and ranged from a low of 16°F in January to a high of 57°F in July. The maximum temperatures during the summer are in the high 90s while wintertime maximums (December and January) are generally in the 50s. Summertime minimum temperatures range from the

Table 3.1 Average monthly temperatures for the period 1951 through 1980 at Montrose, Colorado

Month	Temperature (°F)				
	Means			Extremes	
	Daily maximum	Daily minimum	Monthly	Highest recorded	Lowest recorded
Jan	38	13	26	63	-23
Feb	44	19	31	72	-21
Mar	52	25	39	77	2
Apr	62	33	48	83	9
May	72	42	57	93	23
Jun	83	50	67	99	33
Jul	89	56	73	100	35
Aug	86	54	70	98	37
Sep	79	45	62	94	26
Oct	67	35	51	85	14
Nov	50	24	37	73	-8
Dec	40	15	28	65	-15
Year	64	34	49	100	-23

Ref. NOAA, 1984.

Table 3.2 Average monthly temperatures for the period 1976 through 1985 at Paradox, Colorado

Month	Temperature (°F)				
	Means			Extremes	
	Daily maximum	Daily minimum	Monthly	Highest recorded	Lowest recorded
Jan	39	16	27	55	-10
Feb	47	20	34	67	-11
Mar	53	29	41	74	13
Apr	64	34	50	83	15
May	73	42	58	91	22
Jun	85	50	67	98	35
Jul	90	57	74	101	46
Aug	87	55	71	98	54
Sep	79	49	64	96	30
Oct	66	36	51	85	17
Nov	51	27	39	72	0
Dec	42	19	31	58	-12
Year	65	36	51	101	-12

Ref. NOAA, 1986.

high 30s to mid 50s while wintertime minimum temperatures can fall below zero.

The yearly mean precipitation for Montrose is approximately nine inches while Paradox had 16.5 inches (Tables 3.3 and 3.4). Data from both the Montrose and Paradox sites indicate that the most precipitation falls from July through October while less precipitation occurs during the winter and early spring. The average annual snowfall at the Slick Rock sites is probably 30 to 32 inches (Tables 3.3 and 3.4).

Wind data are not available from the Slick Rock tailings sites. Wind flow data were collected at Disappointment Valley approximately five air miles east of the UC site (Pioneer, 1979). These data indicate that east to southeast down-valley and west to north-northwest up-valley winds are the most frequent, while large scale wind patterns (south to southwest) associated with synoptic-scale conditions are also common.

Valley channeling of winds are expected to be more pronounced at the Slick Rock sites than at Disappointment Valley since the canyon walls along the Dolores River are much steeper than the relatively broad, flat Disappointment Valley. This indicates that north-northwest up-valley and south-southeast down-valley winds would prevail at the Slick Rock sites. The estimated average annual wind speed was approximately seven miles per hour based at Disappointment Valley (Pioneer, 1979); the average wind speed at the Slick Rock sites would be expected to be somewhat less given the protected nature of the Dolores River Valley.

Table 3.3 Precipitation data for the period 1951 through 1980 at Montrose, Colorado

Month	Precipitation (in.)			Snowfall (in.)	
	Average	Greatest monthly	Greatest daily	Average	Greatest monthly
Jan	0.60	1.96	1.36	7.3	22.0
Feb	0.47	1.02	0.53	5.7	17.9
Mar	0.53	1.35	0.53	3.7	11.5
Apr	0.78	1.64	0.79	2.4	8.9
May	0.75	2.11	0.75	0.4	6.4
Jun	0.53	2.26	1.06	0.0	0.0
Jul	0.83	2.27	0.77	0.0	0.0
Aug	1.14	3.22	1.15	0.0	0.0
Sep	1.01	3.22	1.50	0.0	0.0
Oct	1.05	2.60	1.70	0.8	6.5
Nov	0.70	1.31	0.67	4.0	15.2
Dec	0.68	1.98	0.88	7.5	23.5
Year	9.07	3.22	1.70	31.8	23.5

Ref. NOAA, 1984.

Table 3.4 Precipitation data for the period 1976 through 1985 at Paradox, Colorado

Month	Precipitation (in.)			Snowfall (in.)	
	Average	Greatest monthly	Greatest daily	Average	Greatest monthly
Jan	1.33	3.03	0.93	12.4	23.5
Feb	1.13	2.86	0.62	5.2	19.0
Mar	1.56	2.53	0.70	2.1	7.0
Apr	1.04	1.92	0.80	1.4	11.0
May	1.54	3.15	0.65	0.3	3.0
Jun	0.77	2.02	1.25	0.0	0.0
Jul	1.72	3.06	1.80	0.0	0.0
Aug	1.41	2.55	0.22	0.0	0.0
Sep	1.76	3.68	1.60	0.0	0.0
Oct	1.84	4.88	2.12	0.0	0.0
Nov	1.37	3.20	1.30	3.9	7.5
Dec	1.04	2.86	1.27	5.6	16.5
Year	16.51	4.88	2.12	30.9	23.5

Ref. NOAA, 1986.

3.2 AIR QUALITY

The Slick Rock sites are located in Colorado Air Control Region 10. The closest Colorado air monitoring station is in Montrose, Colorado and only total suspended particulates (TSP) are monitored at this station (CDH, 1985). In addition, nine months of ambient TSP data are available from Disappointment Valley. A geometric mean of 19 micrograms per cubic meter (mg/m^3) was calculated from this site. The highest 24-hour mean was 155 mg/m^3 while the second highest 24-hour reading was 107 mg/m^3. The nine month geometric mean is much less than the Federal and state primary and secondary standards (Table 3.5). However, the highest 24-hour reading exceeded the secondary standard. This 24-hour standard was exceeded only once which is permissible under law. The high 24-hour TSP readings were associated with periods of high wind (Pioneer, 1979). The Slick Rock area is considered in attainment for TSP and the other EPA priority air pollutants.

None of the remaining EPA priority air pollutants (sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, and lead) were measured at or near Slick Rock. However, these pollutants, except ozone, are measured in Grand Junction approximately 100 miles north of the Slick Rock sites. Ozone is monitored in the Denver-Fort Collins-Colorado Springs area. The levels of these five pollutants are expected to be very low due to the remote nature of the sites. The gas sweetener plant next to the UC pile releases hydrogen sulfide occassionally but does not release any of the above EPA-monitored pollutants (Stockings, 1987a).

Table 3.5 National and Colorado standards for ambient air quality[a]

Pollutant	Averaging time	Primary standard		Secondary standard
Sulfur dioxide, National	Annual arithmetic mean	80		—
	24-hour[b]	365		—
	3-hour[b]	—		1,300
		Category I (incremental)	Category II (incremental)	Category III (incremental)
State	Annual arithmetic mean	2	10	15
	24-hour maximum[b]	5	50	100
	3-hour maximum[b]	25	300	700
		Primary standard		Secondary standard
Total suspended particulates[c,d]	Annual geometric mean	75		60[e]
	24-hour[b]	260		150
Carbon monoxide[c,d]	8-hour[b]	10,000		10,000
	1-hour[b]	40,000		40,000
Ozone	1-hour[c]	235		235
	1-hour[d]	160		—
Nitrogen dioxide[c,d]	Annual arithmetic mean	100		100
Lead[c]	Calendar quarter arithmetic	1.5		1.5

[a]All concentrations are in micrograms per cubic meter.
[b]Not to be exceeded more than once per year.
[c]National Ambient Air Quality Standard.
[d]Colorado Ambient Air Quality Standard.
[e]An annual geometric mean of 60 micrograms per cubic meter has been established by the State of Colorado as a guide to be used in assessing implementation plans to achieve compliance with the 24-hour standard.

Ref. 40 CFR Part 50; CAQCC, 1979.

3.3 SURFACE AND SUBSURFACE FEATURES

The Slick Rock sites are located in the northeastern part of the Colorado Plateau physiographic province, near its boundary with the Southern Rocky Mountains province. To the west of the site lies the Canyonlands section of the Colorado Plateau province. The eastern part of the Canyonlands section is characterized by large-scale folds, unwarped plateaus, lava-capped mesas, deep, narrow river canyons, and laccolithic mountains (Hunt, 1974). To the north lies the Uncompahgre Plateau region of the Colorado Plateau which is bounded to its south by parallel, northwest-trending anticlines and synclines containing thick salt deposits. Little faulting is associated with these structural upwarps and basins except in the faulted anticline region south of the Uncompahgre Plateau.

The Slick Rock region consists of a high plain rising gradually from the southwest to the gently arched Dolores anticline (Shawe et al., 1968). Northeastward of the northeast limb of the fold, the land surface drops to a relatively low elevation along the synclinal Disappointment Valley. The land surface is deeply incised by the antecedent generally northflowing Dolores River, and deeply dissected by tributary stream canyons. Principal physiographic elements within the study area include the Dolores River Valley, the San Juan River Valley, the La Sal, Abajo, and San Miguel Mountains, and the Uncompahgre Plateau (Figure 3.1). Collapsed salt anticline features include the Paradox, Lisbon, Gypsum, and Spanish Valleys.

Figure 3.1 Physiographic features in the region of the Dolores River drainage basin

REF: FROM HUNT, 1974.

FIGURE 3.1
PHYSIOGRAPHIC FEATURES IN THE REGION OF THE DOLORES RIVER DRAINAGE BASIN

Lithologic units underlying the Slick Rock region range from a Pre-cambrian basement complex (2000 to 4000 feet below MSL) to a thick sequence of marine and continental rocks of Cambrian to Cretaceous age, overlain by igneous rocks of Tertiary age and unconsolidated Quaternary deposits (Figure 3.2). Unconsolidated sediments in the region consist of terrace gravels, mudflows, landslides, alluvial fans, soil, colluvium, talus, and floodplain deposits.

Slick Rock tailings sites

The geologic formations underlying the sites are the Dolores River alluvium, the Entrada Sandstone, and Navajo Sandstone. The Dolores River alluvium is approximately 15 to 30 feet thick beneath the sites; the alluvial deposit under the UC site has lateral dimensions of approximately 2400 by 600 feet while the deposit under the NC site is approximately 2400 by 300 feet. The Entrada Sandstone is laterally extensive and outcrops in the area of both tailings piles. It persists to depths of approximately 55 to 155 feet below land surface. The Navajo Sandstone is fine grained and relatively homogenous and occurs at depths between 55 and 155 feet below land surface in the area of the tailings piles. The proposed disposal area is underlain by the Entrada Sandstone. This formation extends approximately 60 feet below the site and is underlain by the Navajo Sandstone.

Known economically important mineral resources in the region are limited to uranium and vanadium ores and oil and gas deposits. The Slick

Figure 3.2 Generalized composite statigraphic section of the Slick Rock, Colorado region

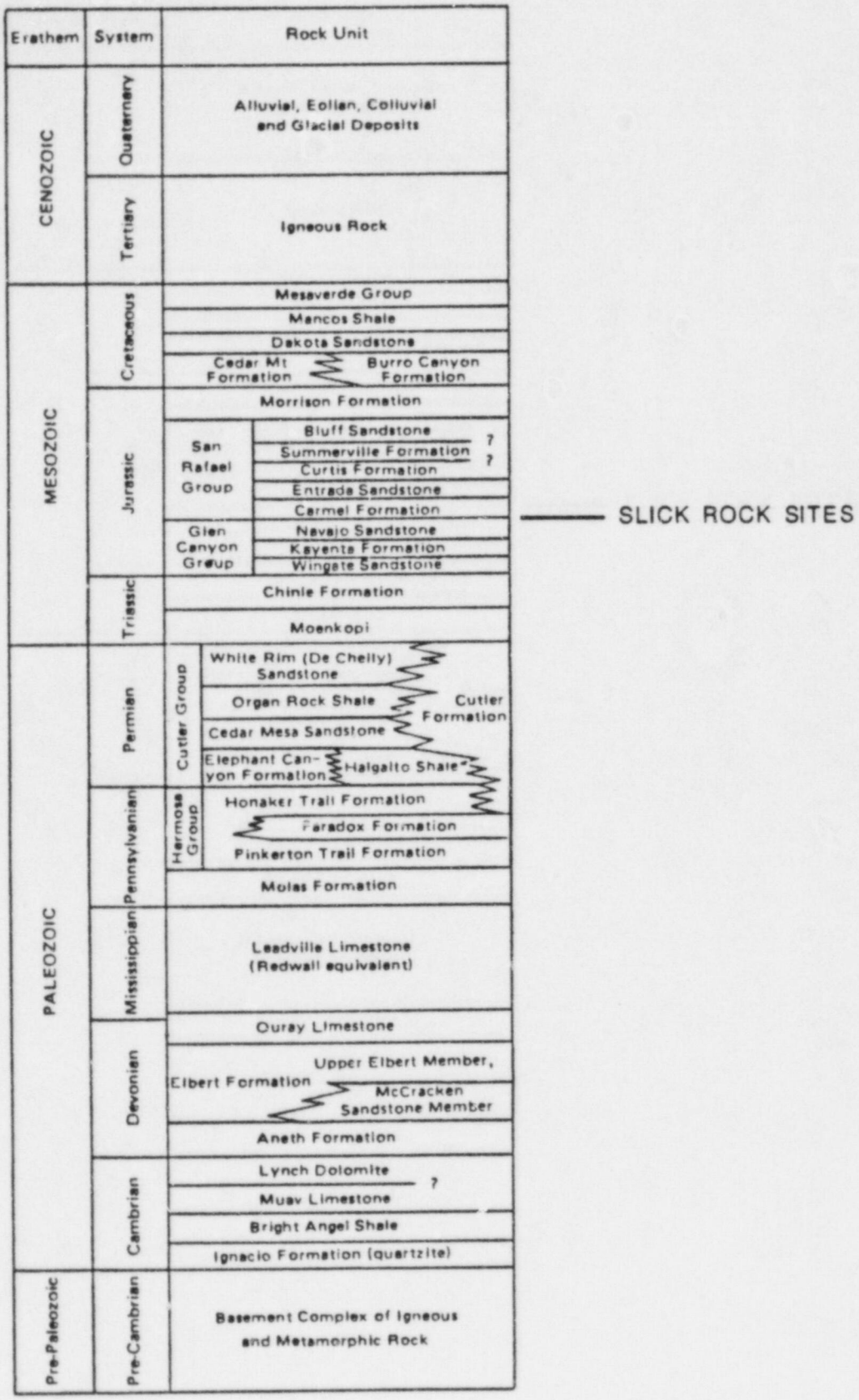


FIGURE 3.2

GENERALIZED COMPOSITE STRATIGRAPHIC SECTION OF THE SLICK ROCK, COLORADO REGION

Rock area has been extensively mined for uranium and vanadium and ore bodies are still present in the area. Mining of these resources has not taken place in the Slick Rock area in recent years. No known oil or gas deposits occur in the Slick Rock tailings piles area.

Borrow sites

The Dolores River borrow site would be the source of erosion protection material and is located on an alluvial terrace of the Dolores River. Deposits of gravels, cobbles, and boulders are structurally similar to the modern channel gravels. This site is underlain by the Entrada and Navajo Sandstones.

The Disappointment Valley borrow site would be the source of radon barrier material. This site has a variable depth of loose, brown, dry, sandy, silty clay overlying hard, dark green-gray, fissile Mancos Shale. The depth of this overlying material ranges from approximately one foot along the northern portion of the central drainage to twelve or thirteen feet in the southwest portion of the site. The northwest corner of the site also exhibits up to ten feet of this sandy clay.

Seismicity

The Slick Rock sites are located near the northeast edge of the Colorado Plateau physiographic provinces. Earthquakes are rare in this province and seismicity of the interior portion of the province has been

characterized as very low level (Wong, 1984). The largest instrumentally recorded earthquakes have ranged from 4.5 to 5.0 on the Richter Scale. A detailed analysis indicated that there are no indications of any capable faults in the area of the sites. No faults pass through the existing tailings piles or the proposed disposal site. The closest mapped fault lies approximately 0.6 mile from the sites and has showed no indication of Quaternary movement. Geologic and geomorphic evidence indicates no evident potential for on-site fault rupture for at least 1000 years.

3.4 WATER

3.4.1 Surface water

This section describes the regional surface-water regime, as well as surface-water conditions at the tailings and borrow sites. A detailed discussion of surface-water features, flood analysis, and surface-water quality, uses, and classifications is contained in Section B.1 of Appendix B, Hydrology.

Regional conditions

The Slick Rock tailings sites and borrow sites are in the Dolores River basin. The Dolores River originates in the western San Juan Mountains near Hermosa Peak. Elevations in the basin

vary approximately 5400 feet above MSL at the site to over 12,000 feet above MSL at the headwaters. Major tributaries to the Dolores River include the West Dolores River, Lost Canyon Creek, and Disappointment Creek upstream of the tailings sites and the San Miguel River downstream of the sites. The Dolores River drains into the Colorado River approximately 10 miles west of the Colorado-Utah state line.

The Dolores River near the Slick Rock sites flows in a deeply incised canyon between steep bluffs and sheer cliffs of sandstone and shale. The channel consists of a series of broad meander loops connected by short straight stretches where the outside of successive meander loops shifts from one bank to the other. The meander loops have terraces arranged in a step-line fashion on the inside of the loop and a sheer bedrock escarpment on the outside. The current is, therefore, directed against bedrock over most of its length and is relatively fixed. Channel shifting of the river may occur; however, it would be confined between the terraces and bedrock escarpments.

Most major flow events on the Dolores River occur during the spring or early summer as a result of snowmelt or the combination of snowmelt and rainfall events. The largest recorded discharge from the Dolores River was 10,000 cubic feet per second (cfs) recorded in October, 1911, approximately 67 miles upstream from Slick Rock.

Since March, 1984, McPhee Reservoir, which is approximately 55 river miles upstream of the sites, has regulated the flow on the river. Maximum release from the dam typically occurs from March through June. Average maximum release is 4000 cfs with a peak release of 4400 cfs in May, 1986 (as a comparison, the 100-year flood event is expected to yield 82,500 cfs). The required minimum release from McPhee Reservoir is 80 cfs which usually occurs during the late summer into the winter. In general, discharge from McPhee Reservoir is indicative of the average flows expected near Slick Rock since the tributary washes downstream of the dam a dry for the majority of the year. However, during periods of minimum discharge from the McPhee Reservoir, flow is often reduced to zero at Slick Rock.

The future potential for flooding and erosion of the tailings sites by the Dolores River is drastically reduced assuming proper maintenance and operation of the McPhee Dam. A static channel level should be maintained under the present flow patterns and the potential for significant aggradation or degradation of the level of the channel at Slick Rock appears to be fairly low.

The water quality of the Dolores River has not been affected by the two tailings piles. No significant increases or decreases in constituent concentrations were detected in the Dolores River from upstream of the NC tailings pile to downstream of the UC tailings pile. Ephemeral waters sampled near the tailings piles were high in calcium and bicarbonate and had elevated levels of radium-226, uranium and vanadium (DOE, 1983b).

Union Carbide site

The tailings pile at the UC site is in the modern floodplain of the Dolores River and ranges from 15 to 150 feet from the river bed. The site lies within a large meander loop of the Dolores River and is bordered by the river on the north, east, and southeast sides. A rock covered earthen dike was placed along the base of the pile next to the river to prevent erosion.

Ephemeral drainages near the UC site include the Summit Canyon Wash which joins the Dolores River approximately 1000 feet downstream of the site and Corral Draw which flows directly south of the site boundary (Figure 3.3). Prior to emplacement of the tailings at the UC site, Corral Draw flowed south of the pile location then northwest to join the lower reach of Summit Canyon Wash. Subsequently, the lower reach of the draw was channeled around a sandstone ridge to enter the Dolores River upstream of the tailings pile. At a later date, a diversion tunnel was cut through the bedrock ridge and Corral Draw waters were diverted through this tunnel and enter the Dolores River further upstream of the tailings pile than the first diversion. Ephemeral flows of Corral Draw are constrained within the main channel by banks composed of well cemented terrace gravels overlying sandstone bedrock. These units are resistant enough to erosion to prevent the encroachment of Corral Draw onto the UC designated site for at least 1000 years.

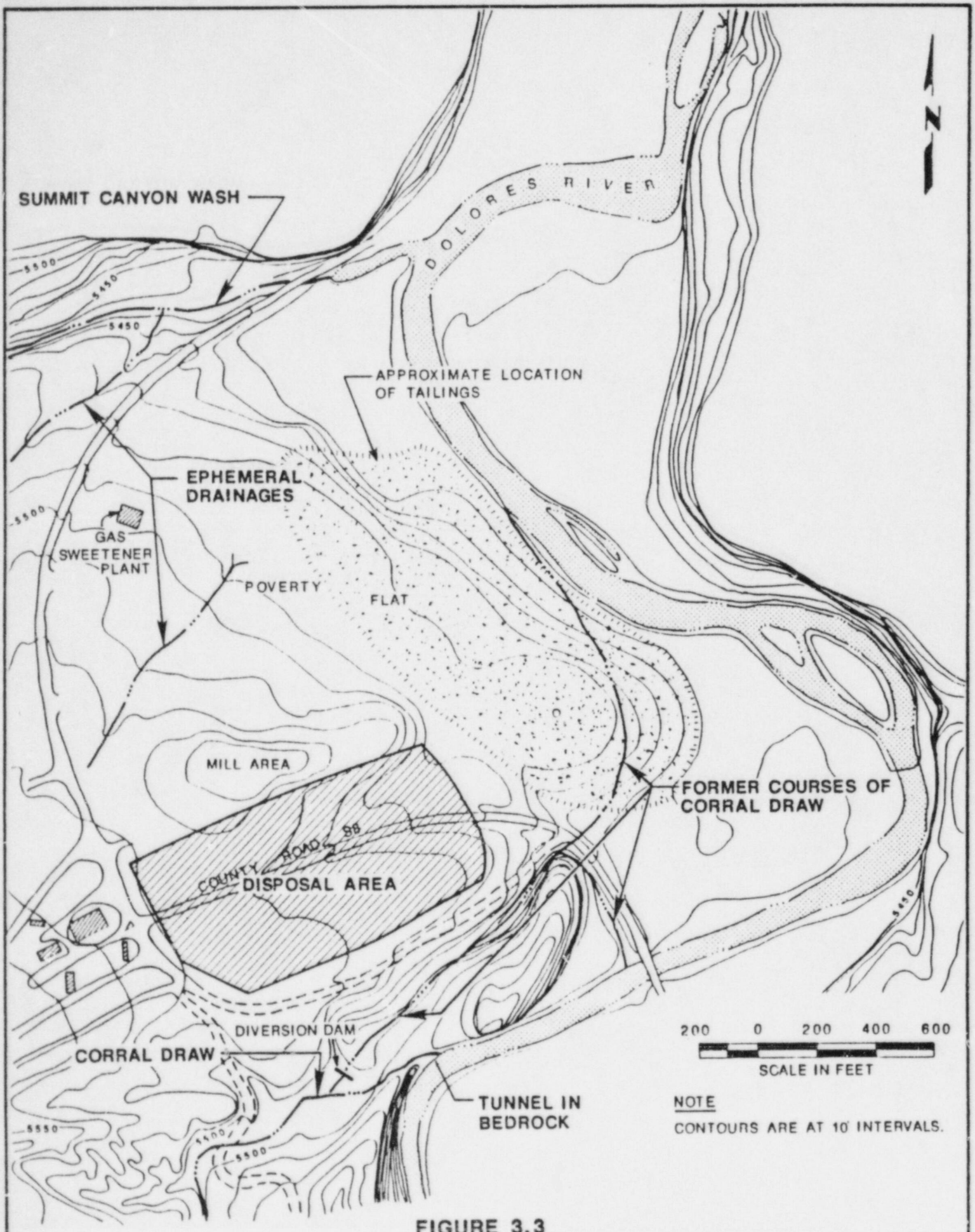


FIGURE 3.3
SURFACE WATER FEATURES, UNION CARBIDE SITE
SLICK ROCK, COLORADO

An ephemeral gully, which drains a small area of Poverty Flat, impinges on the site from the road southwest of the tailings pile and drains to the northwest and southeast. This shallow gully is between the mill site and the gas sweetener plant. A berm along the southwest side of the UC pile diverts surface water flow mainly to the northwest into the Summit Canyon Wash. The area west of the former mill site and north of Poverty Flat drains to a small ephemeral channel which flows approximately 250 feet west of County Road S8 and joins the Summit Canyon wash 600 feet north of the gas sweetener plant. Although the on-site washes are slightly gullied, no active arroyo formation is currently occurring. The UC tailings pile has a gently rolling, sparsely vegetated surface with a thin cover of grass. The cover materials are apparently subject to dispersion by wind, sheet wash, and ephemeral gullying, although the cover appears to be well maintained. No significant gullying is evident on the surface of the pile.

A 100-year flow of 84,200 cfs and a 500-year flow of 107,600 cfs were determined for the Dolores River at Slick Rock using methods described in Section B.1 of Appendix B, Hydrology. The results of this analysis indicate that the base of the UC tailings pile is within the 100-year floodplain. The maximum water level at the UC site during a 100-year event would vary from 5452 to 5446 feet above MSL along the pile. During a 500-year flood event, the water surface at the site would vary from 5456 to 5448 feet above MSL along the pile.

The estimated PMF of the Dolores River at Slick Rock was 410,000 cfs. This flood would require a floodway 850 to 1250 feet wide to convey flow past the UC site. The peak water surface elevation was estimated to vary from 5480 to 5466 feet above MSL along the pile. All floodplain boundaries are shown in Section B.1 of Appendix B, Hydrology.

North Continent site

The tailings pile at the NC site is approximately 1.7 river miles upstream of the UC tailings pile. The site lies in the modern floodplain of the Dolores River within a large meander loop and is bordered by the river on the west, north, and east sides.

The closest ephemeral stream to the NC site flows out of Hanks Pocket (See Figure B.1.2, Appendix B, Hydrology for its location) and drains into the Dolores River approximately 1500 feet downstream of the tailings pile. Surface runoff across the site is limited to overland flow resulting from precipitation events occurring on or immediately above the site. The tailings pile at the NC site is undergoing erosion from surface runoff, wind, downhill creep, and flooding of the Dolores River. The surface of this pile is partially vegetated and strongly gullied.

The outline of the tailings pile has been obscured by the effects of erosion, but portions of the contaminated area lie within the 100-year floodplain as shown in Section B.1 of Appendix

B, Hydrology. Water levels across the pile would rise to a maximum elevation of 5465 feet above MSL during a 100-year flood and 5467 feet above MSL during a 500-year flood event.

The water quality in the Dolores River and in ephemeral waters near the NC site would be similar for that described above.

Borrow sites

The Dolores River borrow site lies in the modern floodplain of the Dolores River between the UC and NC tailings sites. The borrow site is adjacent to the north bank of the river and south of CR-S8. No ephemeral channels cross the site or drain into the river near the site. Runoff across the site is limited to overland flow resulting from precipitation on the site and flows draining from the cliffs northeast of the site to the Dolores River.

The Disappointment Valley borrow site lies adjacent to an ephemeral tributary to Disappointment Creek. Discharge in the 1.5-square-mile drainage area of this ephemeral wash is primarily a result of summer thunderstorm events. Disappointment Creek has no flow at most times of the year with the majority of flow occurring from precipitation associated with summer thunderstorms. There are several small reservoirs and ponds along Disappointment Creek as well as small diversions for irrigation.

The quality of surface water in the vicinity of the Dolores River borrow site is as discussed for the tailings sites. Surface waters in the ephemeral washes near the Disappointment Valley borrow site as discussed in Section B.1 of Appendix B, Hydrology, are generally poor in quality and not potable due to high concentrations of total dissolved solids and chlorides.

Surface-water uses, classifications, and standards

Withdrawals from the Dolores River for agricultural purposes are minimal downstream from the Slick Rock sites to Bedrock, Colorado (45 miles) and upstream to McPhee Reservoir (55 miles). The State of Colorado has classified the Dolores River in the area of the Slick Rock sites as suitable for domestic water supply and for agricultural purposes. In addition, the state has rated the Dolores River as Class 1 recreational waters (i.e., suitable for swimming) and as a Class 1 for cold water aquatic life (CDH, 1986).

Agricultural use of the Disappointment Creek consists of several small ponds and limited diversions for irrigation. There are no users of the waters in the ephemeral wash that occurs near the Disappointment Valley borrow site. Based on the State of Colorado classification, Disappointment Creek and its tributaries are Class 2 recreational waters (i.e., waters suitable for activities that do not require primary contact) and are Class 2 warm water aquatic habitat (CDH, 1986).

3.4.2 Ground water

This section presents a summary of a more detailed analysis of the ground water at the Slick Rock sites which appears in Section B.2 of Appendix B, Hydrology. Ground water occurs in two distinct zones below the UC and NC tailings sites: the Dolores River alluvium and the Navajo Sandstone. These two water-bearing units are separated by an aquitard, the lower Entrada Sandstone.

Dolores River alluvium consists of a mixture of sand, gravel, and cobbles. The alluvium in the area of the sites is confined to the historic floodplain of the Dolores River and is incised into the underlying Entrada Sandstone. The UC tailings site rests upon an alluvial deposit with lateral dimensions of approximately 2400 by 600 feet and a depth of 25 feet; the alluvium underlying the NC tailings site has lateral dimensions of approximately 2400 by 300 feet and a depth of 25 feet. There appears to be little or no hydraulic communication between the discrete alluvial deposits.

The Entrada Sandstone outcrops near the sites and persists to depths of approximately 55 to 155 feet below land surface. This sandstone is reddish-brown, very fine-grained, and contains predominantly silt and clay-sized particles in the lower sections of the unit.

The top of the Navajo Sandstone occurs at depths between 55 and 155 feet below land surface and is of an undetermined total

thickness in the area of the tailings sites. The Navajo Sandstone is light reddish-brown, massive to thinly-bedded, and fine grained. This unit contains ground water and supplies the total domestic water needs of the area.

The top hydrostratigraphic unit for this investigation is considered to be the Dolores River alluvium. Ground water occurs under unconfined conditions at depths between approximately seven to 20 feet below land surface A paleochannel of the Dolores River was identified in one monitor well borehole and several geotechnical borings, approximately 1000 feet west of the UC tailings pile and 40 to 60 feet above the present river channel.

The middle hydrostratigraphic unit is interpreted as the lower section of the Entrada Sandstone. This unit is generally unsaturated, except immediately below the Dolores River alluvium and immediately above the Navajo Sandstone. The Entrada Sandstone contains considerable silt and clay in the lower sections and serves as an aquitard and confining layer for the underlying Navajo Sandstone.

The bottom hydrostratigraphic unit encountered in this investigation is the Navajo Sandstone. Ground water under confined conditions was encountered in every borehole which penetrated this unit.

Ground-water movement

The water table in the Dolores River alluvium ranges from approximately seven to 20 feet below land surface and at both the NC and UC sites, slopes from the upstream Dolores River - alluvium contact toward the downstream extent of the alluvium. Alluvial ground water is recharged by the river at the upstream aquifer boundaries and is discharged into the river in the downstream portions of the alluvial aquifers.

Ground-water flow within the Navajo Sandstone is toward the north and northeast. An upward hydraulic gradient exists within the Navajo Sandstone, relative to the overlying alluvium, and was calculated as approximately 0.18 feet per foot. This upward hydraulic gradient inhibits the downward migration of tailings seepage into the Navajo Sandstone. Calculated hydraulic characteristics of both the alluvial and Navajo Sandstone aquifers presented in Table 3.6.

Water quality

The uncontaminated alluvial ground water is classified as a Ca^{-}, Na-SO_4 type water and is fresh to slightly brackish in quality, with a mean total dissolved solids content of 1185 milligrams per liter (mg/l). Most background samples are essentially neutral with pH values near 7.0.

The only Primary Drinking Water Standard exceeded by the alluvial background samples was a minor exceedence of the standard for chromium at well 505. The Secondary Drinking Water Standards for manganese and total dissolved solids was exceeded by every alluvial background sample. The secondary standard for sulfate was exceeded by all but one alluvial sample, as was the proposed Health Advisory Level for uranium (0.015 mg/l natural uranium).

Table 3.6 Calculated hydraulic characteristics, Slick Rock, Colorado tailings sites

	Well number	Hydraulic conductivity (feet per year)	Hydraulic gradient	Effective porosity[a]	Flow rate (feet per year)
	Alluvium				
Minimum	503	124.0	8×10^{-3}	0.50	2.0
Geometric mean	—	2780.0	8×10^{-3}	0.39	57.0
Maximum	501	12785.0	8×10^{-3}	0.25	409.1
	Navajo Sandstone				
Minimum	670	2.5	2×10^{-2}	0.35	0.1
Geometric mean	—	10.2	2×10^{-2}	0.30	5.0
Maximum	690	63.0	2×10^{-2}	0.25	5.0

[a]Porosity for the alluvium (Freeze and Cherry, 1979) and for the Navajo Sandstone (Cooley et al., 1969) are assumed to equal effective porosity.

The secondary standard for iron was exceeded by samples from wells 503, 504, 505, 506, and 507. The secondary standard for chloride was exceeded by samples from wells 503, 504, and 506, while samples from wells 508 and 510 exceeded the secondary standard for nitrate.

The background samples of the uncontaminated ground water of the Navajo Sandstone show it is classified as a $Ca-HCO_3$ type water and is fresh water quality. The average total dissolved solids content is 368 milligrams per liter and the waters are neutral to slightly alkaline. Wells 669 and 670, exhibit pH values higher than the other Navajo Sandstone wells; these elevated pH values are probably due to incomplete initial development of the wells. This conclusion is supported by the drop in pH values by two units during the five-month period between sampling of these two wells.

The Primary Drinking Water Standards for silver was exceeded by samples from wells 634 and 668. The Secondary Drinking Water Standards are exceeded in a few instances for the Navajo Sandstone water samples. Samples from wells 634 and 687 exceeded the secondary standard for TDS. Samples from wells 669, 670, and 687 exceeded the secondary standard for manganese (Table 3.7).

Alluvial ground water present below and downgradient of the UC tailings pile has been affected by tailings seepage. The highest concentrations of contaminants below the UC pile, relative to background concentrations, are exhibited by nitrate, manganese, and iron. Other contaminants exceeding drinking water standards are chloride, sulfate, total dissolved solids and uranium.

Table 3.7 Exceedences of water quality standards in the alluvium and Navajo Sandstone monitor wells at the Slick Rock sites, Slick Rock, Colorado

	EPA primary standard[a]	EPA secondary standard[a]	Exceedences at monitor wells	
			Alluvium	Navajo Sandstone
Arsenic	0.05		None	None
Barium	1.0		None	None
Cadmium	0.01		None	None
Chloride		250.0	503, 504, 506	None
Chromium	0.05		505	None
Copper		1.0	None	None
Gross alpha[b,c]	15		NA[f]	NA[f]
Iron		0.3	503, 504, 505, 506, 507	None
Lead	0.05		None	None
Manganese		0.05	All wells	669, 670, 687
Mercury	0.002		None	None
Nitrate	44		508, 510	None
pH[d]	6.5-8.5		None	669, 670
Radium-226 + Radium-228[b]	5.0		None	None
Selenium	0.01		None	None
Silver	0.05		None	634, 668
Sulfate		250.0	All wells, except 686	None
Total dissolved solids		500	All wells	634, 687
Uranium[e]	0.015		All wells, except 684	None
Zinc		5.0	None	None

[a]Units in mg/l except where otherwise noted.
[b]picocuries per liter.
[c]Excluding uranium and radon.
[d]Standard units.
[e]Health advisory level.
[f]NA = Not analyzed.

Alluvial ground water present below and downgradient of the NC tailings pile has also been affected by tailings seepage. The highest concentrations of contaminants below the NC pile, relative to background concentrations, are exhibited by chloride, iron, and uranium. Other contaminants exceeding drinking water standards are manganese, sulfate, and total dissolved solids.

Summary

Tailings-related contamination exists within the alluvium beneath and for a distance downgradient of both the UC and NC tailings piles. Contamination is present at each site over the full vertical extent of the alluvium, approximately 25 feet, and persists downgradient for a distance of at least 1000 feet and 500 feet from the UC pile and NC pile, respectively. Tailings-related contamination was not detected past the limits of either alluvial aquifer, as indicated by the return to background water quality downgradient of each tailings pile. The vertical migration of contaminants into the underlying Navajo Sandstone aquifer is minimized by the upward vertical hydraulic gradient within this unit and the thick sequence of low permeability deposits which separates the contaminated alluvium from the uncontaminated Navajo Sandstone.

Water use

There are 11 registered wells within the general vicinity of the Slick Rock tailings sites (Figure 3.4). Nine of these wells (2133F, 2135F, 2163F through 2168F, and 15806F) are no longer in use and suffer from various states of disrepair. Well 2134F is completed within the Navajo Sandstone and supplies the total water supply for the residents of the Slick Rock trailer park. Well 15805F is also completed within the Navajo Sandstone and supplies the water for the Slick Rock post office and cafe. An unregistered well designated as well 672 for inventory purposes, also is completed within the Navajo Sandstone and supplies water for a local resident. In summary, there are no known users of potentially affected ground water in the area of the Slick Rock tailings sites.

3.5 FLORA AND FAUNA

This section presents a summary of a more detailed analysis of the flora and fauna at the Slick Rock sites which appears in Appendix C, Flora and Fauna.

The Slick Rock sites are located in the Great Basin sagebrush habitat of the Colorado Plateau. The tailings piles are near the Dolores River and the surrounding steep slopes are dotted with junipers and desert shrubs. The riparian zone along the river is dominated by shrubs with occasional small clumps of cottonwood.

Figure 3.4 Location of registered wells in the area of the Slick Rock, Colorado tailings sites

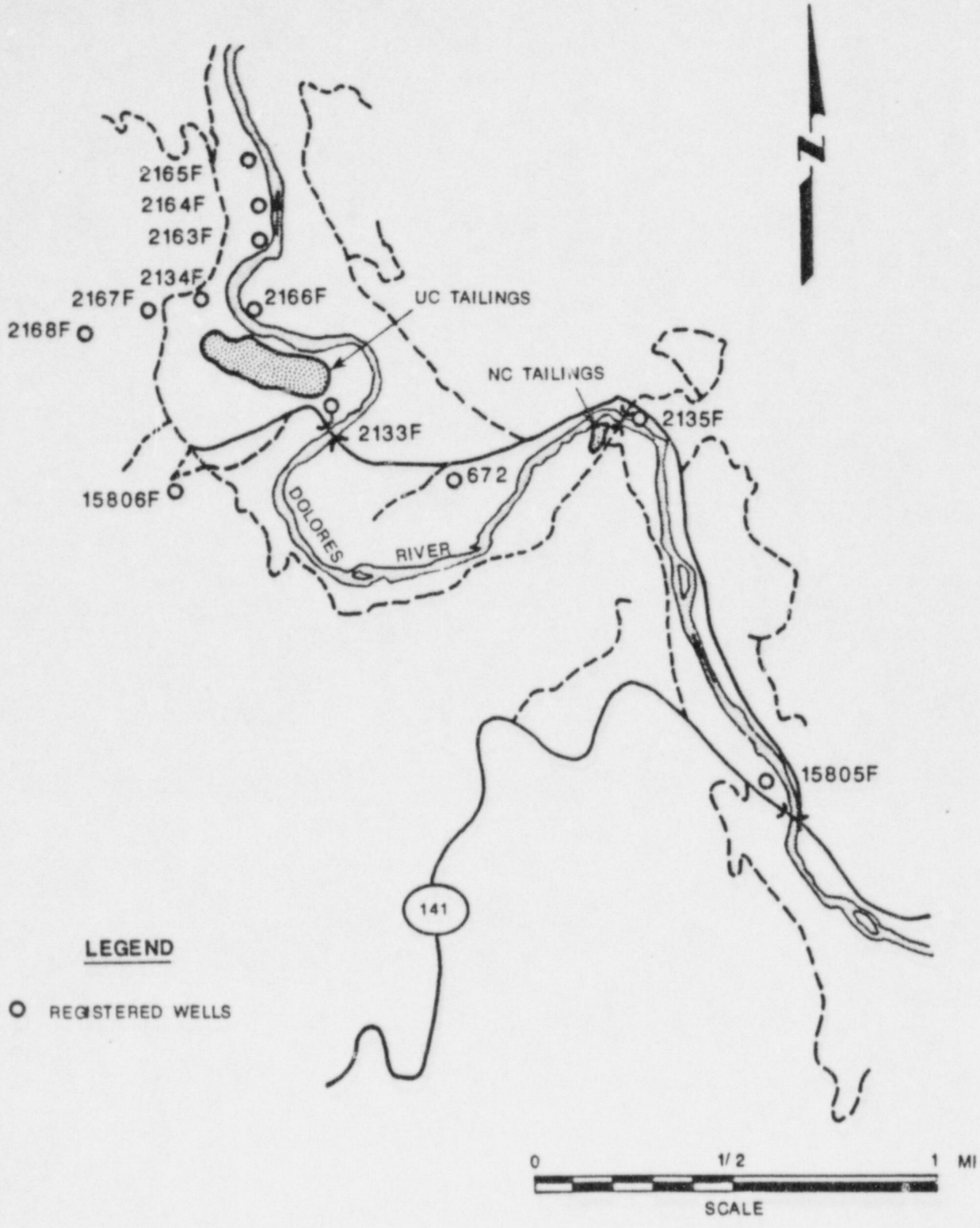


FIGURE 3.4

REGISTERED WELLS IN THE VICINITY OF THE SLICK ROCK, COLORADO TAILINGS SITES

Slick Rock tailings sites

The Slick Rock tailings sites include the two tailings piles and associated windblown and waterborne contaminated areas. Three plant community types were observed in this area; disturbed grassland, desert-shrubs, and riparian. The first type occurred on disturbed areas such as the tailings piles which are characterized by extensive areas of bare ground; grass was the dominant cover type. Scattered shrubs such as fourwing saltbush and rabbitbrush occur in these areas with shrub density being greatest on the NC tailings pile. The desert-shrub habitat is characterized by scattered sagebrush, rabbitbrush, and broom snakeweed. Patches of grass and herbs were the predominant ground cover. The third plant community type consists of riparian vegetation along the Dolores River (see Figures C.1.1 and C.1.2, Appendix C, Flora and Fauna). This type consists of four subtypes with dense willow/saltcedar shrub habitat occurring next to the river. Further back from the river were areas dominated by grass and scattered shrubs such as big sagebrush, greasewood, squawbush, saltcedar, and Russian olive. Another subtype in this area had a much higher frequency of shrubs (principally big sagebrush and greasewood) with a dense ground cover mostly of grass. The remaining subtype was dominated by fairly large cottonwood. The ground cover (mostly grass) was dense and shrubs such as squawbush, big sagebrush, and box elder were scattered throughout.

Fisheries data indicate that approximately nine species of fish occur in the Dolores River (see Table C.1.2 in Appendix C, Flora and Fauna). The majority of fish in the river are non-native species. The

flow characteristics of the river have been drastically altered by irrigation withdrawals from McPhee Reservoir upstream of the site. This has resulted in lowered flows and warmer water temperatures which has promoted the increase of non-native fish species at the expense of native species.

Wildlife that occurs at this site is a mixture of species that occur in riparian and desert-shrub habitats (see Tables C.1.3 through C.1.5 of Appendix C, Flora and Fauna, for typical species). The sagebrush lizard and whiptail were common reptiles observed on the site. A total of 40 species of birds were observed on the site, the yellow-breasted chat, yellow warbler, lazuli bunting, and blue grosbeak were common species in the riparian zone. The only bird of prey known to nest in this area is the kestrel. Some 29 species of mammals may occur at or near the tailings site. Beaver sign (cuttings) were observed along the river and mule deer occur in the area.

Important game species habitat (i.e., big game wintering habitat) is not known to occur at or near the tailings site. In addition, it was determined that important habitat for threatened or endangered (T and E) species does not occur in this area. An occasional bald eagle may use the area in the winter. The peregrine falcon nested successfully in 1986 at a site approximately eight air miles from the site and have nested in the past at another site also approximately eight miles from the site. Peregrine falcons from these areas may occasionally occur at the Slick Rock sites.

Borrow sites

The plant community types at the Dolores River borrow site are cleared pasture dominated by grass and desert shrub dominated by species such as big sagebrush and rabbitbrush with clumps of grass being the most common ground cover. The Disappointment Valley borrow site is located on relatively flat terrain in desert-shrub habitat. Black greasewood was the most common species with widely scattered fourwing saltbush and rabbitbrush also observed.

Wildlife typical of desert-shrub habitat occurs at these borrow sites (see Appendix C, Flora and Fauna). The mule deer would be the most abundant game species at the Dolores River borrow site while the mule deer and an occasional pronghorn antelope and elk (in winter) may occur at the Disappointment Valley borrow site.

As with the tailings sites, an occasional wintering bald eagle and peregrine falcon may be observed near the Dolores River borrow site. An important wintering bald eagle nocturnal roost site is located approximately 1.5 miles south-southeast of the Disappointment Valley borrow site. Eagles from this area may occasionally feed at or near this site if food such as deer carrion is available.

Prairie dog colonies (potential black-footed ferret habitat) do not occur at or near the Dolores River borrow site. However, this species occurs in Disappointment Valley.

The long-billed curlew nests in arid grasslands and open brushy habitat. This habitat type may occur at the Disappointment Valley borrow site. The Paradox lupine occurs on soils derived from Mancos Shale. Appropriate habitat for this species may occur at the Disappointment Valley borrow site.

3.6 RADIATION

Background and existing radiation levels around and on the Slick Rock tailings sites are discussed below. Appendix D, Radiation, contains detailed discussions of radiation and radiation measurements relative to each Slick Rock site.

3.6.1 Background Radiation

Radioactive elements occur naturally throughout the air, water, soil, and rock of the earth. The concentrations of these radioactive elements vary greatly throughout the United States, and the concentrations of natural radioactive elements in the Slick Rock area are generally higher than the averages for other locations because of local uranium mineralization.

The background radiation exposure rate from both terrestrial and cosmic sources, measured at three feet above the ground, ranged from 10 to 20 microroentgens per hour (microR/hr) with an

average value of approximately 13 microR/hr (BFEC 1986; EG&G, 1982). Cosmic radiation (radiation from the sun and other sources external to the earth) contributes approximately five microR/hr of the background exposure rate at Slick Rock (EG&G, 1982).

The average outdoor background radon concentration around the Slick Rock area was measured at 1.5 picocuries per liter (pCi/l) with a range of 1.2 to 1.7 pCi/l (FBDU, 1977).

The average background soil radionuclide concentrations in the Slick Rock area, not influenced by the tailings, have been measured as 1.4 picocuries per gram (pCi/g) of Ra-226, three parts per million (ppm) total uranium, and 2.5 pCi/g of Th-230 (BFEC, 1986).

Background alluvial ground-water quality was characterized by chemical analyses of samples from seven wells. Two of the seven wells were analyzed for Ra-226 and showed concentrations of 0.2 and 0.1 pCi/l. These same two wells exhibited Th-230 concentrations of 0.5 and 0.0 pCi/l. Samples from all seven wells were analyzed for uranium. The range was 0.009 mg/l to 0.05 mg/l with an average of 0.03 mg/l (see Section B.2, Appendix B, Hydrology).

Analyses of ground-water samples obtained from wells completed within the Navajo Sandstone (a confined bedrock acquifer underlying both Slick Rock sites) indicate milling related contamination has not affected this aquifer. These samples had an

average Ra-226 concentration of 0.6 pCi/l and an average uranium concentration of 0.007 mg/l.

3.6.2 Radiation levels

The UC tailings pile covers 17 acres and has an average depth of 12.5 feet, an average Ra-226 concentration of 126 pCi/g, and about 1.3 feet of contaminated soil below the pile. The NC tailings pile and surrounding contaminated locations comprise an area of approximately 46.4 acres with an average depth of 1.3 feet and average Ra-226 concentration of 261 pCi/g (Figure 3.5).

The radon concentration by the UC and NC piles has not been measured. Measurements of radon flux on the UC pile ranged from less than one to about 130 picocuries per square meter per second (pCi/m^2s) with an average estimated at 70 pCi/m^2s while the NC pile ranged from about one to more than 700 pCi/m^2s with an estimated average of 240 pCi/m^2s (FBDU, 1981).

Gamma radiation surface exposure rates on the UC pile ranged from 76 to 113 microR/hr (BFEC, 1986). Across the rest of the site the surface exposure rate ranged from nine to 526 microR/hr. Elevated exposure rates are most common on the pile and in the ore storage areas. Elevated readings were also found in the southeast corner of the designated site where one of Madame Curie's radium mills was operated at the turn of the century. This 1.5-acre area

Figure 3.5 Aerial extent of Ra-226 soil concentrations exceeding 5 pCi/g at the Slick Rock tailings, Slick Rock, Colorado

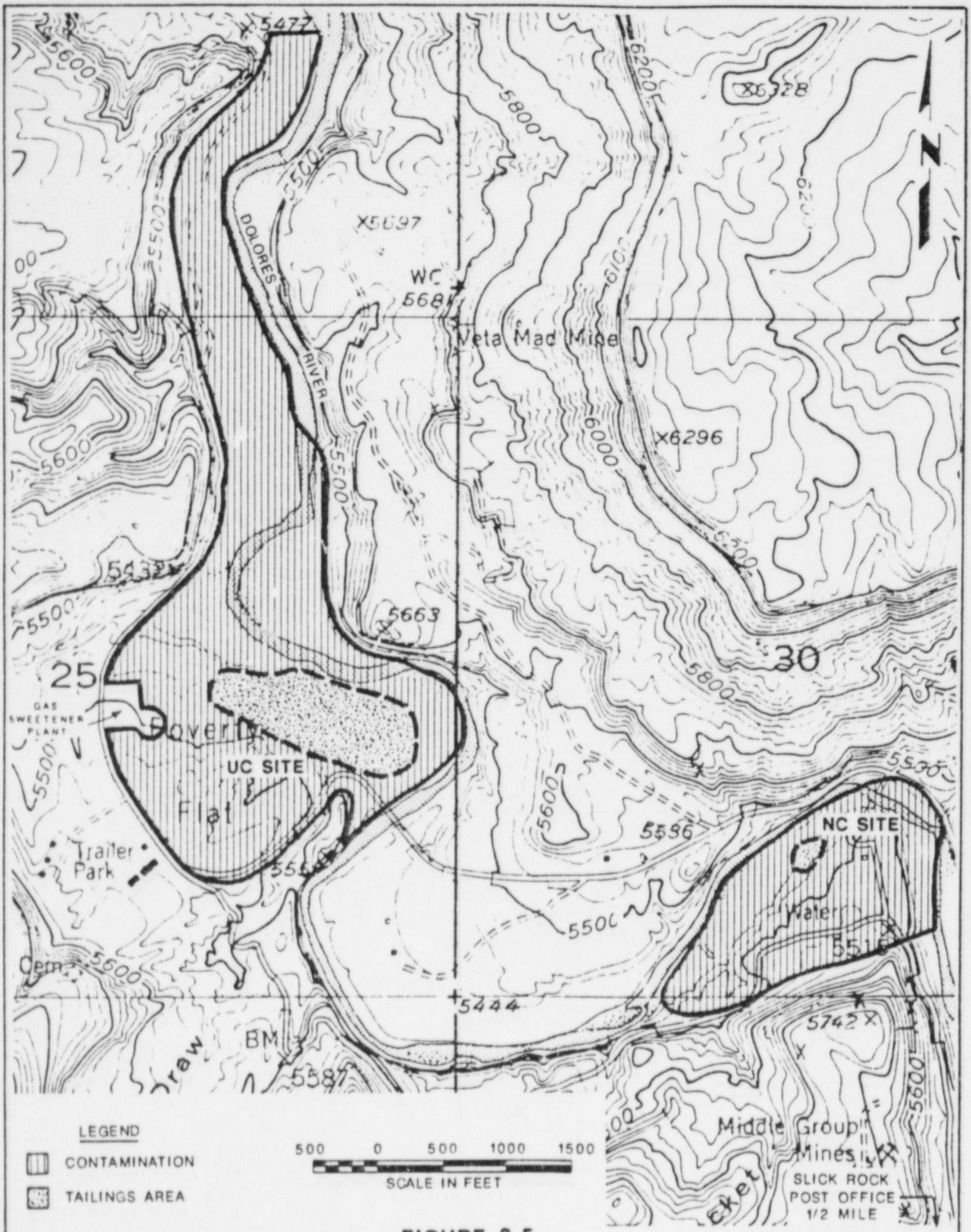


FIGURE 3.5

AREAL EXTENT OF Ra-226 SOIL CONCENTRATIONS EXCEEDING 5 pCi/g AT SLICK ROCK UC AND NC SITES - SLICK ROCK, COLORADO

had an average Ra-226 concentration of 222 pCi/g. Low-lying areas of the floodplain north of the site, on the west side of the river, and in the former mill area also had elevated readings. Measurements in the trailer park and around the gas sweetener plant were at or near background levels (BFEC, 1986; EG&G, 1982).

Gamma exposure rate measurements at the surface of the NC pile had a range of 13 to 467 microR/hr. The surface exposure rate ranged from 12 to 1384 across the rest of the NC site. Exposure rates were generally higher than those found at the UC site. Except for the east and west ends of the contaminated area, elevated readings were found uniformly throughout the floodplain. Additionally, several areas exhibiting elevated exposure rates were located above the pile in the former settlement and mill areas (BFEC, 1986).

Dispersion of the tailings by wind, and possibly water, erosion has contaminated soils around the site. A field survey of the designated tailings site and the immediate vicinity was conducted to determine the areal extent of the displaced tailings (BFEC, 1986). Surface (zero to six inches) Ra-226 concentrations exceeding six pCi/g were found in the river floodplain as far as two-thirds of a mile north of the UC site and about 1000 feet west-southwest of the NC site. Also, elevated Ra-226 was found over about 15 acres across the river immediately north of the UC site. No elevated Th-230 or uranium concentrations were found outside the UC or NC site boundaries.

Filtered surface-water samples were collected in 1983 from the Dolores River adjacent to the UC site and showed background concentrations of 0.6 to 1.0 micrograms per liter (mg/l) for dissolved uranium (DOE, 1983a).

Analyses of ground-water samples from wells near and downgradient of the pile indicate milling-related contamination within the alluvial aquifer. This contamination ends when the individual alluvial aquifer associated with each pile is truncated by the Dolores River. Four wells were sampled at the UC pile and showed uranium concentrations from 0.0139 to 0.199 mg/l. One sample showed 1.1 pCi/l Ra-226. Three wells sampled at the NC pile showed a range of uranium from 2.29 to 3.95 mg/l. One sample showed 2.4 pCi/l Ra-226.

Comparison of heavy metal and trace element concentrations at the UC and NC sites with background readings indicates that some of the values are considerably elevated. These would include copper, lead, cadmium, vanadium, selenium, arsenic, and molybdenum.

3.7 LAND USE

The Slick Rock tailings sites are in west-central San Miguel County, Colorado, less than 10 miles east of the Colorado-Utah state boundary. San Miguel County contains 823,680 acres; approximately 59 percent of the acreage is owned by the Federal Government, three percent is owned by the

state, and 38 percent is privately owned (Hickcox, 1987). Approximately 91 percent of western San Miguel County is rangeland and woodland that are used primarily for livestock grazing and timber production. Dry and irrigated croplands comprise seven and two percent of the land, respectively. Populated areas such as those around Slick Rock and Egnar comprise less than one percent of the western portion of the county (DOE, 1983b). Mineral exploration, extraction, and milling, primarily for uranium and vanadium, have been an important land use in western San Miguel County although the amount of land devoted to mineral activities fluctuates with market conditions (FBDU, 1981).

Slick Rock tailings sites

The UC and NC tailings sites are northwest of the unincorporated town of Slick Rock (Figure 3.6). The Dolores River and (CR-S8) pass immediately adjacent to both sites, and Colorado State Highway 141 (C-141) passes through Slick Rock southeast of the sites. Most of the land along the Dolores River in the vicinity of the tailings sites is privately owned. Both sites are on land owned by the Union Carbide Corporation; however, neither site is in use at the present time. Almost all of the surrounding land is administered by the BLM.

Most of the land around the Slick Rock tailings sites is vacant and used for low-density livestock grazing. Approximately 60 acres of cleared land and irrigated cropland adjacent to the Dolores River between the tailings sites are used for pasture and growing hay, respectively

Figure 3.6 Land use in the Slick Rock, Colorado area

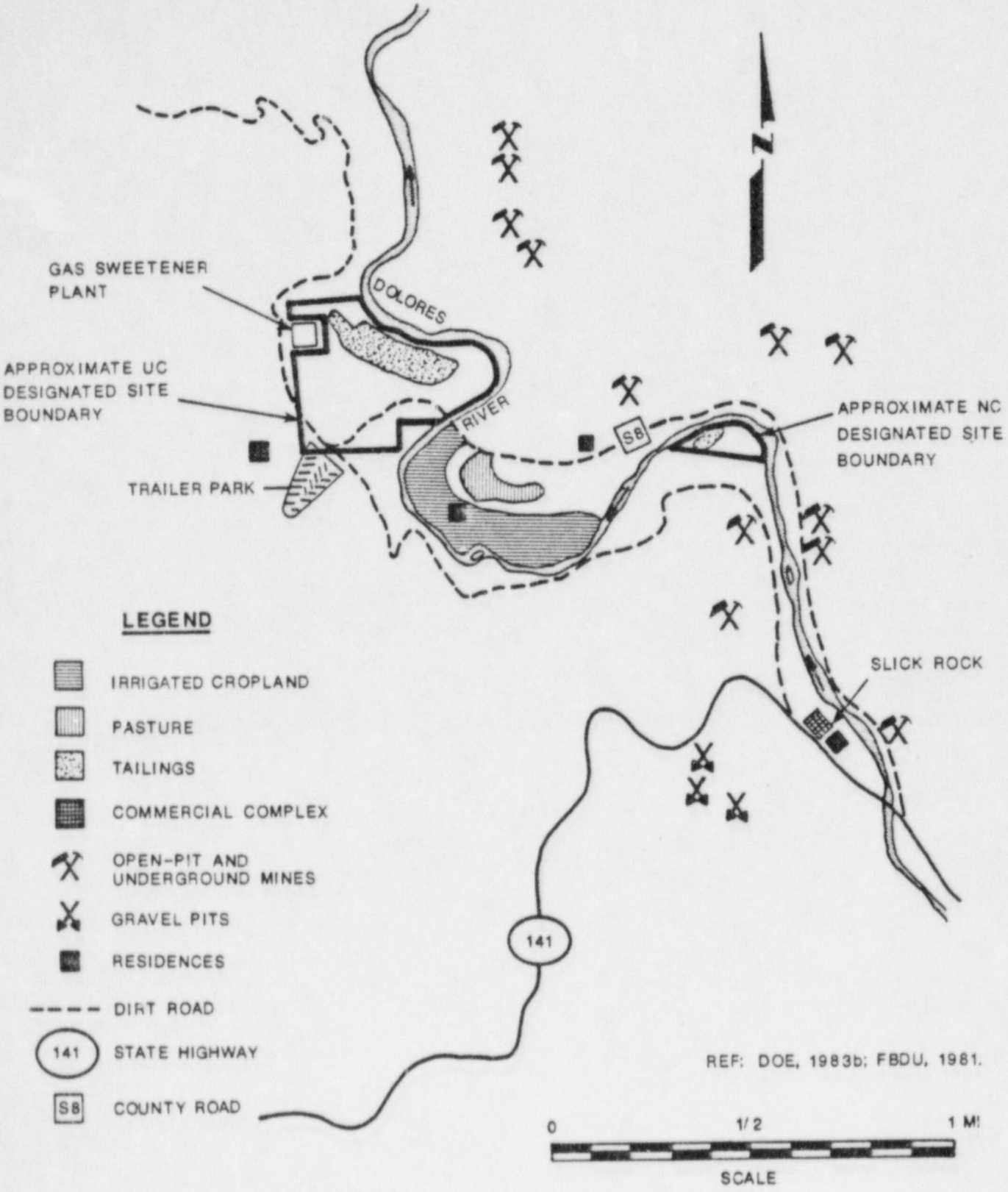


FIGURE 3.6
LAND USE IN THE SLICK ROCK, COLORADO AREA

(Figure 3.6). There are some scattered residences in the area with the only concentration of residences being the mobile home park southwest of the UC site; presently, only five trailers in the 60-unit park are occupied. There is a gas sweetener plant immediately adjacent to the UC site, and the only commercial complex is a single structure along C-141 in Slick Rock that contains a restaurant, liquor store, service station, post office, and a sheriff's office. There are numerous mines and gravel pits in the area; however, none of the mines or gravel pits are operating at this time.

Borrow sites

The Dolores River borrow site is on private land in pasture and desert shrub habitat adjacent to the Dolores River between the tailings sites. The land uses at and around the Dolores River borrow site are the same as those described for the tailings sites.

The Disappointment Valley borrow site is on land administered by the BLM. The land immediately west of the site is privately owned; land on all other sides of the site is administered by the BLM. C-141 is immediately south of the site, and the private land west of the site contains a dirt landing strip and a natural gas pipeline that runs northeast-southwest and connects with the gas sweetener plant adjacent to the UC tailings site (Flinn, 1985). Two forty-acre parcels just outside the site to the north and southeast have been withdrawn by the BLM for public water reserves (Bulinski, 1985).

The land at and around the site is used for low-density livestock grazing, and the site is within a BLM grazing lease that totals 17,255 acres. There are multiple unpatented mining claims at the site, and the site is within an existing BLM oil and gas lease (Hollis, 1987); however, there are currently no mineral nor oil and gas activities at the site.

3.8 AMBIENT NOISE

The major source of noise is C-141 which is approximately 1.0 air mile from the UC site and 0.5 mile from the NC site. Other sources of noise would emanate from the trailer park and gas sweetener plant near the UC site and the Dolores River. Considering the sparse population and the land use in the vicinity of the Slick Rock tailings sites, day-night sound levels (L_{dn}) are probably in the 35- to 40-decibel range on the A-weighted sound measurement scale (Table 3.8). This sound measurement scale aproximates the sensitivity of the human ear.

Table 3.8 Typical day-night sound levels

Land use	Population density (people per square mile)	L_{dn}[a] (decibels)
Rural, undeveloped	20	35
Rural, partially developed	60	40
Quiet suburban	200	45
Normal suburban	600	50
Urban	2000	55
Noisy urban	6000	60
Very noisy urban	20,000	65

[a]Day-night sound level (L_{dn}) is an EPA description of environmental sound. It is the average of daytime and nighttime A-weighted energy-equivalent sound levels with nighttime sound given a penalty of 10 decibels (dBA).

Ref. NAS, 1977.

In October of 1982, noise levels were measured at nine locations near the tailings sites (DOE, 1983b). Noise levels averaged 49 decibels at the mill area and in the center of the UC tailings pile. The noise level at the Slick Rock post office was measured at 72 decibels. The post office is next to C-141 which may explain this high reading. The noise level at the trailer park southwest of the UC site was measured at 44 decibels.

Borrow sites

Noise levels have not been measured at the Dolores River and Disappointment Valley borrow sites; however, noise levels at these sites are probably very similar to those at the tailings sites ranging from 40 to 60 decibels depending on the specific distance from Route C-141.

3.9 HISTORIC AND CULTURAL RESOURCES

The prehistory of the Slick Rock area began with the Proto-Historic Period, which ranged from 10,000 to 5,500 B.C. The people of this time were nomadic game hunters and are known for their distinctive weapons. The post-glacial Archaic Period replaced the Proto-Historic. These people were hunters and gatherers, who also grew corn and made pottery. This period lasted into historic times until the Utes left the area in the 1880s (BLM, 1982).

Settlers entered the region after the Utes were removed to reservations in 1881. The history of the area is influenced by ranching, farming, and mining. In addition, the later rise and fall of the uranium and vanadium industry also influenced the region (BLM, 1982).

A Class III cultural resource survey of approximately 260 acres conducted near the two tailings sites identified one ineligible (to the National Register of Historic Places) lithic scatter site, one eligible historic site, and two isolated finds (CASA, 1987).

The borrow sites have not been surveyed for cultural resources. Cultural resource field clearances conducted for test pit locations did not identify any cultural sites at these locations (CASA, 1986). It is expected that these locations will not contain cultural resources of importance.

3.10 SOCIOECONOMIC CHARACTERISTICS

At the present time, 23 people live within a 1.6 mile radius of the U.C. site. In addition, there are essentially no services or sources of supplies that would be required during remedial action in Slick Rock. For this reason, it is expected that the surrounding towns in southwestern Colorado in San Miguel, Dolores, Montezuma, and Montrose Counties and in San Juan County in western Utah (Figure 3.7) would be the source of workers and supplies for the remedial action. Therefore, the following discussion presents the general socioeconomic characteristics of southwestern Colorado and the adjacent portion of Utah.

Population and employment

The estimated population of San Miguel County in 1980 was 3192 (DOC, 1983a). Telluride is the county seat and the largest city in the county. It is a ski resort town which has been experiencing growth associated with the Telluride Ski Area (Larson, 1987) and is approximately 87 miles from Slick Rock. Telluride would probably not be a service center for

the remedial action due to its mountain location and distance from the site. There are four other towns in San Miguel County, all with less than 500 residents; only one of these, Egnar, is within a reasonable commuting distance (approximately 10 miles) of the Slick Rock sites.

Dolores County had a 1980 population of 1658 (DOC, 1983a); Dove Creek is the largest town and is approximately 18 miles from Slick Rock. It has an estimated 1987 population of 625. Many residents have left Dove Creek in recent years since the decline of the uranium markets (Dame, 1987).

Montezuma County is rural like the preceeding counties and Cortez is the county seat and largest town. In 1980, the population of Cortez was 7095 (DOC, 1983a) and by 1984, had increased to 7500 (Weaver, 1987). Most of the population change was due to energy developments related to carbon dioxide, oil and gas, and the construction of McPhee Dam. However, since the drop in energy markets in 1984 and the near completion of the McPhee Dam, many people have left due to the lack of other employment opportunities.

Montrose is the county seat of Montrose County and has an estimated population of 17,417 in 1987 (Warren, 1986). Total county population in 1980 was estimated at 24,352 (DOC, 1983a) and more recently updated to 25,570 in 1985 (Warren, 1986). The remaining towns in Montrose County are small; Naturita and Nucla had 1987 estimated populations of 729 and 827, respectively (Warren, 1986).

San Juan County, in adjacent Utah, had a 1980 census population of 12,253; Monticello, the largest town, had an estimated 1980 population of 1929 (DOC, 1983b). The Monticello area was hard hit by the decline in the uranium industry in 1981 and has declined in population due to out-migration related to losses in employment opportunity.

Dryland farming, ranching, and uranium mining have occurred historically throughout southwestern Colorado. In addition, exploration and development of carbon dioxide and oil and gas wells have diversified the economy of Montezuma County. The more mountainous western portions of Montrose, San Miguel, and Montezuma counties have different employment bases (e.g., government agencies in Montrose and skiing in Telluride), although ranching and farming also have provided a consistent source of livelihood in unincorporated areas. Overall, approximately 75 percent of all employment is in the private sector and 25 percent in the government sectors.

Unemployment trends are shown in Table 3.9. San Miguel's relatively stable unemployment figure reflects the Telluride Ski Resort growth, while Dolores county's relatively low unemployment rate indicates the relative stability of the farming base in the county. Unemployment in the western portions of these Colorado counties is thought to be higher than the overall county averages.

Table 3.9 Percent unemployment by county in the Slick Rock, Colorado area

	1980	1981	1982	1983	1984	1985
Dolores[a]	6.8	7.7	10.1	8.3	5.2	6.3
Montezuma[a]	7.7	7.5	11.4	8.6	10.1	10.9
Montrose[a]	7.7	8.0	12.3	11.4	11.6	12.1
San Miguel[a]	5.9	9.9	10.7	9.7	8.9	7.0
San Juan, Utah[b]	8.1	7.9	9.8	13.1	11.3	9.15[c]

[a]State of Colorado, 1986
[b]Humphry, 1985
[c]Webb, 1987.

The employment categories of greatest supply are likely in trades related to the construction and mining industries which have been depressed for several years. There are no proposed future projects in any of the counties (with the exception of the continued expansion of the Telluride Ski Resort) which would change the current unemployment trends.

Housing and services

Due to the out-migration of workers and families following the uranium and energy market declines in 1981 and 1984, there should be available vacant housing in most towns. Existing housing supplies and actual vacancy rates are unknown at this time.

The average family size in the five-county area is 3.47 (DOC, 1983a, b). School enrollments are below classroom capacity for all school districts in this five-county area reflecting the population changes which have occurred since 1981.

Emergency medical treatment at the Slick Rock sites would be under the jurisdiction of the San Miguel County Sheriff's department. Medical clinics are located in Telluride, Dove Creek, Naturita, and Norwood. If necessary, the Dolores County Sheriff's department would assist in a medical emergency until the San Miguel County Sheriff's department could respond. Air evacuation to Grand Junction is also available. Both Dolores and San Miguel counties have understaffed sheriff's departments. Due to these limitations, the Slick Rock tailings sites would receive little daily contact from county law enforcement officers.

Since it is unlikely that a large work force would come from any single area or would have an effect on any single town, county finances are not included in this discussion, although the general positive impacts to local economics will be addressed in Section 4.11.

3.11 TRANSPORTATION

Remedial action workers would access the tailings piles and all borrow sites by use of C-141. This is a paved, secondary, two-lane highway designed to carry between 4000 and 6000 vehicles per day in the vicinity of Slick Rock. At Slick Rock, the 1985 average daily

traffic (ADT) was recorded as 220 vehicles of all kinds. Peak hourly traffic is estimated at 24 vehicles (Gilbert, 1986).

Remedial action traffic would exit northwest from C-141 on to CR-S8. This paved, two-lane road would provide direct access to the UC and NC tailings piles and Dolores River borrow site. Existing traffic is minimal; an estimated five to six vehicles per day may use CR-S8 road. The pavement is considered in adequate condition for present use levels (Horner, 1986).

There were no recorded accidents of any type on C-141 or CR-S8 in the vicinity of Slick Rock. According to the Colorado State Highway Department (Gilbert, 1986), the Federal Aid Secondary Rural injury and fatal accident rates for the State of Colorado would provide a reasonable estimate of potential accidents on C-141; CR-S8 does not have a comparable rate based on similar county roads in the State of Colorado. The 1984 injury accident rate which would apply to C-141 was 0.78 per 1,000,000 miles of vehicle travel and the fatal accident rate was 3.83 per 100,000,000 miles of vehicle travel (Colorado Department of Highways, 1985).

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4.0 ENVIRONMENTAL IMPACTS

The environmental impacts of the proposed remedial action are discussed in this section. The impacts discussed for the proposed action represent a realistic upper limit of the severity of the impacts that may occur. The proposed action does not include remedial action at vicinity properties since none occur at the Slick Rock sites. However, if vicinity properties are identified at the Slick Rock sites at some future date, any associated impacts would be addressed in the programmatic environmental report (DOE, 1985a) and, therefore, would not need to be considered in this EA.

4.1 RADIATION

The following sections discuss radiation exposure pathways, the excess health effects that would result during and after the remedial action, and the health effects of construction related accidents that might occur. The procedures used to estimate excess health effects (i.e., cancers) are based on realistic but conservative assumptions. Appendix D, Radiation, contains detailed discussions of radiation exposure pathways and excess health effects calculations.

Exposure to gamma radiation may cause somatic health effects, which are manifested in the exposed individual, and genetic health effects which are manifested in the descendants of the exposed individual. The

genetic risk is approximately two-thirds of the somatic risk for gamma radiation, and a genetic health effect in general may be considered less severe. Measures taken to reduce the somatic health effects would also reduce the genetic effects. Therefore, the discussion of excess health effects reflects only somatic health effects.

4.1.1 Exposure pathways

There are five principal radiological pathways by which individuals could be exposed during the remedial action (Figure 4.1). These are (1) inhalation of radon and radon daughters; (2) direct exposure to gamma radiation; (3) inhalation and ingestion of and submersion in, airborne radioactive particulates; (4) ingestion of contaminated foods produced in areas contaminated by tailings; and (5) ingestion of ground and surface waters contaminated with radioactive materials. For the calculation of excess health effects, only those pathways which would result in the largest radiological doses to the general public were considered in detail. As shown in Figure 4.1, these are inhalation of radon and radon daughters and direct exposure to gamma radiation. Section D.2, of Appendix D, Radiation, briefly discusses why the other pathways were not considered quantitatively.

Figure 4.1 Potential radiation exposure pathways to the general public and remedial action workers

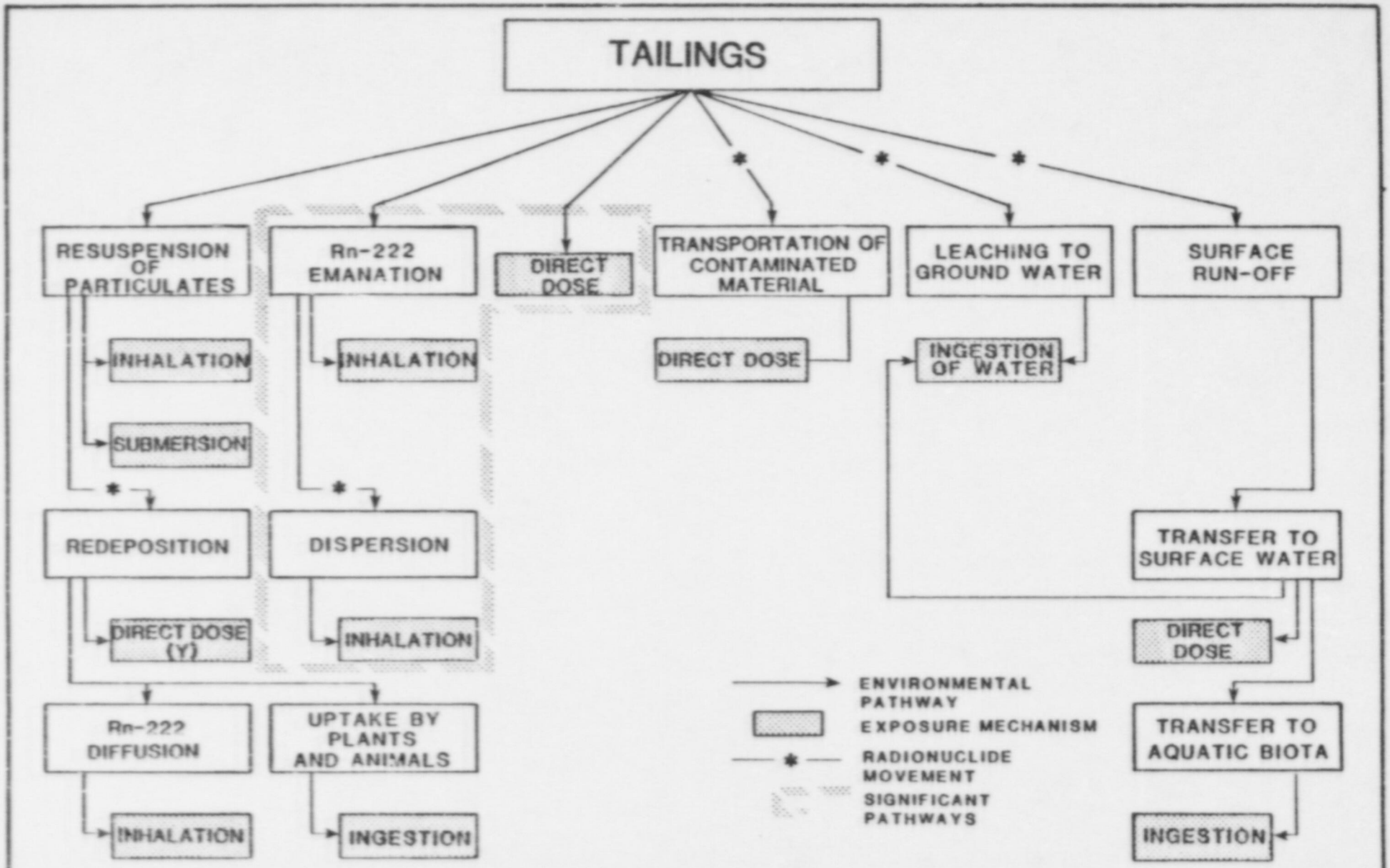

FIGURE 4.1

POTENTIAL RADIATION EXPOSURE PATHWAYS

TO THE GENERAL PUBLIC AND REMEDIAL ACTION WORKERS

Radon is an inert gas (i.e., does not react chemically with other elements) produced from the radioactive decay of Ra-226 in the U-238 decay series. As a gas, radon can diffuse through the tailings and into the atmosphere where it is transported by atmospheric winds over a large area. In the atmosphere, radon decays into its solid daughter products which attach to airborne dust particles and are inhaled by humans. These dust particles, with the radon daughter products attached, may adhere to the lining of the lungs and decay with the release of alpha radiation directly to the lungs.

Gamma radiation is also emitted by many members of the U-238 decay series. Gamma radiation behaves independently of atmospheric conditions and travels in a straight line until it interacts with matter. Gamma radiation emitted from the tailings delivers an external exposure to the whole body.

The general public may be exposed to radon daughters and direct gamma radiation from the uncovered Slick Rock tailings piles. Currently, there are no effective barriers to prevent continued dispersion and unauthorized removal and use of the tailings which could increase the general public's exposure to radon daughters and gamma radiation.

During remedial action, the radon daughters and gamma radiation exposure to the general public would increase as the tailings were disturbed. Remedial action workers would also be

exposed to these pathways during remedial action. Following remedial action, there would be no exposure to direct gamma radiation since the tailings would be covered with earthen material which gamma radiation could not penetrate. However, there would continue to be a small public exposure to radon and radon daughters following remedial action (within EPA standards) since the radon cover would not entirely eliminate this release. The earthen cover would have a very low permeability and most of the radon would decay into its solid daughter products before it could diffuse into the atmosphere.

4.1.2 Short-term health effects

Stabilization on site

Table 4.1 lists the estimated excess health effects that would occur during remedial action for the proposed action. Excess health effects were calculated separately for each site and summed.

Table 4.1 Estimated excess health effects during the proposed action at the Slick Rock, Colorado tailings sites

General public radon daughter health effects	General public gamma health effects	Remedial action worker radon daughters health effects	Remedial action worker gamma health effects	Total excess health effects
0.000046	0.00020	0.00092	0.00037	0.002

The percentage increase in radon released from the tailings during remedial action would be small relative to the radon released prior to remedial action because there are large radon fluxes from the existing tailings piles under present conditions. During remedial action, increases in gamma exposure rates and airborne radioactive particulate concentrations would be larger than the radon concentration increase compared to levels prior to remedial action. These increased exposure rates would be due to disturbance of the tailings. However, control measures (e.g., wetting) would be applied during remedial action to minimize airborne radioactive particulate concentrations.

The elevated gamma exposure rates during disturbance of the tailings would increase the excess health effects to the remedial action workers. The maximum risk to remedial action workers from inhalation of airborne radioactive particulates would be only a small percentage of the risk from exposure to radon daughters and gamma radiation. The airborne radioactive particulate exposure to the general public would be even less than the exposure to workers (DOE, 1985b,c; 1984a,b; 1983; Millard and Baggett, 1984). Exposure to gamma radiation would be the dominant exposure pathway for excess health effects to the general public.

The excess health effects to the general public during remedial action are principally dependent on the amount of tailings and contaminated materials to be moved and the number of people who live nearby. The estimated excess health effects are

very small in comparison to the natural incidence of cancer. For example, the proposed action would result in a total of 0.0003 general public excess health effects during the remedial action based on the present population distribution in the vicinity of the Slick Rock tailings sites. This is a 0.001 percent chance (based on an exposed population of 24 people) of contracting a cancer due to radiation from the tailings sites or approximately one chance in 100,000. In the U.S. population an individual has a 16 percent or one in six lifetime chance of contracting fatal cancer (NAS, 1980). This would mean that approximately four of the 24 persons who live within a 1.6 mile radius of the Slick Rock tailings sites would be expected to die of cancer induced from causes other than the tailing piles.

No action

The no action alternative would result in a total of 0.0003 estimated excess health effects per year to the general public. Of this total, radon daughter health effects would contribute 0.000039 (16%) and 0.00021 (84%) would result from gamma exposure. This is not directly comparable to the total estimated excess health effects for the proposed action which were based on an 11 month period (eleven months were used because that is the approximate amount of time that the tailings would be disturbed and radon gas released). In addition, the total estimated excess

health effects for the no action alternative do not consider factors such as dispersion, population growth or unauthorized removal and use of the tailings which could lead to greater excess health effects than those calculated.

Disposal at the Section 36 site

Stabilization of the contaminated materials at the Section 36 site would be expected to result in fewer excess health effects to the general public from radon daughter exposure and gamma radiation exposure than the proposed action due to a lower average radon flux and the lack of an exposed population at the Section 36 site. The potential exists for increased gamma radiation exposure to the general public as a result of the transportation of the tailings to the Section 36 site. The excess health effects of this exposure pathway have been shown to be negligible at an UMTRA site in Wyoming (DOE, 1985a); this would also be the case for disposal of the Slick Rock contaminated materials at the Section 36 site. It would be expected that the total excess health effects to remedial action workers from radon daughter exposure and gamma radiation would be greater for this alternative than for the proposed action. This is because more workers would be required and those workers would be exposed at the Section 36 site along with the UC and NC sites; additional exposure would be incurred from transporting these materials to the Section 36 site.

4.1.3 Long-term health effects

Stabilization on site

As stated previously, there would be no exposure to direct gamma radiation after remedial action because the earthen cover would reduce gamma radiation from the stabilized pile to approximately background levels. This cover would also ensure that radon releases would be no greater than allowed by the EPA standard. These releases would result in very small yearly excess health effects (Table 4.2) for persons living in the area of the stabilized pile.

Table 4.2 Estimated yearly excess health effects after the proposed action, Slick Rock, Colorado

General public radon daughters health effects per year	General public gamma health effects per year	Total general public excess health effects per year
0.0000029	0.0	0.000003

Table 4.3 lists the estimated total excess health effects incurred during remedial action and for the periods five, 10, 100, 200, and 1000 years after remedial action. These excess health effects would be 0.003 in the 1000 years following stabilization on site. The estimates in Table 4.3 reflect a stable population:

total excess health effects would increase if the nearby population increased.

Table 4.3 Total excess health effects during remedial action and five, 10, 100, 200, and 1000 years after remedial action[a]

Remedial action alternative	General population and workers during remedial action	Number of years after remedial action				
		5	10	100	200	1000
Proposed action	0.002	0.00001	0.00003	0.0003	0.0006	0.003
No action	0.0	0.001	0.002	0.02	0.05	0.2

[a]These estimates assume a constant population size and no dispersion of tailings by natural forces.

No action

This alternative would result in 0.00025 yearly excess health effects to the general public which is 86 times greater than after remedial action. No action would result in continued exposures due to elevated gamma exposure rates and radon emanation from the existing tailings pile and associated contaminated areas. An additional 0.2 excess health effects would occur in a 1000-year period (Table 4.3). The estimated excess health effects do not consider the dispersion of the tailings by natural forces or by man because the level or rate of dispersion cannot be predicted. However, without remedial action, dispersion would occur over time, and the actual total excess health effects might be greater than those shown in Table 4.3.

Disposal at the Section 36 site

The radon daughter excess health effects to the general public after stabilization of the contaminated materials at the Section 36 site would be less than for the proposed action. This is due to a smaller exposed population.

4.2 AIR QUALITY

Stabilization on site

The air quality impacts of the proposed action were estimated by developing a detailed emissions inventory and modeling resultant air pollutant concentrations. Estimates of project related emissions and air quality impacts are conservative. In addition, it is expected that mitigation measures (e.g., wetting) would reduce fugitive dust emissions by 50 percent at the tailings sites and 85 percent along the haul roads.

The emissions inventory include estimated combustion emissions from construction equipment and fugitive dust emissions (total suspended particulates or TSP) from wind erosion and the movement of tailings and borrow materials. Combustion emissions include hydrocarbons (HC), nitrogen oxides (NO_x), sulfur oxides (SO_x), carbon monoxide (CO), and TSP. The combustion and fugitive dust emissions for construction equipment and the movement of materials were calculated using air pollutant emission factors for construction equipment and associated

operations (Table 4.4). These emissions calculations were based on parameters such as fuel consumption, vehicle-miles travelled, vehicle speed, and the volumes of materials moved. Fugitive dust emissions from wind erosion were calculated using an adaptation of the universal soil loss equation which includes components for soil erodibility, local climate, the size of the exposed area, and the vegetative cover (CDH, 1981).

Estimated total air pollutant emissions during the proposed action indicate that NO_x and CO would be the most abundant gaseous air pollutants (Table 4.5). However, the total combustion emissions would be relatively low and temporary (17 months).

Fugitive dust would be responsible for over 400 tons of emissions at all of the Slick Rock work sites during the course of remedial action. A large percentage (32 percent) of fugitive dust emissions would occur along the haul roads between the various sites. Remedial action activities at the disposal site would produce the largest amount of emissions (55 percent). Mitigative measures would be expected to reduce the fugitive dust emissions by approximately 50 percent at the tailings sites and 85 percent along the haul roads.

Ambient air pollution concentrations were estimated using the Industrial Source Complex Short Term (ISCST) dispersion model (EPA, 1986). Given information concerning emission rates, source locations, and meteorology, this computer simulation model predicts air pollutant concentrations downwind from the sources. The ISCST model is

Table 4.4 Air pollutant emission factors used in the Slick Rock, Colorado, air quality analysis

Equipment	Fugitive dust emissions factors[a]	Combustion emission factor[b]				
		HC	NO_x	SO_x	CO	TSP
Compactor	4 lb/hr	0.02	0.49	0.03	0.11	0.02
Bulldozer	32 lb/hr	0.02	0.45	0.03	0.07	0.01
Front-end loader	0.04 lb/cy	0.03	0.41	0.03	0.10	0.03
Grader	32 lb/hr	0.02	0.37	0.03	0.08	0.02
Scraper	16 lb/hr	0.04	0.42	0.03	0.10	0.03
Crane	0 lb/hr	0.03	0.49	0.03	0.09	0.03
Seeder	4 lb/hr	0.03	0.49	0.03	0.09	0.03
Watertruck	4 lb/hr	0.03	0.52	0.03	0.09	0.18
Truck (off-site)						
Dirt roads	29.6 lb/mi	3.30	23.00	2.80	15.40	1.30
Paved roads	2 lb/mi	3.30	23.00	2.80	15.40	1.30
Truck (on-site)	30 lb/hr	0.03	0.52	0.31	0.09	0.18
Dumping	0.04 lb/cy	—[c]	—	—	—	—

[a] lb/hr = pounds per hour; lb/cy = pounds per cubic yard; lb/mi = pounds per mile.

[b] Combustion emission factors are in pounds per gallon of fuel consumed, except for trucks which are in grams per mile.

[c] — Not applicable.

Ref. EPA, 1985; CDH, 1981.

Table 4.5 Estimated total air pollutant emissions during the proposed action at the Slick Rock, Colorado, tailings sites

Source area	Fugitive dust emissions (tons)	Combustion emissions (tons)				
		HC	NO_x	SO_x	CO	TSP
Disposal site	226.87	3.14	48.82	3.34	9.92	2.89
NC site	28.76	0.25	4.92	0.32	0.93	0.25
Disappointment Valley borrow site	13.52	0.13	2.81	0.19	0.50	0.09
Dolores River borrow site	4.37	0.09	1.36	0.10	0.31	0.09
Road construction County Route S8	3.58	0.08	1.43	0.09	0.30	0.14
Haul road dust emissions	132.53	—[a]	—	—	—	—
Totals	409.63	3.69	59.34	4.04	11.96	3.46

[a] — Not applicable.

particularly appropriate for this analysis because it considers gravitational settling of particulates and it can accommodate large area emissions sources and line emissions sources such as haul roads. For the proposed action, only fugitive TSP concentrations were estimated with the ISCST model; emissions of gaseous air pollutants would be much lower than fugitive TSP emissions (Table 4.5), and the resulting concentrations of gaseous air pollutants would be well below the applicable air quality standards.

Modeling for the proposed action was performed for the remedial action activities at the tailings and borrow sites and for truck haulage between the tailings and borrow sites. The short-term fugitive TSP emission rates used in the modeling (Table 4.6) represented those that would occur in the months of maximum activity, and it was conservatively assumed that all equipment used during these peak periods at the tailings and borrow sites would be operating concurrently. For wind erosion, the average monthly rate of fugitive TSP emissions for the remedial action was used. Emissions from unpaved haul roads between the tailings and borrow sites were based on peak truck traffic (i.e., maximum truck trips per hour) over 900-meter lengths of each haul road. Dust control measures at the tailings and borrow sites (water sprays) and on the unpaved haul roads (chemical dust suppressant) were assumed to be 50 and 85 percent effective, respectively (CDH, 1981). For the analysis, receptors were placed downwind of the tailings and borrow sites and haul roads at 250-meter intervals out to a distance of 1500 meters. Light winds (2.5 meters per second) were assumed to blow persistently from a single direction under stable meteorological conditions

Table 4.6 Estimated maximum hourly fugitive dust emission rates for the proposed action at the Slick Rock, Colorado tailings sites

	Disposal site	NC site	Disappointment Valley borrow site	Dolores River borrow site
Month of maximum activity	10	6	8	11
Size of source area (acres)	82	25	10	10
Uncontrolled emissions (lb/hr)				
Compactor	20.00	None	None	None
Bulldozer	192.12	47.88	64.00	None
Front-end-loader	4.13	9.65	6.18	14.21
Grader	256.06	None	None	None
Scraper	160.00	None	None	None
Water truck	24.02	None	None	None
Truck dumping	14.29	3.47	None	None
Wind erosion	64.48	19.50	8.49	8.49
On-site truck	6.95	3.47	1.74	2.61
Total uncontrolled emissions	742.05	83.97	80.41	25.31
Total controlled emissions	371.03	41.99	40.21	12.65
Total controlled emissions (g/sec)	46.79	5.30	5.07	1.60

conditions (Pasquil-Gifford Category F), and these conditions were allowed to persist for the first six hours of the 24-hour modeling period. For the haul roads, the wind was assumed to blow perpendicularly to the roads.

The estimated maximum 24-hour increases in TSP concentrations for the proposed action are presented in Table 4.7. The maximum 24-hour TSP concentrations at or near the disposal site would exceed the applicable primary standard (260 microg/m^3) while the maximum 24-hour concentration at the Disappointment Valley borrow site would exceed the secondary standard (150 microg/m^3). The estimated maximum 24-hour TSP concentration increases along the unpaved haul roads represented less than 50 percent of the applicable primary TSP standards assuming 85-percent dust control with chemical dust suppressants.

The maximum increases in annual TSP concentrations during the proposed action were not estimated due to the lack of data on the annual distribution of wind speeds and stability classes for the Slick Rock area. However, it is likely that annual TSP concentrations in areas very near the tailings and borrow sites would exceed applicable annual TSP standards (see Table 3.3). The Slick Rock sites are in an attainment area although fugitive dust levels may exceed the standards during periods of high winds (see Section 3.2, Air Quality).

Table 4.7 Estimated maximum 24-hour increases in TSP concentrations for the proposed action at the Slick Rock, Colorado tailings sites[a]

Source	Estimated maximum 24-hour increase in TSP concentration (250 m from source)
Disposal site	401
NC site	107
Dolores River borrow site	63
Disappointment Valley borrow site	197
Haul road-Disappointment Valley borrow site	107

[a]Estimated maximum 24-hour increases in TSP concentrations are in micrograms per cubic meter (microg/m^3) and do not include background TSP concentrations.

No action

The no action alternative would not involve any remedial action, and there would be no sources for emissions of gaseous air pollutants (HC, NO_x, SO_x, and CO). However, under this alternative fugitive dust would continue to be dispersed into the atmosphere from the tailings by wind erosion.

Disposal at the Section 36 site

Stabilization at the Section 36 site would result in lower maximum gaseous pollutant and TSP concentrations at the tailings sites relative to the proposed action due to reduced emissions rates from lower

equipment activity levels. However, this alternative would result in greater emissions rates at the Section 36 site because all the contaminated material would be trucked to this site. Fugitive dust emissions and resultant TSP concentrations along the gravelled haul road to the Section 36 site would be greater relative to the proposed action because of the increased truck trips for hauling contaminated materials.

4.3 MINERAL RESOURCES AND SOILS

All of the disposal alternatives, except no action, would result in the consumption of borrow materials, e.g., earth, gravel, and rock. The consumption of borrow material from the proposed local sources would have a negligible impact on the availability of these resources, as all of these materials exist in large quantities in the Slick Rock and Disappointment Valley regions. None of the alternatives would have an impact on other mineral resources in the area. The UC and NC tailing sites, proposed disposal site, the proposed Disappointment Valley borrow site, and the Dolores River borrow site are underlain by geologic formations that contain noncommercial concentrations of minerals at current market values. Regardless, future recovery of any mineral reserves would not be precluded by the proposed action.

Stabilization on site would result in the temporary disturbance and permanent loss of soils. These impacts would result from surface disturbances caused by: (1) the excavation of borrow materials, contaminated tailings, and soils; (2) construction and upgrading of access roads; and (3) construction of staging and stockpiling areas.

Approximately 194 acres of land or 662,000 cubic yards of soil would be disturbed during cleanup in the contaminated areas at and around the UC and NC sites. This includes approximately 113,000 cubic yards of windblown/waterborne contamination. Contaminated soils would be consolidated with the tailings for disposal.

Thirteen acres of soils at the 15-acre disposal site would be covered by the stabilized pile and would be permanently lost. The areas excavated during the cleanup of contaminated materials within and adjacent to the tailings sites would be restored in accordance with applicable permits or approvals. Restoration techniques typically required include recontouring to promote surface drainage and revegetating to minimize erosion.

The proposed action would require the use of the Dolores River and Disappointment Valley borrow sites. The Dolores River borrow area would be the source for gravel and rock to be used for filter, bedding, and erosion protection. About 10 acres of soils would be disturbed to obtain approximately 45,000 cubic yards of materials from this site. Disappointment Valley would be the source of earthen materials for covering the contaminated materials. Approximately 42,000 cubic yards of material covering about 10 acres would be excavated from this site for the radon cover. Use of these areas would not impact mineral resources such as oil and gas since none occur at or near the sites.

Approximately 26,000 cubic yards of soils would be permanently lost in upgrading existing roads, constructing new access roads, and for roadway relocation.

No action

The no action alternative would not involve remedial action; therefore, no new disturbance or loss of soils would occur. Contamination of soils adjacent to the tailings site due to dispersion of the tailings by wind and water erosion would continue. The rate of this continuing contamination cannot be accurately quantified; 194 acres of soil (including the two tailings piles) have been contaminated to date.

Disposal at the Section 36 site

Stabilization at the Section 36 site would result in the same impacts to mineral resources and soils as the proposed action since the site is the same as the Disappointment Valley borrow site. The same amount of soil would be disturbed in the 194-acre contaminated area at the UC and NC sites and the 10-acre Dolores River borrow site. However, the amount of soil disturbed at the Section 36 site would be greater than for the proposed action since more land would be required to dispose of the contaminated material. Radon borrow material would be obtained within the site disturbed for tailings disposal.

4.4 WATER

4.4.1 Surface water

The following section summarizes the potential surface-water impacts and water use during each of the remedial action alternatives that is presented in more detail in Section B.1 of Appendix B, Hydrology..

Stabilization on site

During the proposed action, the stabilization of the tailings and associated contaminated materials would result in surface disturbance and runoff from the disturbed areas at the UC and NC sites. Also, contaminated waste water would be generated by activities such as equipment washing. The remedial action design includes the construction of drainage and erosion controls including waste-water retention ponds to prevent the discharge of contaminated water from the sites. These control measures would be constructed according to applicable regulations (Appendix E, Permits, Licenses, and Approvals). The contaminated water would be retained for evaporation or use in the compaction of the contaminated materials; sediments from the ponds would be consolidated with the tailings during the final reshaping of the stabilized pile. Following remedial action, all disturbed areas would be recontoured to promote drainage and revegetated.

Appropriate drainage and erosion controls would be used at both borrow sites to minimize or prevent erosion and any corresponding surface-water impacts. After remedial action, disturbed areas at both borrow sites would be graded to promote drainage and revegetated.

Erosion control features incorporated into the stabilized pile would prevent waters from excessive rainfall from impacting the pile. These include 1) limiting the sideslopes of the pile to five horizontal to one vertical (20 percent) and the top of the pile to two to four percent slope to promote drainage from the pile with non-erosive flow velocities, 2) placing a rock erosion protection barrier on the top and sideslopes of the pile to resist the erosive forces of severe rainfall events such as a Probable Maximum Precipitation (PMP), and 3) constructing a below-grade rock apron that would be designed to withstand the runoff from the PMP on the pile and the upstream drainage area and prevent erosion of the tailings pile.

No action

The no action alternative would result in the continued exposure of the tailings piles at both sites to erosion from surface runoff and flood flows of the Dolores River. Eventual erosion of the tailings would result in the continued increase in the concentrations of contaminants in the Dolores River floodplain in the site vicinity.

Disposal at the Section 36 site

Relocation of the contaminated materials to the Section 36 site would require erosion protection measures similar to the proposed action to prevent the release of contaminants from the site and to ensure the long-term stability of the pile. These measures would include construction of drainage and erosion controls at the disposal site, placement of a rock erosion protection barrier over the stabilized pile, and construction of a rock apron around the stabilized pile to prevent erosion of the base of the pile. Surface waters near the tailings sites would not be impacted after remedial action because all tailings and contaminated surface material would be removed from the sites. Surface water near the alternate disposal site would not be impacted after remedial action because features incorporated into the design would prevent surface waters from contacting the tailings.

4.4.2 Ground water

Stabilization on site

Stabilization on site would result in the removal of the UC and NC tailings piles and associated contaminated materials from the Dolores River floodplain. This would have a positive impact on the Dolores River alluvium in that the source of contamination of the alluvium would be removed.

The effects that the stabilized pile would have on the ground water beneath the pile would be difficult to quantify. However, general trends in the rates of seepage can be projected. The principal features of the proposed action that would affect seepage release from the stabilized pile are compaction of the tailings, the addition of a low-permeable radon cover, and contouring to promote surface runoff. Compaction would reduce infiltration by reducing the pore spaces. At the same time, water would be added during compaction to aid in the compaction process itself and to serve as a dust suppresant. The volume of water added during remedial action would be minimal when compared to the volume of effluent added to the tailings during active milling which produced most of the existing contamination beneath the present tailings piles.

However, a small quantity of free water in the voids would gradually drain by gravity from the tailings into the underlying, low-permeability bedrock. The other two factors mentioned above (low-permeable cover and contouring) would work to reduce infiltration into the pile.

The Entrada Sandstone is unsaturated and would separate the stabilized pile from the underlying, confined Navajo Sandstone aquifer. Depth to water beneath the disposal site is greater than 60 feet. This unsaturated sandstone, conglomerate, mudstone, and shale beneath the site would act as a physical and chemical buffer to any potential tailings seepage.

No action

Under existing conditions, the rate of seepage from the tailings pile has decreased significantly from the period of active milling since recharge to the pile is limited to natural precipitation and infiltration. As a result of no action, leaching of contaminants from the tailings piles will continue though at a minimal rate. Eventually, contamination of the ground water by tailings leachate would cease.

Disposal at the Section 36 site

The Section 36 site is underlain by approximately 170 to 200 feet of deposits of the Mancos Shale, which is in turn underlain by the Dakota Sandstone. Ground water within the Mancos Shale is unconfined, occurs as perched water tables approximately 40 feet below land surface, and is of poor quality. The Dakota Sandstone is not considered as an aquifer in the area of the Section 36 site because only a limited thickness is present in the subsurface (Pioneer, 1978).

Due to the low permeability and substantial thickness of the Mancos Shale underlying the Section 36 site, the depth to the water table, the naturally poor ground-water quality, the limited extent of this ground water, and the lack of past, present, and anticipated use of this ground water, no adverse

impacts to the ground water due to relocation at this site would be anticipated.

4.5 FLORA AND FAUNA

Flora and fauna would be affected directly and indirectly by remedial action. Direct impacts would include the loss of habitat, loss of less mobile wildlife species, and displacement of other species. Indirect impacts would arise from increased fugitive dust, noise levels, and human activity levels. The duration of the direct impacts would depend on the level of restoration efforts while most indirect impacts would be short term (for the life of the project or less). Impacts on the flora and fauna are assessed in greater detail in Appendix C, Flora and Fauna.

Stabilization on site

Stabilization of the tailings and other contaminated materials at the proposed disposal site would result in the clearing of approximately 194 acres of land; 98 acres would be in upland desert-shrub habitat or disturbed land around the NC and UC piles while 96 acres would be in the floodplain of the Dolores River. An additional 42 acres of upland desert-shrub habitat would be disturbed at two borrow sites and off-site storage areas. Two acres of land needed for haul road construction to each borrow site are included in this total.

The riparian habitat along the Dolores River represents the most productive and diverse wildlife habitat that would be impacted by remedial action. This habitat contains wildlife species found only in this habitat type while also being important to upland wildlife species. The riparian habitat at the Slick Rock site is a diverse mosaic of subtypes. The upper riparian grassland type covers the largest area (50 acres) in the contaminated zone and, relative to the other subtypes, is least important to wildlife because it is the least structurally diverse. The upper riparian shrub subtype is similar to the upper riparian grass type except shrubs are more common. This type covers 14 acres and is more diverse in terms of habitat structure and wildlife use. The final two subtypes are dense riparian shrub (23 acres) next to the river and cottonwood stands (nine acres). These subtypes have the greatest diversity in habitat structure and wildife use.

Important concentration areas for game species such as critical deer winter range do not occur in the areas to be impacted along the Dolores River although mule deer use of the riparian zone along the river appears to be greater than in the surrounding uplands. Mule deer and pronghorn antelope occur in the area of the Disappointment Valley borrow site; project related impacts on these two species would be minimal

T[illegible] species may occasionally occur at the Slick Rock sites; impacts associated with remedial action would be minimal. Remedial action activities along the Dolores River would be expected to have a very minor impact on wintering bald eagles. There would be no eagle concentration areas along the section of river valley to be impacted although occasional

birds would be expected during daily feeding activities. The peregrine falcons, at an eyrie eight miles from the construction zone, would not be impacted due to the relatively long distance and availability of other feeding areas.

Two candidate species (long-billed curlew and paradox lupine) would have a remote potential of occurring in the area of the Disappointment Valley borrow site and surveys for these species would be conducted if this site becomes the final borrow site.

No action

The no action alternative would not involve any remedial action so there would be no impacts to the flora and fauna due to construction activities. Both wild and domestic fauna would continue to use lands contaminated with tailings under this alternative. Recent work with cattle grazing on lands contaminated by uranium mill tailings and mine dewatering operations indicated that these animals exhibit elevated levels of radionuclides (Lapham et al., 1986). These results indicate that wildlife residing in the contaminated areas may also exhibit elevated radionuclide levels. In addition, there is some heavy metal contamination in the area to be excavated and some of these elements such as molybdenum and selenium will enter the food chain (PRC, 1979). Therefore, under the no action alternative, radionuclides and other contaminants may continue to be transported into the food chain. There is not expected to be any impact on humans consuming possibly contaminated food as mentioned in Section 4.1 above.

Disposal at the Section 36 site

The Section 36 site is located in the same area as the Disappointment Valley borrow site. Stabilization at this site would result in the disturbance of the same amount of land and, therefore, the same impacts along the Dolores River as with the proposed action. The impacts would be greater in Disappointment Valley since a larger area than the proposed 10-acre borrow site would be disturbed and there would be a long-term loss of habitat since the stabilized pile would be covered with rock.

Possible impacts on game and T and E species would be similar to those described above for the Disappointment Valley borrow site.

4.6 LAND USE

Stabilization on site

The final tailings disposal site containing the stabilized tailings pile (13 acres) would encompass 15 acres entirely within the designated UC tailings site and will be fenced if required. The final disposal site would be under the direct control of the Federal Government and would be permanently restricted from any public access and development. Consequently, any other use of these 15 acres would be permanently precluded.

During the remedial action, 194 acres within and adjacent to the designated tailings sites would be temporarily disturbed for the cleanup of the tailings piles (19 acres) and adjacent contaminated areas (175 acres). An additional 20 acres next to the UC and NC sites would be disturbed for the construction of staging and stockpile areas. After remedial action, 191 acres of the 214 disturbed acres would be graded to promote surface drainage and revegetated. The acreage not restored would be the 13 acre stabilized pile and 10 acres of roads and bedrock outcrop at the tailings sites. The total of 199 acres would then be released for any uses consistent with existing land use controls while access to the tailings pile (13 acres) and buffer zone (2 acres) would be restricted.

The proposed action would have no effects on existing land uses at the designated tailings sites because the sites are not being used at the present time. However, remedial action at the UC site would necessitate the relocation of approximately 1450 feet of CR-38 northeast of the trailer park and relocation of approximately 500 to 2500 feet of utility lines (natural gas, electricity, water including a fire hydrant, and sewer including a septic tank) that service the trailer park and gas sweetener plant. These relocations would be coordinated with the appropriate county officials and utility providers to avoid or minimize interference with the uses of CR-38 and the utilities.

The proposed action also would result in the disturbance of approximately 22 acres at the Dolores River and Disappointment Valley borrow sites (10 acres of excavation and one acre of haul road at each

site). Disturbance at the Dolores River borrow site would temporarily prevent the use of any pasture land contained within the site; however, the borrow activities would be planned and conducted to avoid the pasture land as much as possible. The borrow activities would not preclude future use of the pasture land because the site and haul road would be reclaimed in accordance with the mining and reclamation permit issued by the Colorado Mined Lands Reclamation Division. Disturbance at the Disappointment Valley borrow site would temporarily disrupt livestock grazing at the site; however, the site represents less than 0.1 percent of the grazing allotment in which it is located. There are no mineral nor oil and gas development activities at the site, and the borrow activities would be planned and conducted to avoid encroachment on the public water reserve withdrawals north and southeast of the site. The borrow activities would not preclude future grazing or mineral or oil and gas activities at the site because the site and haul road would be reclaimed in accordance with the free use permit issued by the BLM and the mining and reclamation permit issued by the Colorado Mined Lands Reclamation Division (Appendix E, Permits, Licenses, and Approvals). Typically, these permits require reclamation that would return the disturbed area to a condition compatible with the surrounding lands.

No action

The no action alternative would allow the tailings piles to continue to affect existing land use patterns. The areas presently occupied by the piles would not be available for alternate uses. In addition,

dispersion of the tailings by wind and water erosion would continue to contaminate lands adjacent to the piles. The piles have not been stabilized to provide protection against erosion from severe weather, and the total amount of land contaminated by the tailings is approximately 194 acres including the tailings piles.

Disposal at the Section 36 site

Compared to the proposed action, disposal at the Section 36 site would result in approximately the same number of acres being permanently restricted from any public access and development, while the final tailings disposal site would be slightly larger than the disposal site under proposed action. The entire UC and NC sites would be released for any uses consistent with existing land use controls. This alternative would not require the relocation of CR-S8, but would require relocation of the same utilities as the proposed action. In addition, the acres disturbed by the borrow activities for this alternative would be slightly less than those for the proposed action. The Disappointment Valley borrow site would be in the same location as the Section 36 site; the Dolores River borrow site would be slightly larger since the final tailings disposal site would be larger.

4.7 NOISE

Remedial action would involve the operation of heavy earth-moving and transportation equipment. This section describes the impacts of this equipment on noise levels in adjacent areas and on sensitive receptors (i.e., human population) living near the tailings sites. The impacts of the noise would be different for each alternative, depending on location of sources and receptors, and the types and numbers of equipment used. Typical sound levels generated by the type of equipment used during remedial action are presented in Table 4.8. A noise prediction model (Kessler et al., 1978) was used to estimate the maximum A-weighted equivalent sound level (L_{eq}) emitted from the tailings, disposal, and borrow sites. Use of the noise-level model produces conservative results (i.e., the noise levels that it predicts are probably higher than would be realized), since no attenuation for air absorption, berms, or foliage is considered in the model. The model does assume that all machinery is in good working condition and that mufflers are functioning as designed. In addition, the model predicts equivalent sound levels which are averages where a single event sound could be greater than the predicted average.

Stabilization on site

During the peak construction period, maximum equivalent noise levels at the center of the disposal site would be approximately 92 dBA. This would result in an elevation of maximum outdoor noise levels of

Table 4.8 Sound levels for equipment used during remedial action at the Slick Rock, Colorado tailings sites

Equipment	Sound level at 50 feet (dBA)
D-8 bulldozer	88
Front-end loader	86
Scraper	87
Water truck	89
Haul truck	88
Compactor	87
Grader	80

Ref. Kessler et al., 1978.

approximately 60 dBA at the trailer park south of the UC site. Two residences occur approximately 0.5 mile and 0.75 mile east of the UC site along CR-58. Maximum noise levels above background from the disposal site at these residences would be 58 dBA and 54 dBA, respectively. However, noise levels at these residences during most of the remedial action would be four to 10 dBA lower.

The maximum noise levels at the center of the NC site would be approximately 87 dBA. Maximum noise levels at the trailer park, Slick Rock post office, and two residences would be 58, 41, and 59 dBA, respectively. For the duration of the remedial action, maximum noise levels would be eight to 12 dBA lower at each location.

The Dolores River borrow site is approximately 0.5 mile from the UC and NC sites. Two discrete periods of activity would occur at the site. Maximum noise levels during these periods would be elevated by approximately 88 dBA at the center of activity. Two residences are located approximately 0.25 mile east and west of the borrow site. Maximum noise levels at these locations would be approximately 59 dBA.

The Disappointment Valley borrow site is approximately five air miles southeast of the disposal site and four miles east of the Slick Rock post office. Two discrete periods of activity would occur and maximum noise levels during these periods would be elevated by approximately 89 dBA. Noise levels at this site are not expected to impact any sensitive receptors given the remote nature of the site.

County Road S8 and C-141 would be used to move tailings and borrow materials. The heaviest concentration of traffic would occur on CR-S8 between the UC and NC sites. During peak remedial action, a total of 17 trucks would be in operation. The greatest impact on noise levels would be in the vicinity of the two residences east and west of the Dolores River borrow site. The predicted worst case for truck activity is 224 trips per day (see Section 4.12, Transportation).

The maximum noise level for a single truck at 50 feet would be 85 dBA. Maximum noise levels for one residence 500 feet from the road would be 65 dBA while it would be 59 dBA for the residence 1000 feet from the road. These levels would vary depending on the number of trucks which would occur near a location at a given point in time.

Traffic along C-141 due to remedial action would be approximately one-half that estimated for CR-S8 near the NC site. Noise levels for individual trucks would be the same, but the frequency, number and timing of the trips would be lower.

High levels of truck activity may cause annoyance to the residents in the UC and NC areas and at the Slick Rock post office. Currently, an average of five to six vehicles per day pass along CR-S8 in the vicinity of the UC and NC sites.

These potential noise levels would occur only during daytime hours and are representative of peak construction activity.

No action

The no action alternative would have no impact on existing noise levels in the area.

Disposal at the Section 36 site

Noise levels associated with disposal at the Section 36 site would be expected to be similar at the UC and NC sites relative to the proposed action. Increased noise and annoyance to residents living along CR-S8 would be expected due to the larger volume of material being trucked to the Section 36 site (all of the UC and NC materials plus the Dolores

River borrow site materials). Noise levels along C-141 from Slick Rock to the Section 36 site would increase due to the significant increase in truck trips to move all the contaminated materials. In addition, the noise levels at the Section 36 site would increase substantially over the proposed action alternative, which would involve use of this area only as a borrow site.

4.8 HISTORIC AND CULTURAL RESOURCES

No archaeological resources that are eligible for inclusion on the National Register of Historic Places (NRHP) would be impacted near the processing sites under the two action alternatives. One historic site eligible to the NRHP could be impacted by both the stabilization on site and disposal at the Section 36 alternatives. Further study would be required before it could be determined if the site would be impacted. If the site were impacted, a data recovery plan would be designed and implemented in conjunction with the State Historic Preservation Officer (SHPO).

The no action alternative would not impact any cultural resources.

The Section 36 site and borrow sites have not been surveyed for cultural resources. Prior to surface disturbances in these areas, a Class III cultural resource survey would be conducted. A data recovery plan approved by the SHPO, the BLM (if applicable), and the DOE would be implemented if eligible sites were identified in areas to be disturbed.

4.9 POPULATION AND EMPLOYMENT

Impacts on population and employment in the Slick Rock area were assessed by evaluating the effects of the average and peak remedial action labor requirements. It was projected that workers would reside in towns within a five-county area (San Miguel, Montrose, Dolores, Montezuma, and San Juan). The average work force of 58 for the proposed action is relatively small; it is unlikely that appreciable indirect employment would result from remedial action expenditures occurring in several towns in the area. Indirect employment effects were not considered for that reason. It was assumed that the general labor force needs, such as truck drivers, heavy equipment operators, and mechanics, would be available within the surrounding five-county area. All supervisory positions would likely be filled by temporary personnel from outside the area.

Stabilization on site

The average work force would consist of 20 supervisory personnel and 38 general work force employees. Throughout the project, the number of supervisory personnel would remain constant while the number of general work force employees would vary from a minimum of 17 to a maximum of 88. The 12-month projected work schedule would require two construction seasons due to winter weather shutdowns. The number of skilled, experienced workers who are currently unemployed or under employed in the mining and construction industries is unknown. It is assumed that most

of these workers would be available in nearby towns within commuting distance.

The towns of Naturita, Nucla, Dove Creek, Monticello, Cortez, and others, have been affected by past mining cycles and likely have unemployed workers with appropriate work experience. The short term employment of between 17 and 88 local workers originating from a five-county area would have a negligible effect on overall unemployment. The average unemployment rate for the five-county area (Section 3.10) is approximately nine percent, although the Colorado-Utah border area is thought to be experiencing higher levels of unemployment.

Supervisory management personnel would likely in-migrate for the 12-month project duration and reside in area towns. Studies of construction workers done by Mountain West Research, (1979) found that 60 percent of construction workers would bring families to a job site. Although it is unlikely that, due to the short duration of the remedial action, families would accompany the in-migrant workers, the analysis of maximum population increases is presented as a worst case situation. Of the 20 supervisory personnel, 12 workers would bring families. Assuming a family size of 3.47 (Section 3.10) an estimated in-migrant population of 50 individuals could be expected (12 married workers with spouses and 18 children, and eight workers without spouses or children). Since no town is located near the tailings sites, it is likely that in-migrant workers would reside in any of several area towns. The effect of 50 temporary residents would have a negligible effect on current population levels.

No action

Without remedial action, short term relief of area unemployment would be foregone. Since population out-migration is still occurring due to a lack of employment opportunity, the no action alternative would not change this trend.

Disposal at the Section 36 site

Under this alternative, the contaminated material would be moved further and a larger general work force would likely be necessary. A larger general work force would provide greater local employment opportunities as compared to the proposed action. The effects of increased employment would be distributed among several area towns as would occur under the proposed action.

4.10 HOUSING AND COMMUNITY SERVICES

Stabilization on site

Since in-migrant workers are projected to live in several area towns, it is unlikely that housing would be a problem. Using the five-county area (San Miguel, Montrose, Dolores, Montezuma, and San Juan) an average household size of 3.75 (DOC, 1983a), then a maximum of 20 houses would be needed for the supervisory workers and families. This

represents a conservative estimate since it is unlikely that in-migrant workers would bring families for a 12-month work schedule which would be divided by winter into two construction seasons.

Due to the overall area declines in population, most community services are under utilized. An increase in school enrollments by 18 school aged children would have a negligible effect on the already under utilized school systems (Section 3.10). Other area services would also not be affected by this small population increase.

No action

The no action alternative would not involve any remedial action and there would be no in-migration of people to affect the existing vacant housing supplies or availability of community services.

Disposal at the Section 36 site

The larger volumes of materials to be transported would not affect the number of supervisory positions. Impacts would be similar to those for the proposed action.

4.11 PUBLIC FINANCE

Remedial action would have a direct positive impact on area economies through wages and salaries paid to the workers and expenditures for materials, supplies, and equipment. There would be additional indirect positive benefits on local economies as these wages, salaries, and other expenditures were respent locally on other goods and services. Indirect expenditures would also generate local and state taxes. Direct purchases specifically for remedial action would not be subject to taxes because this is a Federally funded project.

Stabilization on site

The estimated cost of stabilization on site would be $5,382,625. This figure includes costs associated with the remedial action, labor, and purchases or rentals of all equipment, materials, and supplies. The amount which would benefit the local economy would include $1,456,102 for wages and salaries and $643,842 for local contracts and purchases of materials and supplies. Wages and salaries are based on gross wages and 20 to 30 percent would be withheld for taxes and would not reach the local economy. Materials and supply purchases would include the soil and rock, borrow materials; fencing; and miscellaneous purchases for fuel, tools, equipment repair, and the like. The amount of the total construction cost which would not reach the local economy was estimated at $3,282,681. These monies would be spent for equipment and supplies which likely would not be available locally and for profit and overhead.

In addition to direct local expenditures, revenue would be generated indirectly as money circulated throughout the economies. Research on the indirect impacts of similar construction projects on rural areas in the Western United States suggests use of an indirect income multiplier of 1.23 (Mountain West Research, 1979) to determine the monies generated from the re-spending of project related dollars. Indirect revenues are estimated at $344,903. The total estimated gross revenue which would reach local residents and in turn would positively benefit the local economy would be $2,434,847.

Once the remedial action is completed, the 15-acre restricted site would become the property of the Federal government and would therefore not be subject to property tax. Decontaminated adjacent areas as well as the NC site would remain the property of the original owner or would be sold.

No action

The no action alternative would eliminate the opportunity for area residents to benefit from the direct and indirect revenues associated with the remedial action.

Disposal at the Section 36 site

Stabilization at the Section 36 site would require a larger work force and more equipment, materials, and supplies. Direct and indirect expenditures would be higher resulting in a greater positive financial impact on San Miguel, Montrose, Montezuma, Dolores, and San Juan counties than the proposed action.

4.12 TRANSPORTATION

The remedial action alternatives would require use of C-141 and CR-S8 for transport of the tailings, borrow materials, worker commute trips, and miscellaneous trips. Miscellaneous trips between the tailings and borrow sites would be necessary for construction management purposes or would occur as supplies and materials were brought to the work sites. Workers would be commuting from several area towns northeast or south of Slick Rock and would use C-141 to access CR-S8. Use of C-141 by commuting workers would not affect the traffic patterns occurring during the work day on C-141 in western San Miguel County.

Stabilization on site

During the proposed action, the major transportation impacts would occur on CR-S8. A conservative analysis evaluated the cumulative impacts of trucks originating at the Disappointment Valley borrow,

Dolores River borrow, and NC tailings sites. Based on construction schedule and equipment estimates, a maximum of 224 truck trips per day could occur over a one- or two-month period as materials of all kinds were transported on CR-S8 to the disposal site. If construction phases do not overlap it is projected that truck trips would range from 34 to 108 per day.

To sustain the additional truck traffic, CR-S8 would need to be upgraded from its current condition. As stated in Section 3.11, the current road condition would be adequate for the existing use level.

Average daily traffic on C-141 in 1985 was below the design highway level of service (see Section 3.11). C-141 is designed to safely carry between 4000 and 6000 vehicles per day. A projected increase of 261 vehicles per day (worker commute traffic and haulage truck trips), although greater than the 1985 daily traffic count of 220 (Section 3.11), would not impact local use of the highway.

No action

Without any type of remedial action, traffic on C-141 and CR-S8 would remain at current levels.

Disposal at the Section 36 site

This alternative would result in higher vehicle use of CR-S8 and C-141 than the proposed action. This is because the UC and NC contaminated material plus the Dolores River borrow site material all would have to be transported to the Section 36 site.

4.13 ENERGY AND WATER CONSUMPTION

The action alternatives would require the consumption of fuel and electricity to operate the construction equipment and for on-site operations (e.g., field offices). In addition, water would be needed for the remedial action workers, the shower and laundry facilities, and for activities such as compaction of the tailings, washing of the construction equipment, and dust control.

Stabilization on site

Total estimated fuel, electricity, and water consumption for the proposed action would be 333,000 gallons, 156,000 kilowatt-hours, and 5,384,100 gallons, respectively. Section A.2.5 of Appendix A, Conceptual Designs, provides details on the estimated energy and water consumption.

The fuel for the proposed action would be trucked from a commercial source(s) to the site and would probably be stored at the site in tanks. No impacts on local fuel sources would be expected.

Electricity would probably be supplied by the San Miguel Power Company at the site; this would not affect the availability of electricity to the surrounding areas. Potable water for the activities at the site would probably be supplied from nearby production wells or by drilling a production well on or nearby the site. Nonpotable water would probably be obtained from the Dolores River. The use of water from these sources would not affect the availability of water in the area.

No action

The no action alternative would not involve any remedial action; therefore, no fuel, electricity, or water would be required.

Disposal the Section 36 site

Disposal at the Section 36 site would require greater amounts of fuel, electricity, and water than the proposed action. More truck trips would be required to relocate the tailings resulting in greater fuel and water use. The fuel for this alternative would be trucked from a commercial source(s) to the site and would probably be stored at the site in tanks. Both potable and nonpotable water would probably be supplied by a commercial source near the site. Electricity would be provided at both the tailings and disposal sites which would result in greater electric use. The power would probably be supplied by portable generators located on the site, or by the San Miguel Power Company. The

energy and water consumption at the Section 36 site would not be expected to affect the availability of these resources in the area.

4.14 ACCIDENTS NOT INVOLVING RADIATION

Remedial action would require truck trips as tailings and borrow materials are transported to the disposal site. Additional traffic would result from remedial action workers commuting to the sites and from miscellaneous trips related to remedial action needs. This traffic would pose the risk of accidents and resulting injuries and fatalities.

For the purpose of this analysis, it was assumed that although workers would commute from several area towns, the average one-way commute distance to the disposal site would be 40 miles. Due to the remoteness of the site, infrequent miscellaneous trips for supplies between the tailings sites and both borrow sites would occur and were included in the mileage estimates.

In addition to injury and fatal accidents related to remedial action traffic, accidents associated with the operation of construction equipment and materials handling activities would occur during the remedial action. These hazards would be similar to those encountered in any large earthmoving project such as surface mining or heavy construction. Based on 1981 accident data for the mining and construction industries, approximately 0.0422 injury accident and 0.00045 fatal accident would occur per man-year of labor (DOC, 1983b).

Stabilization on site

An estimated 1,249,414 miles of off-site vehicle travel would be associated with the proposed action. This would result from tailings and borrow haulage trips (72,849 miles), worker commute trips (1,169,280 miles), and miscellaneous trips (7285 miles). Approximately 82 man-years of labor would be associated with the remedial action. Based on State of Colorado injury and fatal accident rates presented in Section 3.11, an estimated 0.97 injury accident, and 0.0479 fatal accident could occur during the remedial action.

The estimated number of equipment use accidents was based on the total man-years of labor associated with the remedial action. An estimated 3.46 injury accidents and 0.037 fatal accidents may occur over the term of the remedial action.

No action

The no action alternative would not involve any remedial action and, therefore, would not result in any traffic or equipment use accidents.

Disposal at the Section 36 site

This alternate would require moving the contaminated material and erosion protection materials nine road miles to the Section 36 site.

Moving these materials to this site would require more haulage trips, a larger work force, and a longer duration to complete the remedial action than was estimated for the proposed action. This would result in more accidents than the proposed action.

4.15 MITIGATIVE MEASURES

The following mitigative measures were incorporated into the design and approach for the remedial action alternatives in order to reduce the environmental impacts:

- Establishment of a site security system at the tailings sites to control traffic entering and leaving the sites.

- Construction of drainage controls and a waste-water retention pond(s) at the tailings sites to prevent contaminated waste water and surface runoff from leaving the sites during remedial action.

- Construction of erosion control measures for all disturbed areas to prevent increased siltation in the Dolores River.

- Removal of all contaminated soils (consistent with the EPA standards) adjacent to the tailings pile and consolidation of the contaminated soils with the tailings.

- Application of water or chemical dust suppressants to disturbed areas and gravelled haul roads to inhibit dust emissions.

- Immediate cleanup of any off-site spills of contaminated materials in compliance with applicable regulations.

- Selection of borrow sites which are as close to the tailings site as possible to reduce costs and eliminate the impacts of long haulage distances.

- Design of the stabilized tailings pile to withstand a design earthquake.

- Backfilling, grading, and revegetating the areas disturbed during the cleanup and consolidation of the tailings and contaminated materials.

- Implementation of complex cover designs to inhibit plant root penetration, burrowing by animals, and inadvertent human intrusion after remedial action.

- Construction of compacted, earthen tailings covers to inhibit radon emanation (consistent with the EPA standards) and surface-water infiltration.

- Construction of a rock cover on the stabilized tailings pile to ensure that the stabilized pile would withstand the erosive effects of a Probable Maximum Precipitation (PMP).

- Construction of other erosion control measures (e.g., below-grade rock apron) to assure the long-term stability of the stabilized tailings pile.

- Construction of drainage controls to direct surface runoff around and away from the stabilized tailings pile and prevent long-term erosion.

- Construction of a coarse sand and gravel filter and bedding layer to protect the radon barrier against erosion from surface runoff.

- Construction of fencing with warning signs around the stabilized pile to restrict human access to the stabilized tailings if required.

- Implementation of a preventative equipment maintenance program to assure proper functioning of combustion emissions and noise control devices.

- Firmly securing tailgates and any other metal source during transportation to avoid unnecessary noises.

- Maintaining haul roads to reduce secondary noise impacts from nonuniform road conditions, chuckholes, or washboard effects.

- Cleanup of any equipment used before release to prevent the spread of contaminated materials.

- Use of local labor whenever possible to reduce the sociological impacts to the local communities and to provide economic benefits.

- Conducting operations only during normal work hours to minimize noise disturbance to local residents.

- Maintaining close communication with the local population through an established public information task force.

Mitigative measures necessary to ensure the protection of remedial action workers and the long-term stability of the tailings are described in the UMTRA Project Environmental, Health, and Safety Plan (DOE, 1985d), the Remedial Action Plan (DOE, 1987), and Guidance for UMTRA Project Surveillance and Maintenance (DOE, 1986).

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GLOSSARY

absorbed dose, radiological	Radiation energy absorbed per unit mass, usually given in units of rads.
alluvium	Sediment deposited by a flowing river.
alpha particle	A positively charged particle emitted from certain radionuclides. It is composed of two protons and two neutrons and is identical to the helium nucleus.
aquifer	A subsurface formation containing sufficiently saturated permeable material to yield usable quantities of water.
atom	A unit of matter; the smallest unit of an element consisting of a dense, central, positively charged nucleus surrounded by a system of electrons, equal in number to the number of nuclear protons and characteristically remaining undivided in chemical reactions except for a limited removal, transfer, or exchange of certain electrons.
A-weighted scale	Sound level scale which most closely matches the response of the human ear. This scale is most commonly used to measure environmental noise and is often supplemented by the time and duration of the noise to determine the total quantity of sound affecting people.
background radiation	Radiation arising from radioactive material other than that under consideration. Background radiation due to cosmic rays and natural radioactivity is always present, and there is always background radiation due to the presence of radioactive substances in building materials, and the like.
beta particle	Charged particle emitted from the nucleus of an atom during radioactive decay with mass and charge equal to those of an electron.
bioassay	A method for quantitatively determining the concentration of radionuclides in a body by measuring the quantities of those radionuclides that are eliminated from the body, usually in the urine or the feces.
Class III archaeological survey	A Class III survey is an in-depth inspection of an area to determine the presence of archaeological materials where the likelihood of their occurrence is high based on the history of the area.
contamination	In this report, the presence of radioactive materials in concentrations above natural levels.

Curie (Ci)	The unit of radioactivity of any nuclide, defined as precisely equal to 3.7×10^{10} disintegrations per second.
daughter product(s)	A nuclide resulting from radioactive disintegration of a radionuclide, formed either directly or as a result of successive transformations in a radioactive series; it may be either radioactive or stable.
decay, radioactive	Disintegration of the nucleus of an unstable nuclide by spontaneous emission of charged particles, photons, or both.
decontamination	The reduction of radioactive contamination in an area to a predetermined level set by a standards-setting body such as the EPA by removing the contaminated material.
disintegrations per minute or second	The number of radioactive decay events occurring per minute or second.
disposal	The planned, safe, permanent placement of radioactive waste.
dose	A general term denoting the quantity of radiation or energy absorbed, usually by a person; for special purposes, it must be qualified; if unqualified, it refers to absorbed dose.
dose, absorbed	The amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material at the point of interest; given in units of rads.
dose commitment	The cumulative dose equivalent that will result from exposure to radioactive materials over a discrete time period; given in units of rems.
dose equivalent	The quantity that expresses all kinds of radiation on a common scale for calculating the effective absorbed dose; defined as the product of the absorbed dose in rads and modifying factors, especially the qualifying factor; given in terms of rems; often abbreviated "dose."
exposure	The presence of gamma radiation that may deposit energy in an individual; given in units of roentgens or microroentgens.

external dose	The absorbed dose that is due to a radioactive source external to the individual as opposed to radiation emitted by inhaled or ingested sources.
fault	A surface or zone of rock fracture along which there has been movement.
floodplain	Lowland or relatively flat areas that are subject to flooding. A 100-year floodplain has a one percent or greater probability of flooding in any given year.
flux, radon	The emission of radon gas from the earth or other material; usually measured in units of picocuries per square meter per second.
gamma	A high energy and deeply penetrating form of radiation.
gamma dose	Radiation dose caused by gamma radiation.
gamma logging (or logs)	A technique for determining gamma radiation levels at various depths in a borehole.
gamma ray	High energy electromagnetic radiation emitted from some radionuclides. The energy levels are specified for different radionuclides.
gamma spectral analysis (gamma spectroscopy)	An analytical technique for identifying radionuclides based on their different gamma energy levels.
general-storm PMP	Probable Maximum Precipitation (PMP) estimated for basin sizes of 10 to 5000 square miles and duration of six to 72 hours based on convergence (precipitation due to atmospheric processes not affected by terrain) and orographic (precipitation from moist air forced upward by mountain slopes and the triggering of rainfall near first upslopes) PMP components.
ground water	Water below the land surface, generally in a zone of saturation.
ground water, confined	Confined ground water is under pressure significantly greater than atmospheric, and its upper limit is the bottom of the bed of distinctly lower hydraulic conductivity than that of the material in which the confined water occurs.
ground water, unconfined	Unconfined ground water in an aquifer that has a water table.
half-life	The time required for 50 percent of the quantity of a radionuclide to decay into its daughters.

head	When used alone, it is understood to mean static head. The static head is the height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point.
head, total	The total head of a liquid at a given point is the sum of three components: (1) elevation head, h_e, (2) pressure head, h_p, and (3) velocity head, h_v. Under conditions to which Darcy's Law may be applied, the velocity of ground water is so small that the velocity head, $h_v = v^2/2g$, is negligible.
health effect	Adverse physiological response from radiation exposure (in this report, one health effect is defined as one cancer death from exposure to radioactivity).
hydraulic conductivity	The volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.
hydraulic gradient	The change in static head per unit of distance in a given direction.
inert gas	One of the chemically unreactive gases: helium, neon, argon, krypton, xenon, and radon.
in-situ	In the natural or original position.
internal dose	The absorbed dose or dose commitment resulting from inhaled or ingested radioactivity.
isotopes	Nuclides having the same number of protons in their nuclei but differing in the number of neutrons; the chemical properties of isotopes of a particular element are almost identical.
leachate	Leachate is the solution generated by the percolation of water through a body of soil, waste rock, or solid waste.
licensing	In this report, the process by which the NRC will, after the remedial actions are completed, approve the final disposition and controls over a disposal site. It will include a finding that the site does not and will not constitute a danger to the public health and safety.
local-storm PMP	Probable Maximum Precipitation (PMP) estimated for basin sizes up to 500 square miles and durations from 15 minutes to six hours based on storms resulting from convective lifting of moist air.

maintenance, custodial (passive)	The repair of fencing, the repair or replacement of monitoring equipment, revegetation, minor additions to soil cover, and general disposal site upkeep such as mowing grass.
man-rem	Unit of population exposure obtained by summing individual dose equivalent values for all people in the population. Thus, the number of man-rems attributed to one person exposed to 100 rems is equal to that attributed to 100 people each exposed to one rem.
micro	A prefix meaning one millionth (1/1,000,000 or 10^{-6}).
milli	A prefix meaning one thousandth (1/1000 or 10^{-3}).
monitor	To observe and make measurements to provide data for evaluating the performance and characteristics of the disposal site.
National Register of Historic Places	Established by the Historic Preservation Act of 1966, the Register is a listing of archaeological, historical, and architectural sites nominated for their local, state, or national significance by state and Federal agencies and approved by the Register staff.
nuclide	A general term applicable to all atomic forms of the elements; nuclides comprise all the isotopic forms of all the elements. Nuclides are distinguished by their atomic number, atomic mass, and energy state.
perched ground water	Ground water separated from an underlying body of ground water by unsaturated rock.
permeability	The ease with which liquids or gases penetrate or pass through a layer of soil. Technically, it is the volume of fluid that will flow through a unit area under a unit hydraulic gradient; measured in centimeters per second or equivalent units.
permissible dose	That dose of ionizing radiation that is considered acceptable by standards-setting bodies such as the EPA.
pico	A prefix meaning one trillionth (1/1,000,000,000,000 or 10^{-12}).
picoCurie	A unit of radioactivity defined as 0.037 disintegrations per second.
porosity	The porosity of a rock or soil is its property of containing interstices or voids and may be expressed quantitatively as the ratio of the volume of its interstices to its total volume. Also called total porosity.

porosity, effective	Effective porosity refers to the amount of interconnected pore space available for fluid transmission.
potentiometric surface	The potentiometric surface is a surface which represents the static head.
Probable Maximum Flood (PMF)	The hypothetical flood (peak discharge, volume, and hydrograph shape) that is considered to be the most severe reasonably possible, based on comprehensive hydrometeorological application of the Probable Maximum Precipitation (PMP) and other hydrologic factors favorable for maximum flood runoff such as sequential storms and snowmelt.
Probable Maximum Precipitation (PMP)	The estimated depth of precipitation for a given duration, drainage area, and time of year for which there is duration, drainage area, time of year for which there is virtually no risk of exceedence.
proton	An electrically positive elementary particle found in the nucleus of an atom. Also, the nucleus of a hydrogen atom.
quality factor (QF)	The principal modifying factor by which absorbed doses are multiplied to obtain dose equivalents for radiation protection purposes and thus express the effectiveness of absorbed doses on a common scale for all kinds of ionizing radiation. The quality factor depends on the type and energy of the radiation being considered.
rad	A unit of measure for the absorbed dose of radiation. It is equivalent to 100 ergs per gram of material.
radioactive decay chain	A succession of nuclides, each of which transforms by radioactive disintegration into the next nuclide until a stable nuclide results.
radioactivity (radioactive decay)	The property of some nuclides of spontaneously emitting particles or gamma radiation or of spontaneous fission.
radioisotope	A radioactive isotope of an element with which it shares almost identical chemical properties.
radionuclide	A radioactive nuclide.
radium-226 (Ra-226)	A radioactive daughter product of uranium-238. Radium is present in all uranium bearing ores; it has a half-life of 1620 years.
radon-222 (Rn-222)	The gaseous radioactive daughter product of radium-226; it has a half-life of 3.8 days.

radon-daughter product	One of several short-lived radioactive daughter products of radon-222. All are solids.
recharge	Resupply or replenish.
rem	A unit of dose equivalent equal to the absorbed dose in rads times the quality factor times any other necessary modifying factor. It represents the quantity of radiation that is equivalent in biological damage to one rad of x-rays.
Richter scale (magnitude)	A measure of the total energy released by an earthquake.
Riparian	Along the bank of a river or lake.
roentgen	A unit of measure of ionizing radiation in air; one roentgen in air is approximately equal to one rad and one rem in tissue.
secular equilibrium	The condition of a radionuclide decay chain in which the rate of decay of any radioactive product is just equal to its prduction from the previous member of the chain.
slimes	In this report, fine-grained waste materials from uranium ore processing that are mixed with small amounts of water.
soil infiltration rate	The rate at which water enters the soil surface and moves vertically.
soil percolation rate	The rate at which water moves through soil in all directions.
solifluction	The slow viscous downslope flow of saturated soil and other unsorted surficial material; especially the flow occurring at high elevations in regions underlain by frozen ground that acts as a downward barrier to water percolation.
stabilization	The reduction of radioactive contamination in an area to a predetermined level by a standards-setting body such as the EPA by encapsulating or covering the contaminated material.
storage coefficient	The storage coefficient is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

surveillance	The observation of the disposal site for purposes of visual detection of need for custodial care, evidence of intrusion, and compliance with other license requirements.
tailings, uranium mill	The wastes remaining after most of the uranium has been extracted from uranium ore.
thorium-230 (Th-230)	A radioactive daughter product of uranium-238; it has a half-life of 80,000 years and is the parent of radium-226.
thorium-232 (Th-232)	A naturally occurring radioisotope with a half-life of 14 billion years.
transmissivity	Transmissivity is the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.
UMTRA Project	Uranium Mill Tailings Remedial Action Project of the U.S. Department of Energy.
unconfined aquifer	An aquifer without an upper confining layer. Also known as phreatic or water-table aquifers.
uranium-238	A naturally-occurring radioisotope with a half-life of 4.5 billion years; it is the parent of uranium-234, thorium-230, radium-226, radon-222, and others.
water table	The surface of a body of unconfined water at which the pressure is equal to that of the atmosphere.
working level (WL)	A measure of radon daughter products concentrations; technically, it is any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of alpha particles with a total energy of 130,000 million electron volts.
working level-month (WLM)	The exposure resulting from inhalation of air with a concentration of one WL for 170 working hours. Continuous exposure of a member of the general public to one WL for one year results in approximately 53 WLM.
zone, unsaturated	The unsaturated zone is the zone between the land surface and the deepest water table.

ABBREVIATIONS AND ACRONYMS

ADT	Average daily traffic
AEC	U.S. Atomic Energy Commission
atm	Atmosphere; a unit of pressure equal to 30 inches of mercury
BEIR	Advisory Committee on the Biological Effects of Ionizing Radiation of the National Academy of Sciences (also their report)
BFEC	Bendix Field Engineering Corporation, Grand Junction, Colorado
BLM	U.S. Bureau of Land Management
CASA	Complete Archaeological Service Associates, Cortez, Colorado
CDOW	Colorado Division of Wildlife
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
cfs	Cubic feet per second
cfs/ft	Cubic feet per second per foot
Ci	Curie; a unit of radioactivity = 3.7×10^{10} radioactive disintegrations per second
cm	Centimeter; a unit of length = 0.394 inch
cm/sec	Centimeters per second
CO	Carbon monoxide
COE	U.S. Army Corps of Engineers
Cy	Cubic yard; a unit of volume = 27 cubic feet
dBA	Decibels on the A scale; a logarithmically based unit of sound intensity weighted to account for human auditory responses
dbh	Diameter at breast height
dpm/100cm^2	Disintegrations per minute per 100 square centimeters

DOC	U.S. Department of Commerce
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EA	Environmental assessment
EGR	External gamma radiation
EIS	Environmental impact statement
EPA	U.S. Environmental Protection Agency
et al.	And others
°F	Degrees Fahrenheit
FBDU	Ford, Bacon & Davis, Utah, Inc.
fps	Feet per second
FR	Federal Register
ft^2	Square foot; a unit of area equal to 144 square inches
ft	Foot; a unit of length equal to 12 inches
g	Gram; a unit of weight equal to 0.035 ounce; also a measure of acceleration where 1 g equals 32 feet per second per second
gpd	Gallons per day
gpm	Gallons per minute
g/s	Grams per second
HC	Hydrocarbon
hr	Hours
i.e.	That is (to say)
ISCST	Industrial Source Complex Short-Term dispersion model; an air quality computer code
km	Kilometer; one thousand meters
kw	Kilowatt; one thousand watts

kwh	Kilowatt-hours
l	Liter; a unit of volume equal to 1.057 quarts
lb	Pound; a unit of weight equal to 16 ounces
lb/cy	Pounds per cubic yard
lb/hr	Pounds per hour
lb/mile	Pounds per mile
L_{eq}	Equivalent sound level measured in decibels
LLD	Lower limit of detection
m	Meter; a unit of length equal to 3.28 feet; also milli, a prefix meaning one-thousandth (1/1000 or 10^{-3})
m^2	Square meter, a unit of area equal to 10.76 square feet
MeV	Million electron volts
mg/l	Milligrams per liter
mg/m^3	Milligrams per cubic meter
mi	Mile
micro	Micro, a prefix meaning one-millionth (1/1,000,000 or 10^{-6})
microg	Microgram; a millionth of a gram
$microg/m^3$	Micrograms per cubic meter
microR	Microroentgen; a millionth of a roentgen
microR/hr	Microroentgens per hour
mg	Milligram; a thousandth of a gram
mgd	Million gallons per day
MPC	Maximum Permissible Concentration
mph	Miles per hour
mR/hr	Milliroentgens per hour

MSL	Mean Sea Level
NAAQS	National Ambient Air Quality Standards
NAS	National Academy of Sciences
NEPA	National Environmental Policy Act of 1969 (PL91-190)
NOAA	National Oceanic and Atmospheric Administration, U.S. Department of Commerce
NO_x	Nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
NRHP	National Register of Historic Places
p	Pico, a prefix meaning one trillionth (1/1,000,000,000,000 or 10^{-12})
Pb-210	Lead-210
pCi/g	PicoCuries per gram
pCi/l	PicoCuries per liter
pCi/m^2s	Picocuries per meter squared per second
pH	A logarithmic scale of hydrogen-ion concentration, and hence an indication of acidity or alkalinity; pH equal to 7 is neutral; pH less than 7 is acidic; pH greater than 7 is alkaline
PL95-604	Public Law 95-604, Uranium Mill Tailings Radiation Control Act of 1978
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
ppm	Parts per million
R	Roentgen; a unit of gamma radiation equal to one rem
RAC	Remedial Action Contractor
RAECOM	Radon Attenuation Effectiveness Cost Optimization Model

RAP	Remedial Action Plan
Ra-226	Radium-226
RDC	Radon daughter concentration
Rn-222	Radon-222
SHPO	State Historic Preservation Officer
SO_x	Sulfur oxides
T and E	Threatened or endangered species
TDS	Total dissolved solids
Th-230	Thorium-230
Th-232	Thorium-232
TLD	Thermoluminescent dosimeter; a device for measuring radiation
TOC	Total organic carbon
TSP	Total suspended particulates
TSS	Total suspended solids
U-234	Uranium-234
U-235	Uranium-235
U-238	Uranium-238
U_3O_8	Uranium oxide, also called yellowcake
UMTRA Project	Uranium Mill Tailings Remedial Action Project
UMTRCA	Uranium Mill Tailings Radiation Control Act of 1978 (PL95-604)
USFWS	U.S. Fish and Wildlife Service, U.S. Department of the Interior
USGS	U.S. Geological Survey, U.S. Department of the Interior
WL	Working level (a measure of radon daughter product concentration)
WLM	Working level-month (exposure to one WL for 170 hours)

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APPENDIX A

CONCEPTUAL DESIGNS

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A.1 INTRODUCTION

A.1.1 PURPOSE

This appendix provides the information needed to understand the conceptual designs for the remedial action alternatives addressed in the environmental assessment. This appendix is intended to provide sufficient detail for the reader to evaluate the feasibility and assess the environmental impacts of each remedial action alternative. However, this appendix is not intended to provide the detailed engineering necessary to implement the alternatives. The selected conceptual design is subject to change during the final design process.

The details of the conceptual design (e.g., radon barrier thickness) for the proposed action are based upon field studies, laboratory testing, and various modeling techniques. The data and calculations for these details are available in the draft Remedial Action Plan (RAP) (DOE, 1987). In addition, the Technical Approach Document (TAD) (DOE, 1986) describes the general approaches and design criteria that have been adopted by the U.S. Department of Energy (DOE) in order to prepare a RAP and final design that comply with the U.S. Environmental Protection Agency (EPA) standards. For the alternative design, assumptions regarding various factors (e.g., soil type and availability) have been made based upon the data and calculations applicable to the proposed action.

A.1.2 DESIGN OBJECTIVES

The purpose of the remedial action is to stabilize and control the uranium mill tailings (residual radioactive wastes) and other contaminated materials in a manner which complies with the EPA standards (40 CFR Part 192). Consistent with EPA Standards, the following major design objectives have been established:

- Reduce the average radon flux from the site to 20 picocuries per square meter per second (pCi/m^2s), or 0.5 picocurie per liter (pCi/1), above background levels outside the disposal site.

- Design controls to remain effective for up to 1000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.

- Prevent inadvertent human intrusion into the stabilized tailings.

- Minimize plant root penetration and burrowing by animals into the stabilized tailings.

- Ensure, to the extent practicable, that existing or anticipated beneficial uses of surface and ground waters are not adversely affected.

- Reduce radium-226 (Ra-226) concentrations in areas released for unrestricted use to five picocuries per gram (pCi/g) averaged in the first 15 centimeters (cm) of soil below the surface and 15 pCi/g averaged in 15-cm thick layers of soil more than 15 cm below the surface.

- Make a reasonable effort to achieve, in any occupied or habitable building, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 working level (WL). In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL, and the level of gamma radiation shall not exceed the background level by more than 20 microroentgens per hour (microR/hr).

- Minimize the land area to be occupied by the stabilized tailings.

- Protect against releases of contaminants from the site during construction.

- Minimize the areas disturbed during construction, and minimize human exposure to contaminated materials.

The conceptual design discussed in this Appendix will meet these design objectives.

A.2 PROPOSED ACTION - STABILIZATION ON SITE

A.2.1 PRESENT CONDITIONS

The tailings and contaminated materials exist at two locations along the Dolores River: the Union Carbide (UC) site and the North Continent (NC) site (Figure A.2.1). The designated UC tailings site covers 81.5 acres including the tailings pile, evaporation ponds, and the former mill and ore storage areas. The tailings pile covers approximately 17 acres, has a volume of approximately 344,000 cubic yards (cy), and is partially surrounded by a fence. Approximately 72,100 cy of tailings and contaminated material covering 41 acres are contained in the evaporation ponds and former mill and ore storage areas. Dispersion of the tailings by wind and water has contaminated the remainder of the designated site (24 acres) and an additional 66.5 acres. These areas contain approximately 113,000 cy of contaminated material. The total volume of contaminated material at the UC site is estimated to be 565,100 cy covering 148 acres. The UC tailings also lie in the modern floodplain of the Dolores River within a large meander bend. The tailings overlap from one terrace level to the level that forms the overbank area west of the main river channel.

Approximately 97,000 cy of tailings and contaminated materials are present at the NC site. The designated NC site covers 24.5 acres. The tailings pile covers approximately two acres and windblown and

Figure A.2.1 Locations of the Slick Rock tailings sites near Slick Rock, Colorado

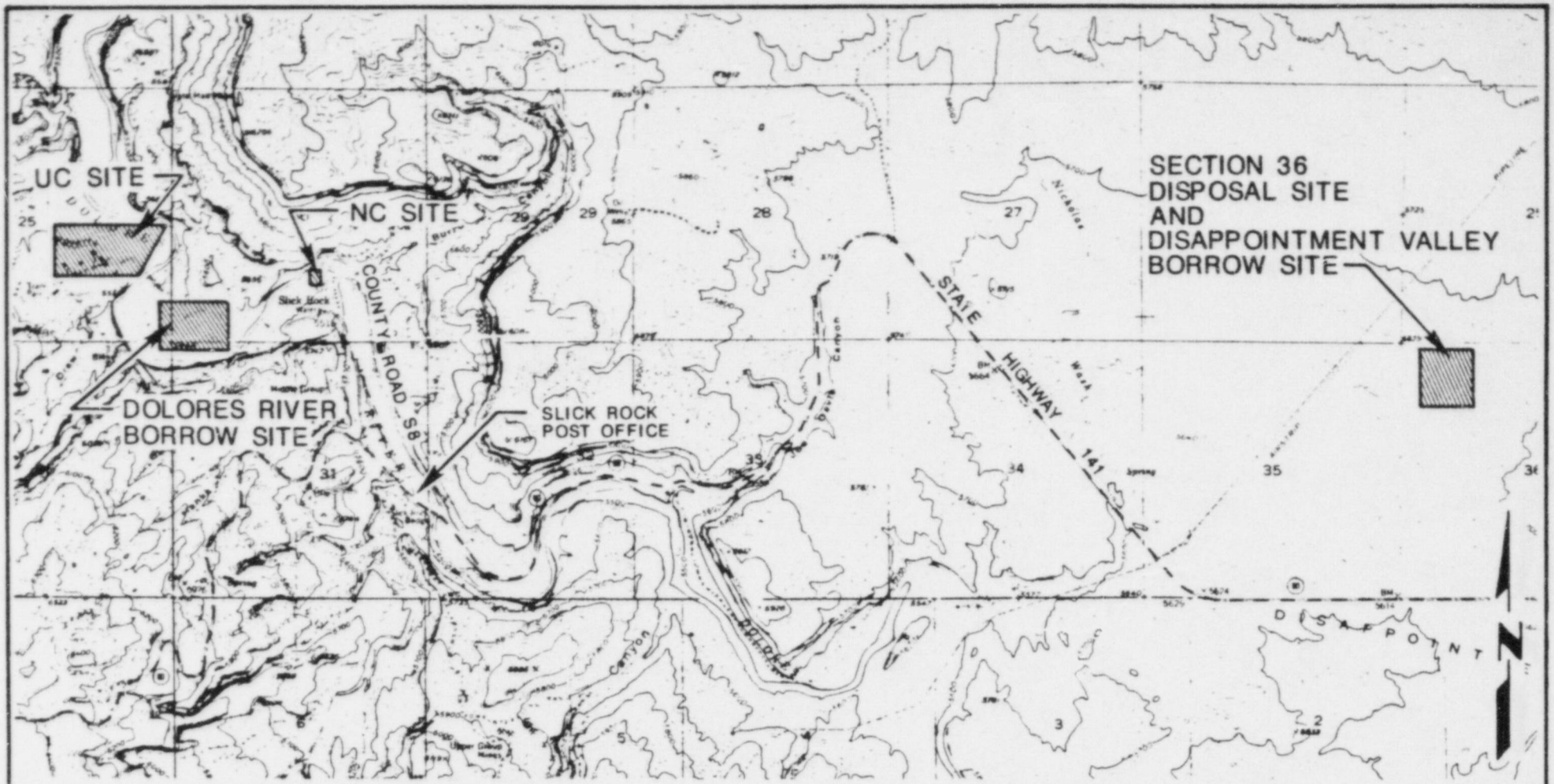


FIGURE A.2.1
LOCATION OF THE SLICK ROCK TAILINGS PILES NEAR SLICK ROCK, COLORADO

waterborne contaminated material is spread over an additional 44 acres. The pile is on a moderately vegetated terrace that forms a portion of the west bank of the Dolores River within a large meander bend of the river. The site is approximately 1.2 miles downstream of the Colorado State Highway 141 (C-141) bridge over the river. Limits of contamination at both the UC and NC sites are shown in Figure A.2.2. Seepage from the tailings piles has contaminated ground water in the alluvium beneath the piles.

There are no structures at either designated site with the exception of concrete foundations and stem walls at the UC site. County Road S8 (CR-S8) crosses over the Dolores River approximately 300 feet southeast of the UC pile and bends north along the western boundary of the site. The road provides access to the trailer park 1600 feet southwest of the tailings pile, and the gas sweetener plant 500 feet west of the pile.

A.2.2 FINAL CONDITIONS

The proposed action for the Slick Rock tailings sites is stabilization on site within the UC designated site. Tailings and contaminated material from both sites would be placed in an excavated area southwest of the UC pile between the pile and the trailer park (Figure A.2.3). The base of the excavation would be approximately 60 feet above and 900 feet southwest of the streambed of the Dolores River. The stabilized pile would have sideslopes of 20 percent (five horizontal to one vertical) and topslopes of two to four percent.

Figure A.2.2 Areal extent of Ra-226 soil concentrations exceeding 5 pCi/g at Slick Rock tailings sites, Slick Rock, Colorado

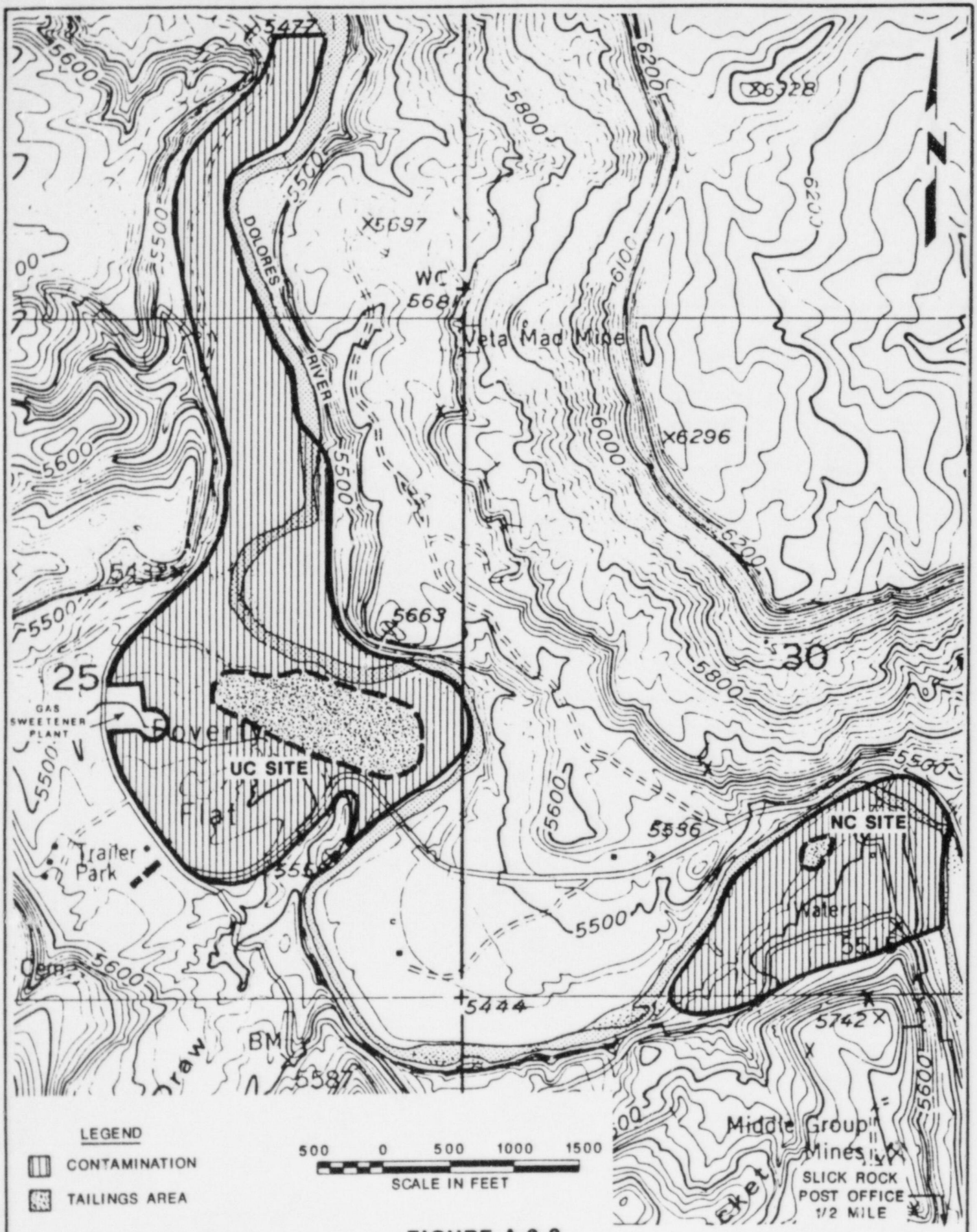


FIGURE A.2.2

AREAL EXTENT OF Ra-226 SOIL CONCENTRATIONS EXCEEDING 5 pCi/g AT SLICK ROCK TAILINGS SITES, SLICK ROCK, COLORADO

Figure A.2.3 Location of the stabilized pile at the Union Carbide site, Slick Rock, Colorado

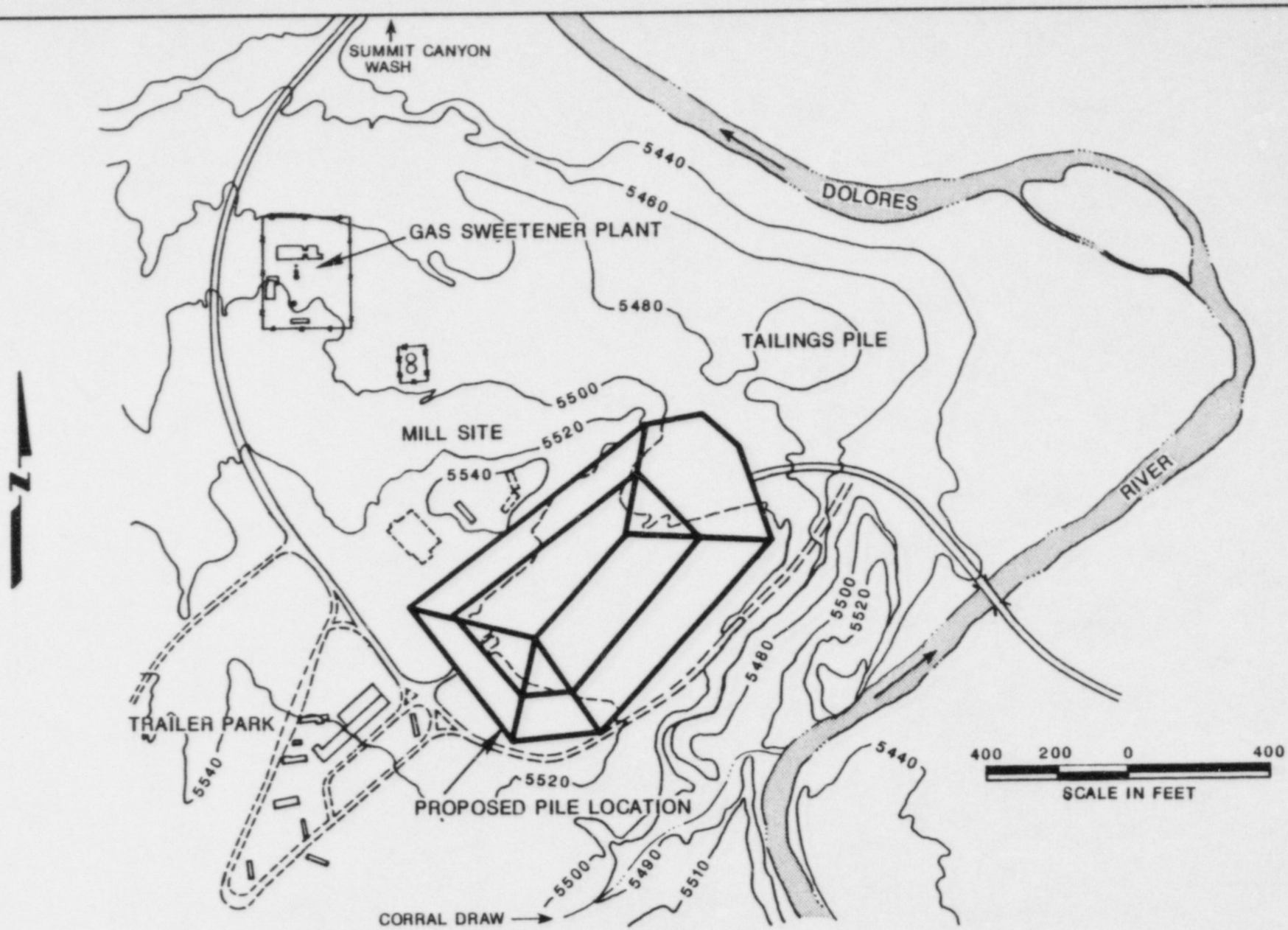


FIGURE A.2.3
LOCATION OF THE STABILIZED PILE AT THE UNION CARBIDE SITE
SLICK ROCK, COLORADO

The tailings and contaminated materials would be covered with a two-foot-thick layer of compacted earth to inhibit radon emanation. The topslopes and sideslopes would be covered with a two-foot-thick layer of sand, gravel, and small rock for erosion protection and the associated bedding and filter layers. The rectangular pile would cover approximately 13 acres and measure approximately 1050 feet by 620 feet. The pile would rise a maximum of 50 feet, averaging 41 feet above the surrounding terrain. The below-grade excavation would average 22 feet, extending to a maximum of 30 feet below the existing surface.

The stabilized tailings pile would be surrounded by a below-grade, tapered rock apron, except on the north end where the pile would tie into a bedrock outcrop. The rock apron would be keyed to bedrock to protect against potential gully intrusion or formation along the sides of the pile. The apron would be approximately five feet wide, would extend to bedrock, and would be constructed at a three to one slope. The proposed pile configuration and a typical cross section are illustrated in Figures A.2.4 and A.2.5, respectively.

The areas of the existing tailings piles, the former mill site, and ore storage areas would be restored with uncontaminated fill from the disposal site excavation and revegetated. All disturbed areas within the Dolores River floodplain would be restored and revegetated. The final restricted area would cover approximately 15 acres and would be enclosed by a perimeter fence if required. The remainder of the designated sites would be released for any use consistent with existing land use controls following completion of remedial action.

Figure A.2.4 Proposed pile configuration for the proposed action, Slick Rock, Colorado

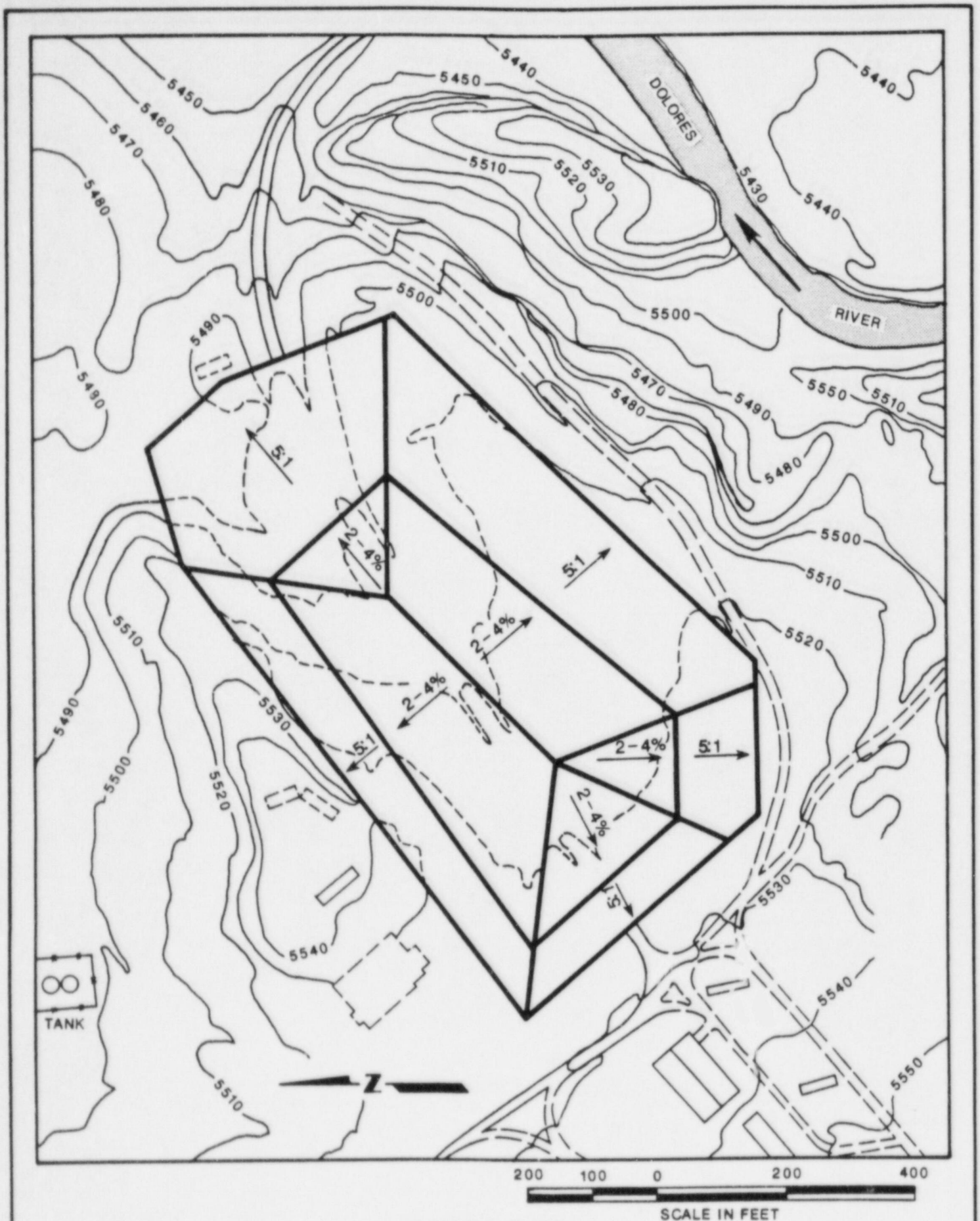


FIGURE A.2.4

PROPOSED PILE CONFIGURATION, STABILIZATION ON SITE, SLICK ROCK, COLORADO

Figure A.2.5 Typical cross section for the proposed action, Slick Rock, Colorado

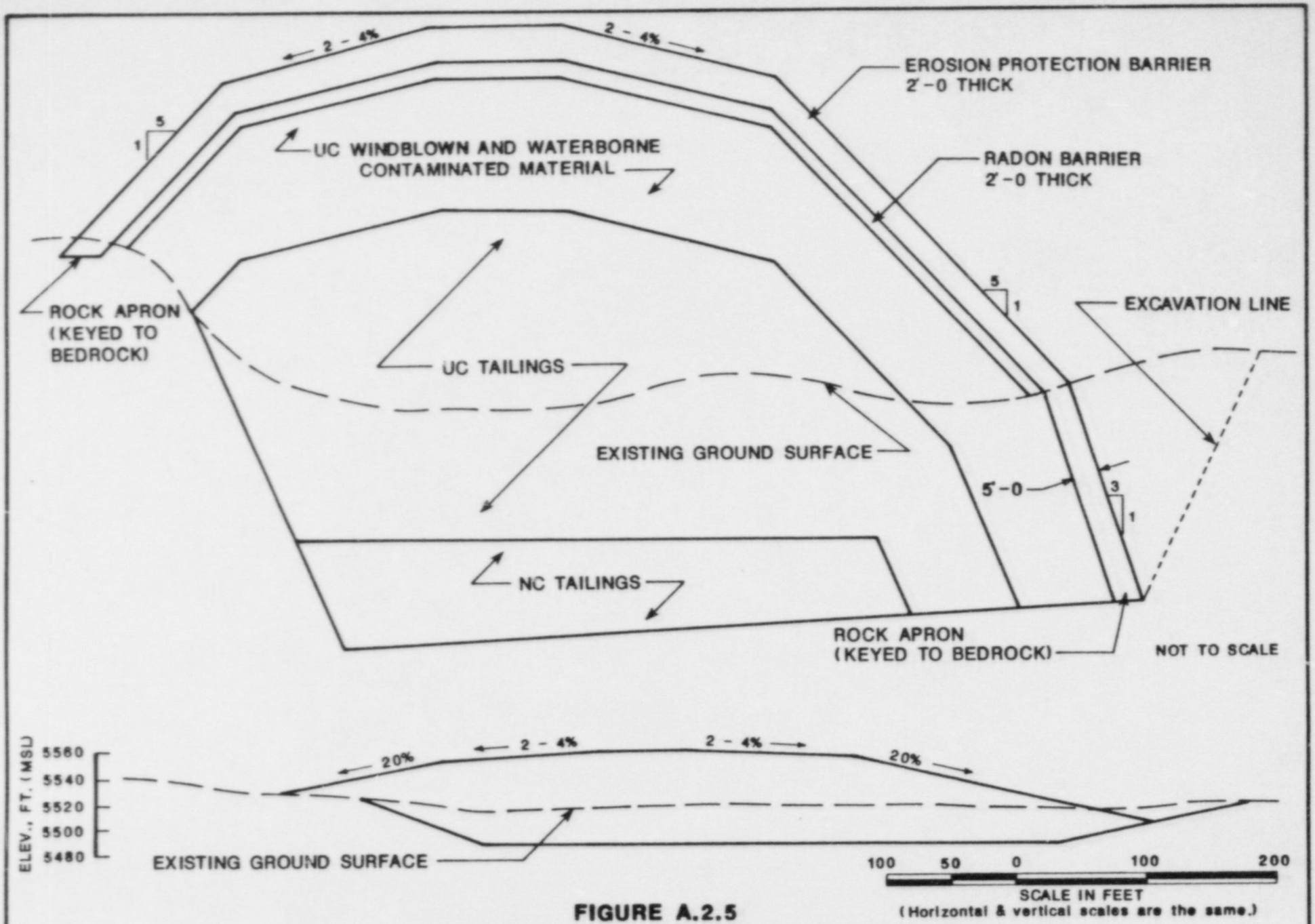


FIGURE A.2.5
TYPICAL CROSS SECTION, STABILIZATION ON SITE
SLICK ROCK, COLORADO

A.2.3 MAJOR CONSTRUCTION ACTIVITIES

The major feature of the stabilization on site conceptual design is the consolidation of all tailings and contaminated materials associated with the Slick Rock sites on the terrace level overlooking the existing UC tailings pile. The tailings would be stabilized in a partially below-grade pile. The base of the disposal area excavation would be scarified and moisture conditioned. The tailings and other contaminated materials would be placed and covered with a layer of earthen material (radon barrier) to inhibit radon emanation, water infiltration, and plant root penetration. The earthen material would be excavated from the Disappointment Valley borrow site approximately nine road miles east of the disposal area (Figure A.2.1). Material from the Dolores River borrow site, approximately 0.75 road mile east of the UC site, would be used to upgrade the temporary haul roads, to construct a filter and bedding layer to be placed over the radon barrier, and to construct the erosion-protection layer. Rock from this borrow site would also be used to construct the rock apron. It should be noted that the borrow sites included in this EA were selected as the sources of the necessary borrow materials for impacts analyses purposes. Although the borrow sites to be used for the remedial action will be selected during the final design, the impacts identified for borrow sites included in this EA are conservative and represent a realistic upper limit on the severity of the impacts that may occur.

Stabilization on site would require the following major construction activities:

Site preparation

- Upgrading and construction (where required) of access roads at the tailings, disposal, and borrow sites. Upgrading of the haul road from the NC site and the borrow sites as required.

- Construction of a temporary bridge over the Dolores River from the NC site to CR-S8.

- Relocation of on-site utilities and CR-S8.

- Construction of a decontamination pad, equipment storage area, and contractor facilities at the UC site and erection of a security fence around these areas.

- Construction of a decontamination pad and erection of a security fence at the NC site.

- Construction of waste-water retention ponds.

- Construction of drainage control measures to direct all generated waste-water and storm-water runoff to the retention ponds at both sites during remedial action.

- Installation of erosion-control measures for all disturbed areas.

Tailings relocation

- Excavation of the disposal area including placement of excavated material in a stockpile for later use as restoration material.

- Excavation, relocation by truck, and consolidation of all the tailings and contaminated materials from the NC site in the disposal area excavation.

- Excavation, relocation, and consolidation of all tailings and contaminated materials from the UC site to the disposal area.

- Even distribution of contaminated debris and grubbed vegetation within the consolidated tailings and contaminated materials.

Radon barrier

- Excavation, haulage, and placement of a two-foot-thick, compacted earthen cover over the relocated, consolidated tailings and contaminated materials.

Erosion protection

- Excavation, haulage, and placement of a six-inch-thick layer of coarse sand and gravel (filter and bedding layer) over the radon barrier.

- Excavation, haulage, and placement of a 1.5-foot-thick layer of rock over the filter and bedding layer on the pile topslopes and sideslopes.

- Excavation, haulage, and placement of a below-grade, tapered rock apron around the base of the stabilized tailings pile.

Site restoration

- Backfilling and grading for drainage control of disturbed areas in the Dolores River floodplain and at both tailings sites.

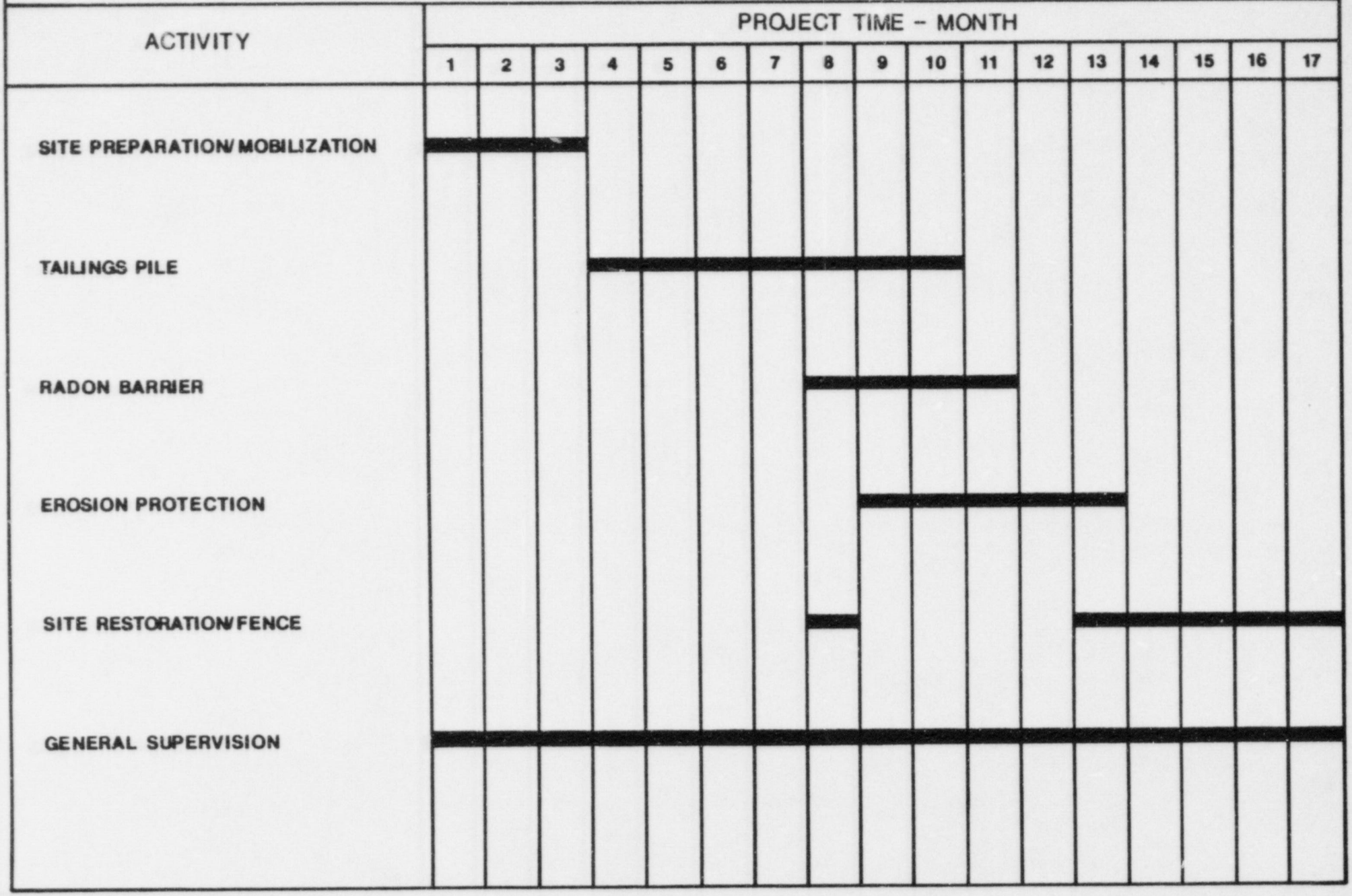
- Revegetation of restored areas at both sites.

- Construction of a security fence around the stabilized tailings pile if required.

A remedial action schedule for stabilization on site is shown in Figure A.2.6.

Figure A.2.6 Remedial action schedule for the proposed action, Slick Rock, Colorado

FIGURE A.2.6 REMEDIAL ACTION SCHEDULE: STABILIZATION ON SITE
SLICK ROCK, COLORADO



A.2.4 MAJOR DESIGN CONSIDERATIONS

Pile layout

Several pile layouts and locations were evaluated in determining the proposed conceptual design. Pile sideslopes from six to 20 percent were analyzed. Efforts were made to minimize the areal extent of the pile while maximizing the below-grade disposal capacity and to minimize the rock sizes required for erosion protection on the sideslopes as well as for protection from off-pile flows.

The proposed stabilization on site location places the stabilized pile out of the Probable Maximum Flood (PMF) floodplain of the Dolores River, Summit Canyon Wash, and Corral Draw (Figure A.2.3). Advantages of this location are its proximity to the majority of the contaminated material thus requiring minimal truck haulage, and its proximity to existing access roads for importing borrow and NC contaminated materials.

The pile layout is designed to effectively use the site area in order to minimize off-site material requirements. This would be accomplished by the partial below-grade disposal which would minimize the amount of imported cover material required and by placing lesser contaminated material on the top of the pile which would minimize the radon-barrier thickness. In addition, the uncontaminated excavated material would be used for restoration and therefore eliminate the need to obtain restoration material off the site.

Geomorphic

One concern for long-term site stability is the potential for erosion from a shallow wash in the trailer park area and from along the edge of Corral Draw. In addition, shifting of the Dolores River channel may place a future channel closer to the site than the current channel, but such a channel would not reach the disposal site.

A small ephemeral wash draining the surface runoff from the trailer park area of Poverty Flats passes through the center of the proposed tailings site. The wash is a shallow gully and no active arroyo formation is occurring. Placement of the stabilized tailings pile between the bedrock ridges would eliminate the gully. Surface runoff from the small area near the trailer park would be routed away by the armored pile edge. In addition, the pile perimeter would be graded so that runoff would not approach the pile.

Accelerated erosion is occurring in the upper three to eight feet of sandy silt and alluvial gravel overlying the firmly cemented coarse terrace gravels along Corral Draw near the southwest side of the proposed disposal site. The rate of erosion should be reduced when the firmly cemented gravels beneath the sandy eolian and alluvial deposits are encountered. Proper setback and bank armoring of the pile would prevent future erosion along Corral Draw from affecting the stabilized pile (see Section B.1 of Appendix B, Hydrology).

Channel shifting of the Dolores River probably will occur within the design life of the tailings pile. The recent alluvial terrace along the present river channel consists of fine-grained silt, sand, and gravel, and is subject to flooding and erosion. This terrace lies approximately 600 feet from the proposed disposal site. In addition, the high sandstone bedrock ridge south of the disposal site separates the river from the site area and also deflects the river flow away from the disposal site. No river erosion would occur through the ridge.

In the unlikely event that large volumes of surface runoff do impact the pile, the rock apron would prevent erosion of the tailings pile and protect the area beneath the pile from gully intrusion. (See Erosion Protection section, below.)

Seismicity

The seismotectonic study area around the Slick Rock sites includes portions of the Colorado Plateau interior and the more active regions of the Rio Grande Rift, the Arizona Basin and Range province, and the Intermountain Seismic Zone. Details regarding the seismotectonic study at the Slick Rock sites are in DOE, 1987. This study analyzed all the capable faults within a 40-mile radius of the Slick Rock sites and the design earthquake for these sites was determined to be a magnitude 6.2 event occurring at a distance of 9.3 miles (15 kilometers) from the site. Such an event might occur as a "floating" earthquake not associated with a known tectonic structure. The resulting free field,

nonamplified, peak horizontal bedrock acceleration at the site is estimated to be 0.21g. Due to the shallow depth to bedrock this is also considered the site ground surface acceleration.

Geohydrology

The principal design features for ground-water protection are:

- The relocation of the tailings and contaminated materials from the floodplain of the Dolores River onto the unsaturated, low-permeability bedrock.

- Placement of a sloping, low-permeability infiltration barrier that would cover the tailings.

Relocation of the tailings would prevent alluvial ground water from contacting the tailings during times of large flows in the Dolores River and would also remove the source of tailings leachate, thereby preventing further contamination of the alluvial ground water at the current tailings sites. (See Section B.2, Appendix B, Hydrology.) The sloping, low-permeability barrier installed on the top and sides of the recontoured tailings would reduce infiltration.

The Entrada Sandstone below the disposal area is unsaturated and would separate the stabilized pile from the underlying, confined Navajo Sandstone aquifer. Depth to water beneath the disposal site would be

approximately 60 feet. The unsaturated sandstone, conglomerate, mudstone, and shale beneath the site would act as a physical and chemical buffer to any potential tailings seepage. The amount of leachate that may eventually drain out of the stabilized tailings pile and toward the Dolores River alluvial aquifer would be small and would have very little or no effect on water quality.

Surface water

The disposal site lies west of and at an elevation approximately 70 feet above the modern floodplain of the Dolores River. Other surface-water features in the site area include the ephemeral washes flowing to the river from Corral Draw upstream of the pile and Summit Canyon downstream of the pile. Detailed descriptions of surface-water characteristics in the project area and the flood analyses are presented in Section B.1 of Appendix B, Hydrology.

The watershed to the proposed pile location consists of approximately 35 acres of relatively flat terrain. Flows from this area are directed around the disposal area by shallow gullies and the drainage channels forming alongside CR-S8 and the dirt roads near the disposal area.

After remedial action, flow would be directed away from the pile by grading the pile perimeter. Under extreme runoff conditions (i.e., approaching discharges associated with a Probable Maximum Precipitation

(PMP)), the discharge would overflow the drainage features and may impinge upon the stabilized pile. The discharge resulting from a PMP over the upland area was used to determine the erosion-protection requirements for the rock apron (see Erosion Protection, below). In addition, the placement of diversion ditches upstream of the pile was considered but eliminated because the size of ditches required and the transition of flow from ditches to existing channels would require large quantities of material that would not be warranted by these small design discharges.

Geotechnical

Slope stability, liquefaction, and settlement of the stabilized pile were analyzed using material properties determined from laboratory testing or estimated values of the soils and bedrock.

Stability analyses were performed using the design parameters shown on Table A.2.1. In addition, a sensitivity analysis of the tailings strength parameters was performed in order to confirm the stability of the slope. This comparison is shown as the angle of internal friction or cohesion required to provide the minimum acceptable factors of safety within the slope. As a result of these analyses, the slopes would remain stable as shown by the factors of safety and the sensitivity analyses on the strength of the pile materials (Table A.2.1).

Table A.2.1 Results of slope stability analysis

Table A.2.1 Results of slope stability analysis

		Material properties used in analysis										
		Erosion cover & natural gravels		Radon cover		In-situ foundation sand and bedrock[a]		Compacted tailings				
Condition analyzed	Seismic coefficient (k)	Moist unit weight (pcf)	Strength ϕ,c(psf)	Moist unit weight (pcf)	Strength ϕ,c(psf)	Moist unit weight (pcf)	Strength ϕ,c(psf)	Moist unit weight (pcf)	Strength ϕ,c(psf)	Calculated safety factor	Minimum required safety factor	Minimum required ϕ,c(psf)
End of construction static	0.0	130	37.0	133	0,1050	95	25,230	102	35.5.0	3.9	1.3	0,575
End of construction with earthquake	0.10	130	37.0	133	0,1050	95	25,230	102	35.5.0	2.5	1.0	0,670
Long-term static	0.0	130	37.0	133	31,0	95	31,0	102	35.5.0	3.5	1.5	15.75,0
Long term with earthquake	0.14	130	37.0	133	31,0	95	34,0	102	35.5.0	2.0	1.0	19.0,0

[a]Bedrock assumed to be hard bottom in stability analysis.

There is no potential for liquefaction at the disposal site since the ground water is deep within bedrock and the alluvial aquifer does not exist beneath the disposal area. There would be no perched or raised water table in the pile during the design life. The tailings will be placed as a compacted and engineered fill and have densities well above the threshold of values below which liquefaction occurs.

A preliminary evaluation of settlement has been completed for the proposed action using available data (DOE, 1987). The analyses show that all settlement due to pile construction will occur during construction. Secondary settlement will continue at a decelerating rate throughout the design life. The total calculated secondary settlement is less than 0.25 foot. Tensile strains in the radon cover as a result of this settlement will be well below those which could cause cover cracking.

Radon/infiltration barrier

Data on the distribution of radium in the tailings and other contaminated materials and the physical properties of the locally available earthen material were used in the RAECO Model (NRC, 1984) to estimate the thickness of the radon barrier necessary to control radon emanation to meet the EPA standard. According to this analysis, radon emanation could be controlled to meet the standard by using the following techniques:

- o Decontamination of the site by excavating and placing lesser contaminated materials (i.e., windblown tailings, contaminated alluvium) on top of the relocated tailings.

- o Placement of a two-foot-thick, compacted earthen cover over the consolidated tailings and contaminated materials.

Erosion protection

The rock layer on the pile top and sideslopes has been designed to prevent erosion due to runoff resulting from the one-hour PMP on the pile. The erosion protection required on the pile sideslopes to resist flow off the pile was compared to that required to resist flow from the upland area and the greater of the two was specified for the entire pile sideslopes.

A design discharge of 216 cubic feet per second (cfs) was determined for the upland watershed using methods outlined in DOE, 1986. This flow was used to determine rock size requirements along the north side of the pile adjacent to the northernmost bedrock ridge. The rock required to resist erosion at the base of the pile along this face was greater than that required to resist erosion from flow off the pile and was therefore specified for the entire pile sideslopes.

Erosion-protection requirements, layer thickness, design velocities, and design discharge for the conceptual design are summarized in Table A.2.2.

Table A.2.2 Erosion protection requirements for the proposed action, Slick Rock, Colorado

Location	Rock size requirements (inches)	Layer[a] thickness (feet)	Design velocity (feet per second)	Design discharge
Topslopes	$D_{50} \geq 1.5$ $D_{100} \leq 5.0$	2.0	2.43	0.250 cfs/ft
Sideslopes	$D_{50} \geq 4.0$ $D_{100} \leq 10.0$	2.0	9.36	216 cfs

[a]Includes bedding and filter layer. Actual bedding and filter gradation requirements and layer thicknesses will be determined during final design using the methods and criteria presented in the TAD (DOE, 1986). For conceptual design purposes it was assumed that a six-inch bedding and filter layer will be required.

The erosion barrier serves to resist the impacts of wind and water erosion. These forces are greatest during the PMP, which is the design event. The maximum PMP rainfall intensity was determined using charts and tables from Hansen et al., 1977. The local one-hour PMP for the site was calculated to be 8.3 inches. This value was converted to a maximum intensity based on the time of concentration (t_c) for flow off the pile. The t_c and corresponding maximum intensity were 2.5 minutes and 54.8 inches per hour for the sideslopes, respectively.

The required rock size for the embankment top slopes was determined using the Safety Factors Method (Stevens et al., 1976). This method is detailed in DOE, 1986.

In addition to the erosion barrier, a rock apron will be constructed around the entire toe of the pile except on the north side where the pile erosion protection would tie into bedrock. This apron would protect the toe against any headcutting as a result of the runoff from a PMP or any lesser storm event and protect against erosion from sheet flow off the sides of the pile. The rock apron will take the form of a buried riprap wall extending to competent bedrock and provide a continuous, erosion resistant surface to ensure the integrity of the tailings pile. Extending the apron to bedrock would not cause construction difficulties or increases in project costs. The volume of material required to construct the apron is not excessive since the lateral extent of the pile perimeter is not extensive.

The apron was designed at a slope of three horizontal to one vertical. Critical design parameters and subsequent erosion protection requirements were specified for the entire apron as summarized in Table A.2.3.

Table A.2.3 Erosion protection for rock apron for the proposed action, Slick Rock, Colorado

Rock size requirements (inches)	Layer thickness (feet)	Design velocity (feet per second)	Design discharge (cubic feet per second)
$D_{50} \geq 6.0$ $D_{100} \leq 14.0$	5.0	8.0	261

A.2.5 CONSTRUCTION ESTIMATES

Preliminary estimates of equipment and personnel requirements; fuel, energy, and water consumptions; major earthwork volumes; and construction costs for the proposed action are summarized in Tables A.2.4 through A.2.10.

Table A.2.4 Equipment requirements for the proposed action at the Slick Rock, Colorado, sites

Type of equipment	Pieces of equipment per month of remedial action																	Total Equipment-months
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Compactor-825C	1	1	1	0	0	0	0	5	5	5	1	1	1	1	2	2	2	28
Dozer-D8	7	7	1	6	6	12	12	8	8	8	0	1	1	0	0	0	0	77
Loader	1	1	1	0	0	2	2	3	5	5	3	0	1	1	1	0	0	26
Grader	1	1	1	0	0	1	1	8	8	8	1	1	2	2	4	3	3	45
Scraper	1	1	1	4	4	4	4	10	10	10	0	0	0	0	4	4	4	61
Truck-10 cy	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Truck-20 cy	0	0	0	0	0	7	7	12	17	17	6	0	6	6	6	0	0	84
Water truck	1	1	1	0	0	0	0	5	5	6	1	1	1	1	2	2	2	29
Seeder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
Crane	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Total	14	14	7	10	10	26	26	51	58	59	12	4	12	11	19	12	12	357

Table A.2.5 Personnel requirements for the proposed action at the Slick Rock, Colorado, sites[a]

Type of personnel	Number of personnel per month of remedial action																	Total man months
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Truck drivers	2	2	2	0	0	7	7	17	22	23	7	1	7	7	8	2	2	116
Equipment operators	12	12	5	10	10	19	19	34	36	36	5	3	5	4	11	10	10	241
Operator supervision	2	2	1	1	1	2	3	5	6	6	2	1	1	2	2	2	2	41
Field services and general supervision	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	340
Laborers	1	8	7	7	7	9	11	14	16	17	8	6	6	8	9	8	0	142
Mechanics	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	102
Total	43	50	41	44	44	63	66	96	106	108	48	37	45	47	56	48	40	982

[a]Personnel requirements based on one eight-hour shift per day, five days per week.

Table A.2.6 Fuel consumption summary for the proposed action at the Slick Rock, Colorado, sites

Type of Equipment	Gallons consumed
Compactor	37,700
D8 bulldozer	95,700
Loader	13,500
Grader	23,300
Scraper	88,500
Truck–10 cy	1,200
Truck–20 cy	60,900
Water truck	9,000
Seeder	600
Crane	1,700
Total Consumption	332,100

Table A.2.7 Energy consumption summary for the proposed action at the Slick Rock, Colorado, sites

Facility	Kilowatt hours consumed
Field offices	35,000
Change/shower trailer	81,000
Laundry	40,000
Total consumption	156,000

Table A.2.8 Water consumption summary for the proposed action at the Slick Rock, Colorado, sites

Activity/facility	Gallons consumed
Compaction	
o North Continent tailings	321,000
o Union Carbide tailings	646,000
o Contaminated materials	777,000
o Radon barrier	1,058,000
o Site restoration	306,000
Compaction subtotal	3,108,000
Drinking/laundry/showers	233,000
Decontamination	282,000
Dust control	1,761,000
Total consumption	5,384,000

Table A.2.9 Summary of major earthwork volumes for the proposed action at the Slick Rock, Colorado, sites

Activity	Estimated in-place cubic yards
SITE PREPARATION	
o Temporary roads	
1. Subbase	8,600
2. Gravel	17,200
o Waste-water retention pond	
1. Excavate	32,000
2. Construct pond berms	8,500
o Drainage facilities	
1. Construct berms	15,200
o Initial earthmoving, contaminated materials	25,000
TAILINGS RELOCATION/PILE CONSTRUCTION	
o Excavate, and stockpile disposal area	294,000
o Excavate, haul, and place NC tailings and contaminated materials	97,000
o Excavate, haul, and place UC tailings	380,000
o Excavate, haul, and place contaminated materials from UC site	185,100
RADON BARRIER	
o Excavate	65,000
o Haul, spread, and compact	42,000
EROSION PROTECTION BARRIER	
o Excavate and screen	10,000
o Haul and place filter and bedding layer	68,300
o Haul and place erosion protection barrier	31,000
o Excavate, haul, and place rock apron	4,300
SITE RESTORATION	
o Backfill excavations	93,000
o Restore NC site	21,000
o Restore UC site	207,000

Table A.2.10 Summary of construction costs for the proposed action at the Slick Rock, Colorado, sites[a]

Activity	Estimated cost in 1987 dollars
Site preparation	1,494,000
Decontamination	86,000
Tailings relocation	874,000
Radon barrier	391,000
Erosion protection barrier	360,000
Site restoration[b]	2,178,000
Total	5,383,000

[a]These estimates do not include the costs of:

- o Property acquisition.
- o Engineering design.
- o Construction management (except field supervision).
- o Overall project management.
- o Long-term surveillance and maintenance.

[b]Includes the cost of a perimeter fence.

A.3 DISPOSAL AT THE SECTION 36 SITE

A.3.1 FINAL CONDITIONS

This remedial action alternative would involve relocation of the tailings and contaminated materials from both existing tailings sites to a disposal excavation in Section 36 (see Figure A.2.1). The stabilized tailings pile would have approximately the same shape as the stabilization on site pile design; other final conditions (e.g., radon and erosion-protection barriers, filter and bedding layer, perimeter apron, and fencing) would be identical or essentially the same as those for the proposed action. The stabilized pile would cover approximately 20 acres and would average approximately 40 feet above the surrounding terrain. The final restricted area would cover approximately 24 acres. Figures A.3.1 and A.3.2 show the proposed pile configuration and a typical cross section for the stabilized pile, respectively. As with the proposed action, disturbed areas at both sites would be restored with uncontaminated fill and revegetated.

A.3.2 MAJOR CONSTRUCTION ACTIVITIES

The major features of this remedial action alternative are the relocation of tailings and contaminated materials from the existing sites and consolidation in a partially below-grade disposal at the Section 36 site. This alternative would require essentially the same

Figure A.3.1 Proposed pile configuration disposal at the Section 36 site, Slick Rock, Colorado

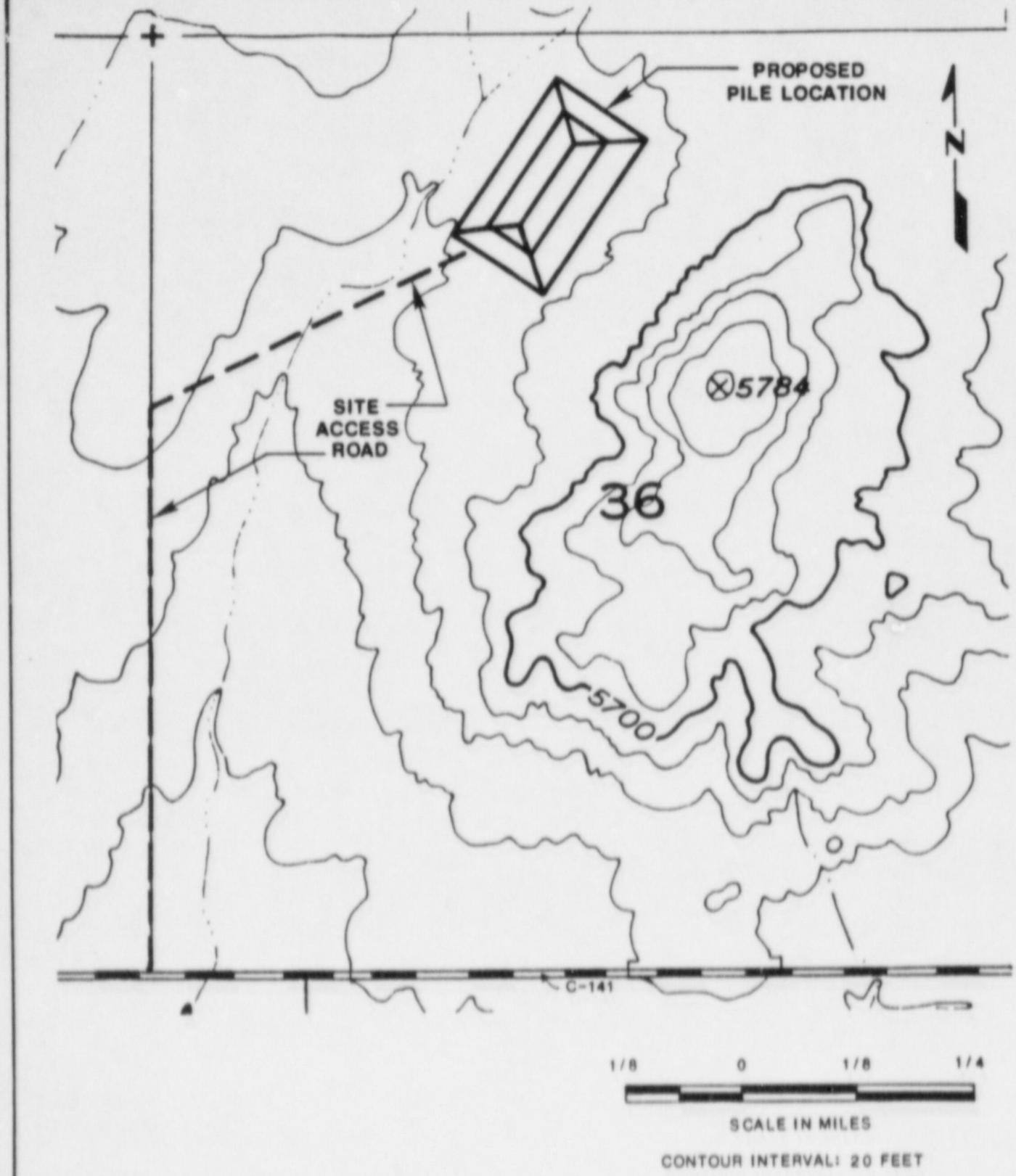


FIGURE A.3.1
PROPOSED PILE CONFIGURATION
AT THE SECTION 36 DISPOSAL SITE
SLICK ROCK, COLORADO

Figure A.3.2 Typical cross section disposal at the Section 36 site, Slick Rock, Colorado

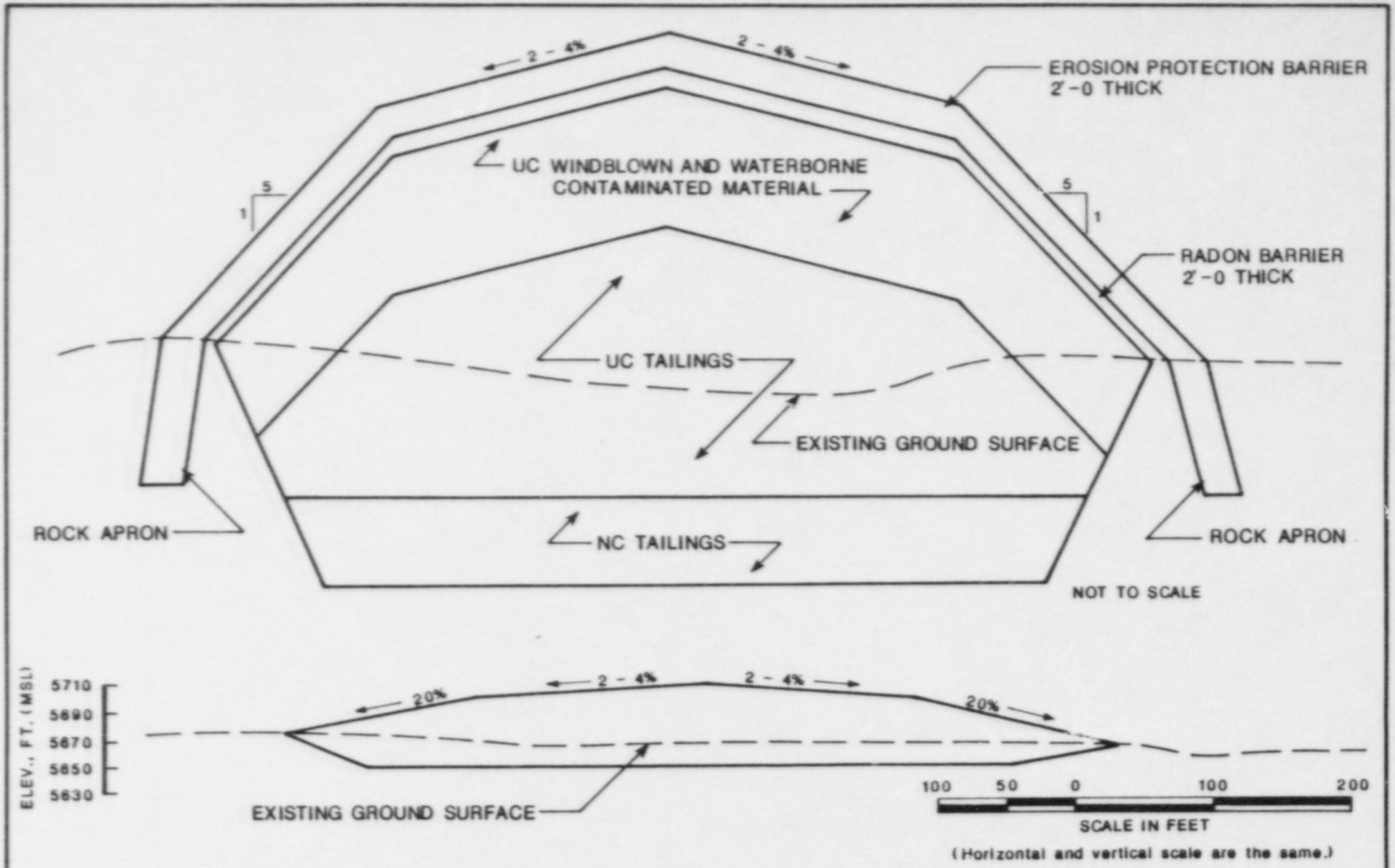


FIGURE A.3.2
TYPICAL CROSS SECTION
AT THE SECTION 36 DISPOSAL SITE
SLICK ROCK, COLORADO

major construction activities as the proposed action (Section A.2.3) except that the NC tailings and contaminated material would be transported to the Section 36 site rather than the UC site. Also, a temporary bridge over the Dolores River would not be required since the NC site contaminated material would be transported to C-141 on the existing, although upgraded, access road. The UC tailings would be transported to C-141 along CR-S8.

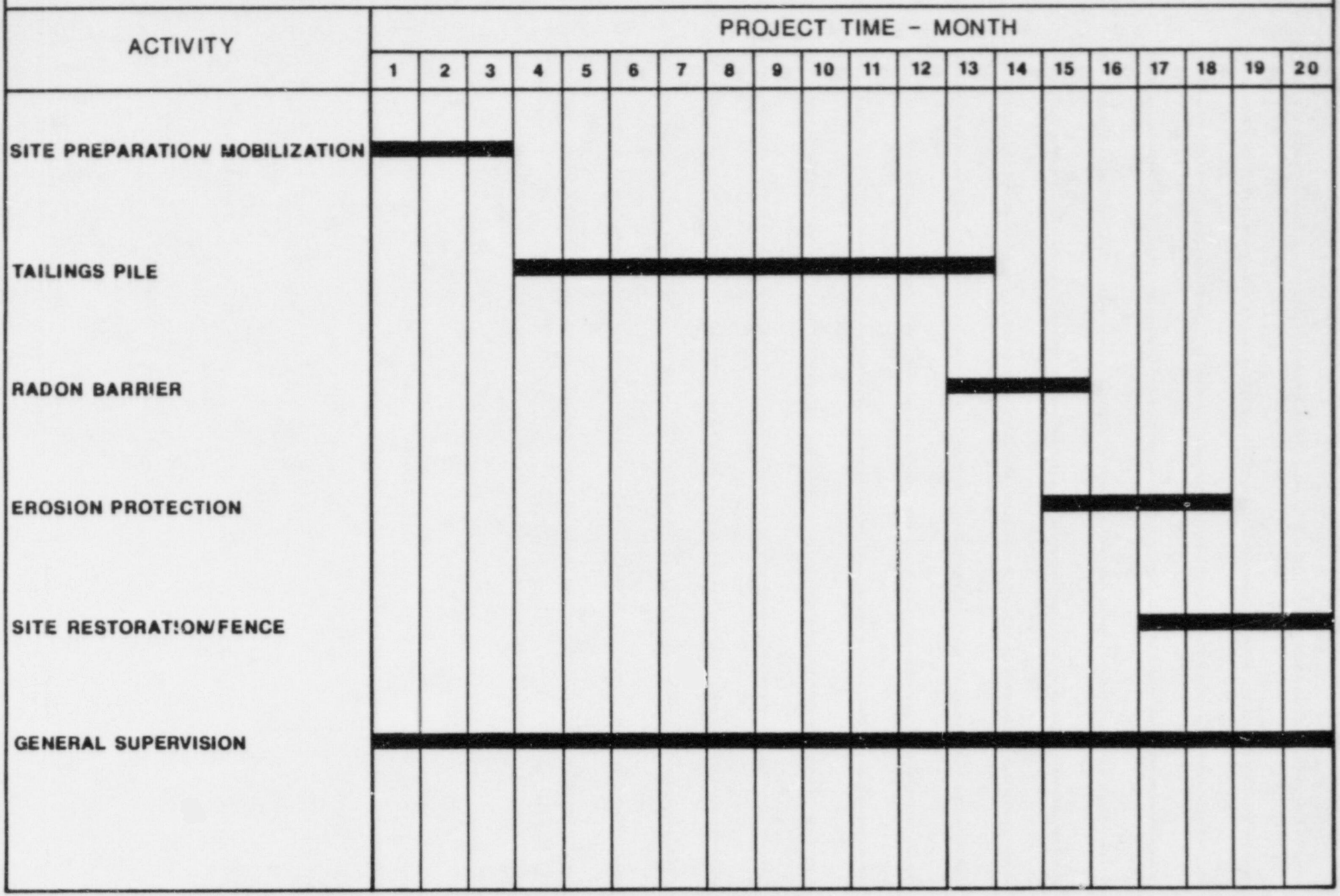
The tailings pile would be constructed in a manner similar to the proposed action. Material from the disposal site excavation would be used as radon barrier material as well as site restoration material. Erosion barrier, filter, and bedding material would be obtained from the Dolores River borrow site. CR-S8 would not be relocated under this alternative. A remedial action schedule for relocation to the Section 36 alternate disposal site is shown in Figure A.3.3.

A.3.3 MAJOR DESIGN CONSIDERATIONS

The location and configuration of the stabilized pile for the relocation to the Section 36 site alternative were dictated by the topography of the area, the subsurface conditions, and the quantity of material required for the radon barrier and restoration. Since the stabilized pile would be placed in the same layering sequence as in the proposed action, the discussion of radon control for the proposed action in Section A.2.4 would be applicable.

Figure A.3.3 Remedial action schedule, disposal at the Section 36 site, Slick Rock, Colorado

FIGURE A.3.3 REMEDIAL ACTION SCHEDULE: SECTION 36 DISPOSAL SITE SLICK ROCK, COLORADO



Most of the design considerations for this alternative were the same or very similar to those for the proposed action.

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APPENDIX B

HYDROLOGY

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B.1 SURFACE WATER

B.1.1 INTRODUCTION

The major surface-water feature related to the remedial action for the Slick Rock tailings sites is the Dolores River (Figure B.1.1). A tributary to the Colorado River, the Dolores River flows in a northwesterly direction in the vicinity of the tailings sites. The river bends sharply to the west as it approaches the NC tailings pile and then to the south as it flows past the site (Figure B.1.2). It then flows west past the Dolores River borrow site and then turns northwestward toward the UC tailings pile. The river is directed to the northeast by a bedrock escarpment approximately 2300 feet upstream of the UC site and then to the north and west by the steep bedrock cliffs directly across the river from the site. Downstream of the UC site, the river is restricted to a northwestern direction by bedrock cliffs along both banks.

A description of the Dolores River drainage basin, historical flows, and a brief discussion on the geology and geomorphology of the river in the Slick Rock sites vicinity are contained in Section B.1.2. The design flood analysis for the Dolores River is presented in Section B.1.3.

Figure 8.1.1 Regional surface-water characteristics near Slick Rock, Colorado

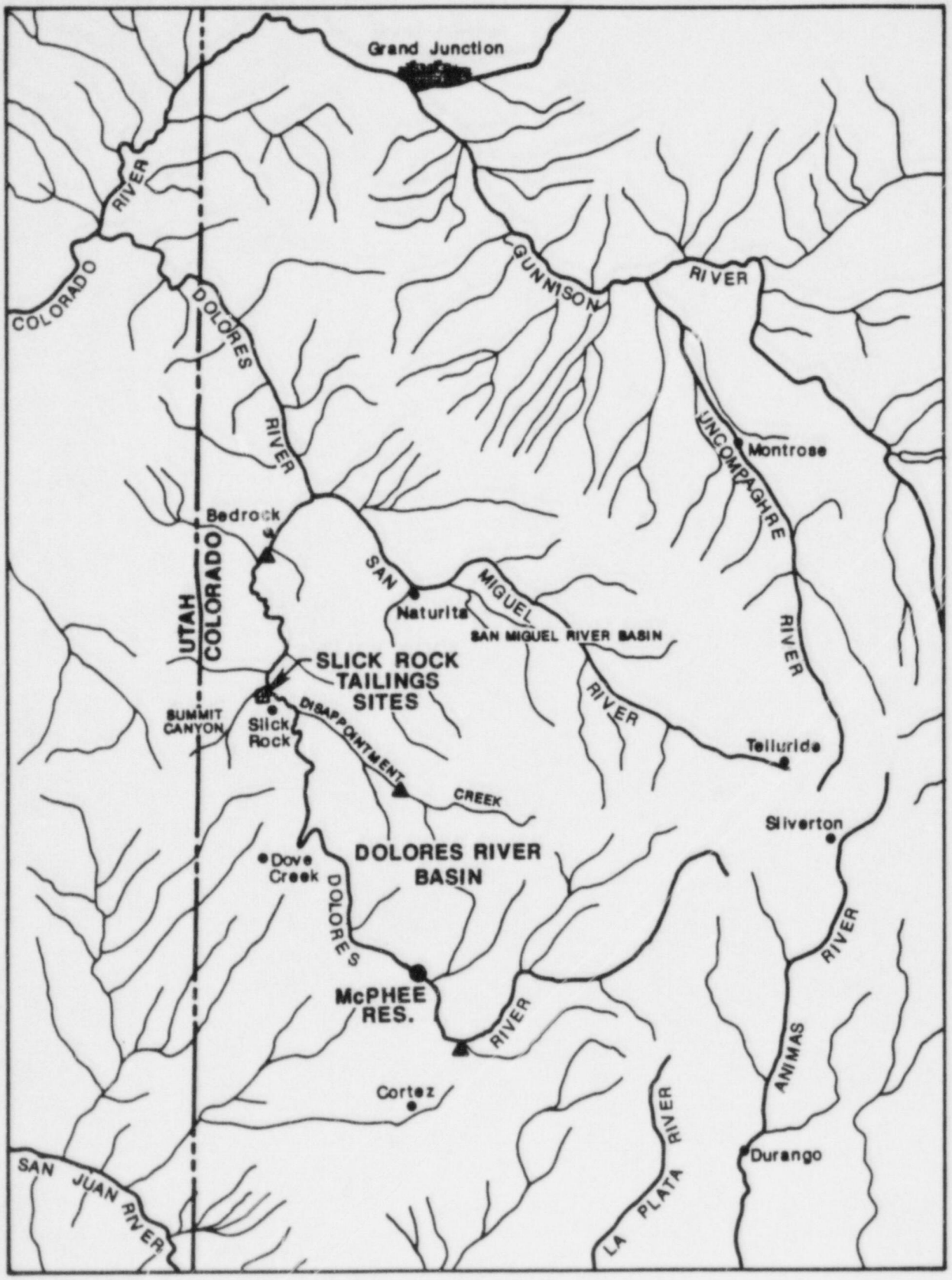

FIGURE B.1.1
REGIONAL SURFACE-WATER CHARACTERISTICS
NEAR SLICK ROCK, COLORADO

Figure B.1.2 Surface-water characteristics at the Slick Rock sites, Slick Rock, Colorado

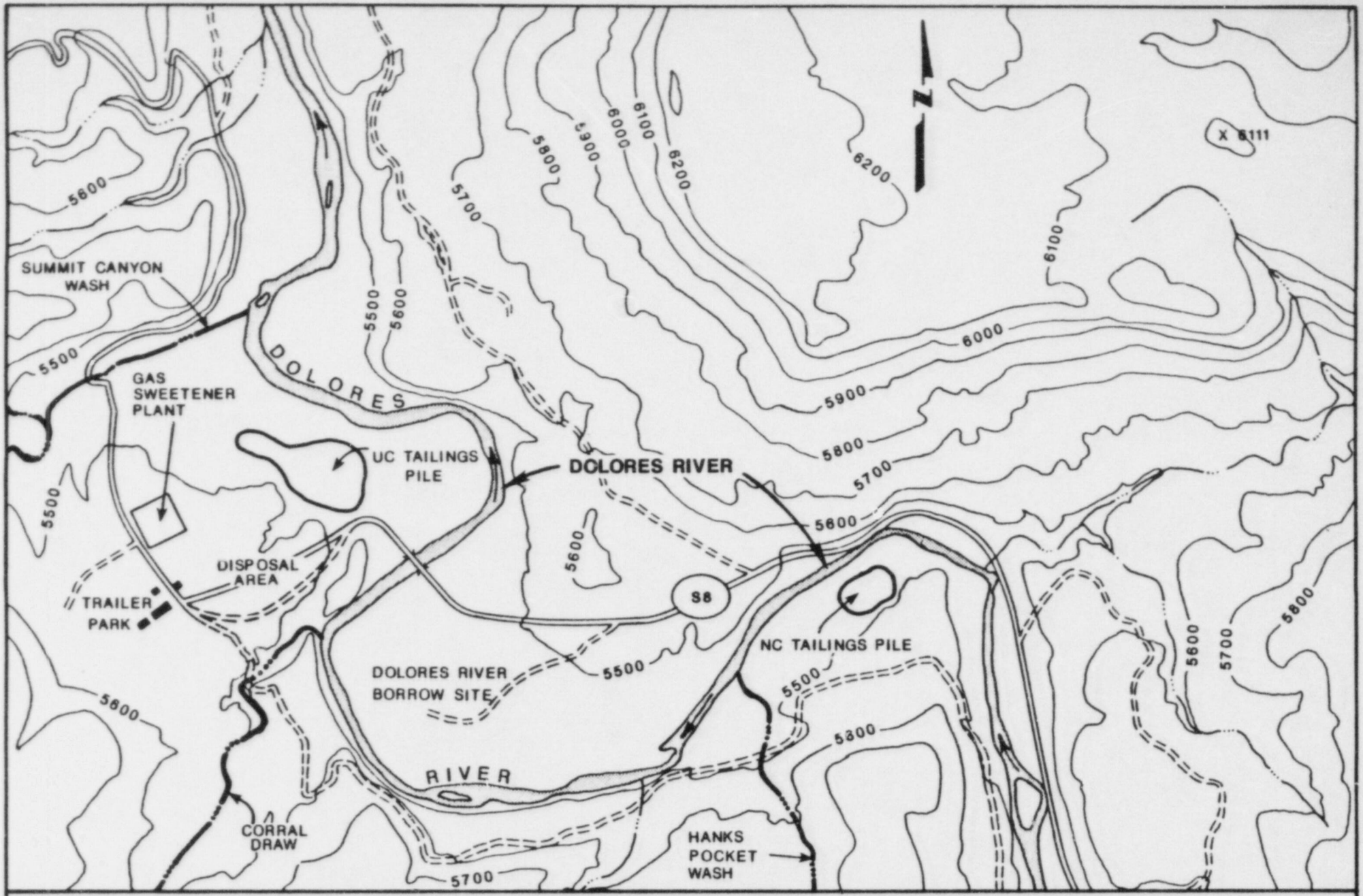

FIGURE B.1.2

SURFACE WATER CHARACTERISTICS AT THE SLICK ROCK SITES, SLICK ROCK, COLORADO

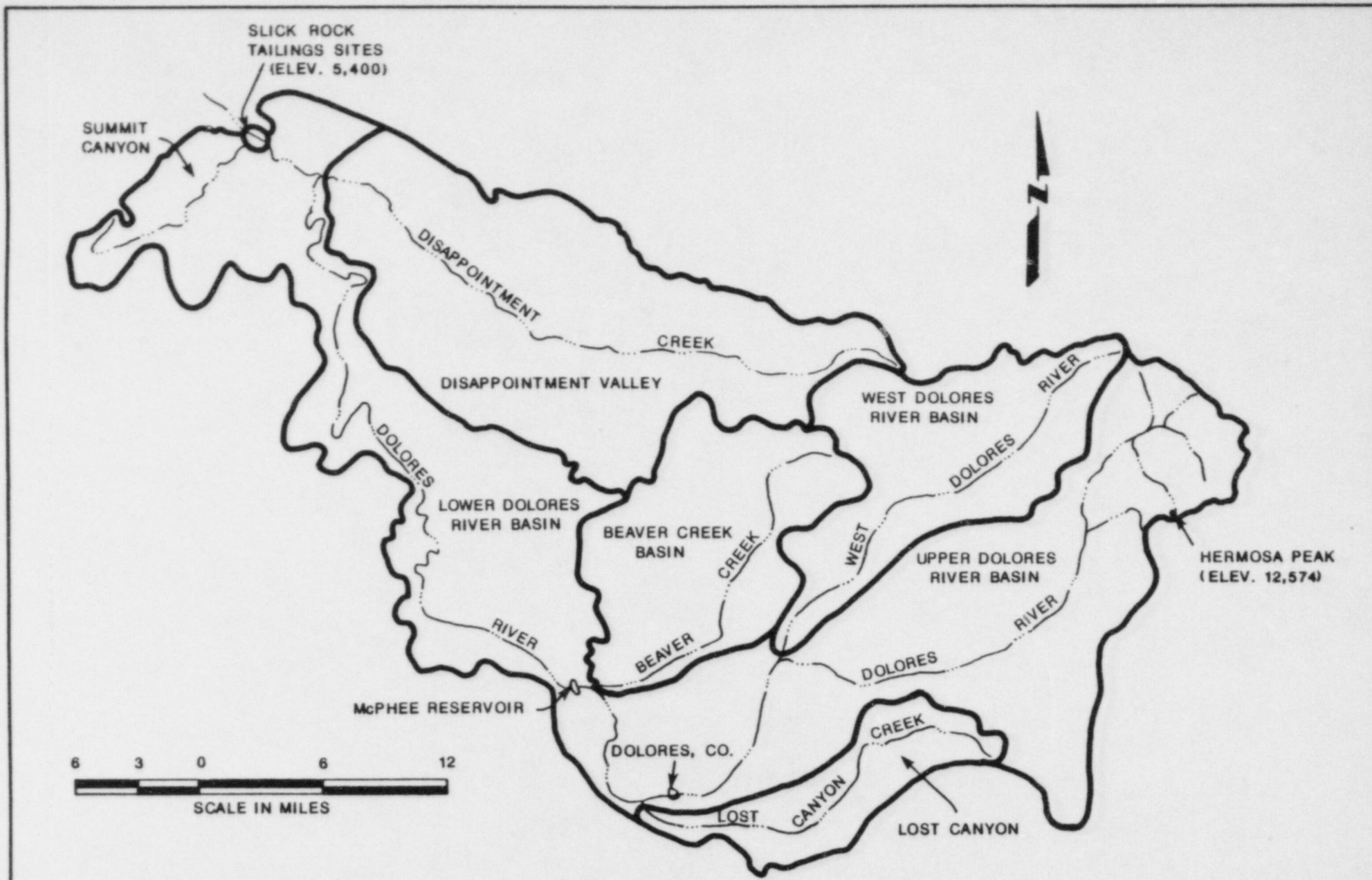

FIGURE B.1.3

DOLORES RIVER WATERSHED BOUNDARY ABOVE SLICK ROCK, COLORADO

B.1.2 SURFACE-WATER FEATURES

B.1.2.1 Dolores River

The Dolores River basin upstream of the Slick Rock tailings sites comprises approximately 1450 square miles. The river originates in the western San Juan Mountains near Hermosa Peak (elevation 12,574 feet above mean sea level (MSL)). Elevations in the basin vary from approximately 5400 feet above MSL at the sites to over 12,000 feet above MSL at the headwaters. Major tributaries to the Dolores River include the West Dolores River, Lost Canyon Creek, and Disappointment Creek upstream of the tailings sites and the San Miguel River downstream of the sites (Figure B.1.3). The Dolores River drains into the Colorado River approximately 10 miles west of the Colorado-Utah state line (see Figure B.1.1).

Four U.S. Geological Survey (USGS) gaging stations were maintained or are still in use on the Dolores River. Two gaging stations were maintained near the town of Bedrock, Colorado, approximately 45 river miles downstream of the sites, one station was operated at McPhee, Colorado, approximately 55 river miles upstream of the sites, and another station is still in operation at Dolores, Colorado, approximately 12 river miles upstream of the McPhee gage. The drainage areas at the gage locations range from 504 square miles at Dolores to 2145 square miles near Bedrock, bracketing the 1450-square-mile drainage area for the Slick Rock sites.

Figure B.1.3 Dolores River watershed boundary above Slick Rock, Colorado

The largest discharge recorded in the Dolores River was 10,000 cubic feet per second (cfs) at the Dolores gage in October, 1911. However, most major flow events on the Dolores River occur during the spring or early summer as a result of snowmelt or the combination of snowmelt and rainfall events (Table B.1.1).

Peak discharge frequency curves for the 10-year, 100-year, and 500-year events at each of the USGS gaging stations have been developed (PNL, 1985) (Table B.1.2). Peak discharge increases from the Dolores gage to the McPhee gage; however, peak discharge downstream of the McPhee gage is essentially unchanged for the 100-year and 500-year events. This is because snowmelt derived runoff is important in historic flooding and the lower elevation drainage areas do not contribute significant runoff during snowmelt derived flood events.

McPhee Reservoir has been in operation since March, 1984, (USBR, 1987) and is approximately 55 river miles upstream of the Slick Rock tailings sites. This reservoir regulates flows in the river at the Slick Rock sites and maximum releases from the dam occur from March through June. The average maximum release is 4000 cfs with a peak release of 4400 cfs in May, 1986. Minimum releases occur during late summer, fall, and winter and must be at least 80 cfs.

Table B.1.1 Maximum recorded flow on the Dolores River upstream of the Slick Rock sites

Gage location	Date	Peak discharge (cfs)
At Dolores	10/05/1911	10,000
Near McPhee	10/13/1941	8,650
Near McPhee	05/14/1941	8,430
At Dolores	06/19/1949	8,140
At Dolores	05/14/1941	8,070
At Dolores	05/05/1922	7,970
Near McPhee	05/16/1944	7,540
Near McPhee	06/19/1949	7,530
At Dolores	06/28/1927	7,030
At Dolores	06/06/1957	6,690
At Dolores	05/16/1944	5,690
At Dolores	09/05/1970	5,190

Ref. USBR, 1974.

Table B.1.2 Discharge-frequency for the Dolores River

Station	Drainage area (sq miles)	Return period (yrs) 10	100	500
Dolores River at Dolores	504	6,150	10,100	13,100
Dolores River near McPhee	817	8,800	16,300	22,400
Dolores River at Bedrock	2,024	9,100	15,900	20,800
Dolores River near Bedrock	2,145	10,500	17,500	22,200

Ref. PNL, 1985.

The Dolores River flows in a deeply incised canyon between steep bluffs and sheer cliffs of sandstone and shale in the Slick Rock area. The channel consists of a series of broad meander loops connected by short straight stretches where the outside of successive meander loops shifts from one bank to the other. The sinuosities of the present river channel are most likely entrenched meanders inherited from the ancestral Dolores River that flowed on a flat Miocene surface prior to uplift of the Colorado Plateau. The meander loops have terraces arranged in a step-like fashion on the inside of the loop and a sheer bedrock escarpment on the outside. The current is, therefore, directed against bedrock over most of its length and is relatively fixed.

Two distinct terrace sets are exposed in the sites' vicinity, one approximately five to eight feet above the modern floodplain and one approximately 25 to 35 feet above the floodplain. Both terrace deposits rest on top of an erosion surface of the Entrada Sandstone Formations.

Channel shifting of the Dolores River probably will occur within the next 1000 years since the lower terrace surface is subject to flooding and erosion. The cemented gravel deposits comprising the upper terrace surface are subject to slow erosion by shifts in the Dolores River channel. The high

sandstone bedrock ridge south of the UC tailings site separates the river from the site area. No river erosion would occur through this ridge.

The future potential for flooding and erosion of the disposal site area is drastically reduced assuming proper maintenance and operation of the McPhee Dam. Although the Dolores was formerly a perennial stream, the flow has been subsurface during the fall and early winter in recent years, reducing the channel to a string of shallow pools. The discharge into the Dolores River below McPhee Dam and above Slick Rock is not sufficient to maintain perennial flow. The potential for significant aggradation or degradation of the level of the channel at Slick Rock also appears to be fairly low. Assuming present flow characteristics are maintained, a static channel level should also be maintained.

B.1.2.2 Union Carbide site

The tailings pile at the UC site is in the modern floodplain of the Dolores River approximately 15 to 150 feet from the river bed. The designated site lies within a large meander loop of the Dolores River and is bordered by the river on the north, east, and southeast sides. As it flows past the site, the river varies in elevation from 5430 to 5422 feet

above MSL. The base of the pile is approximately 5440 feet above MSL. A rock-covered earthen dike was placed along the base of the pile next to the river to prevent erosion.

Summit Canyon Wash is an ephemeral stream flowing out of Summit Canyon and joining the Dolores River approximately 1000 feet downstream of the UC tailings pile (Figure B.1.4). This wash drains approximately 55 square miles and flow near its mouth is confined to a narrow deep channel with steep cliffs on either side. The channel widens approximately 800 feet upstream from the confluence with the Dolores River.

Corral Draw is a second ephemeral tributary of the Dolores River which passes close to the UC site. This draw has a drainage basin of 650 acres and prior to emplacement of tailings, the lower reach of the draw flowed south of the tailings pile then toward the northwest to join the lower reach of Summit Creek. Subsequently, the lower reach of Corral Draw was channeled around a sandstone ridge to enter the Dolores River upstream of the UC tailings pile.

At a later date, a diversion tunnel was cut through the bedrock ridge and the waters of Corral Draw were channeled through this tunnel and enter the Dolores River farther upstream than the first diversion. An earth dam blocks the lower part of the draw preventing it from flowing into its historic channel.

Figure B.1.4 Surface-water features at the Union Carbide site, Slick Rock, Colorado

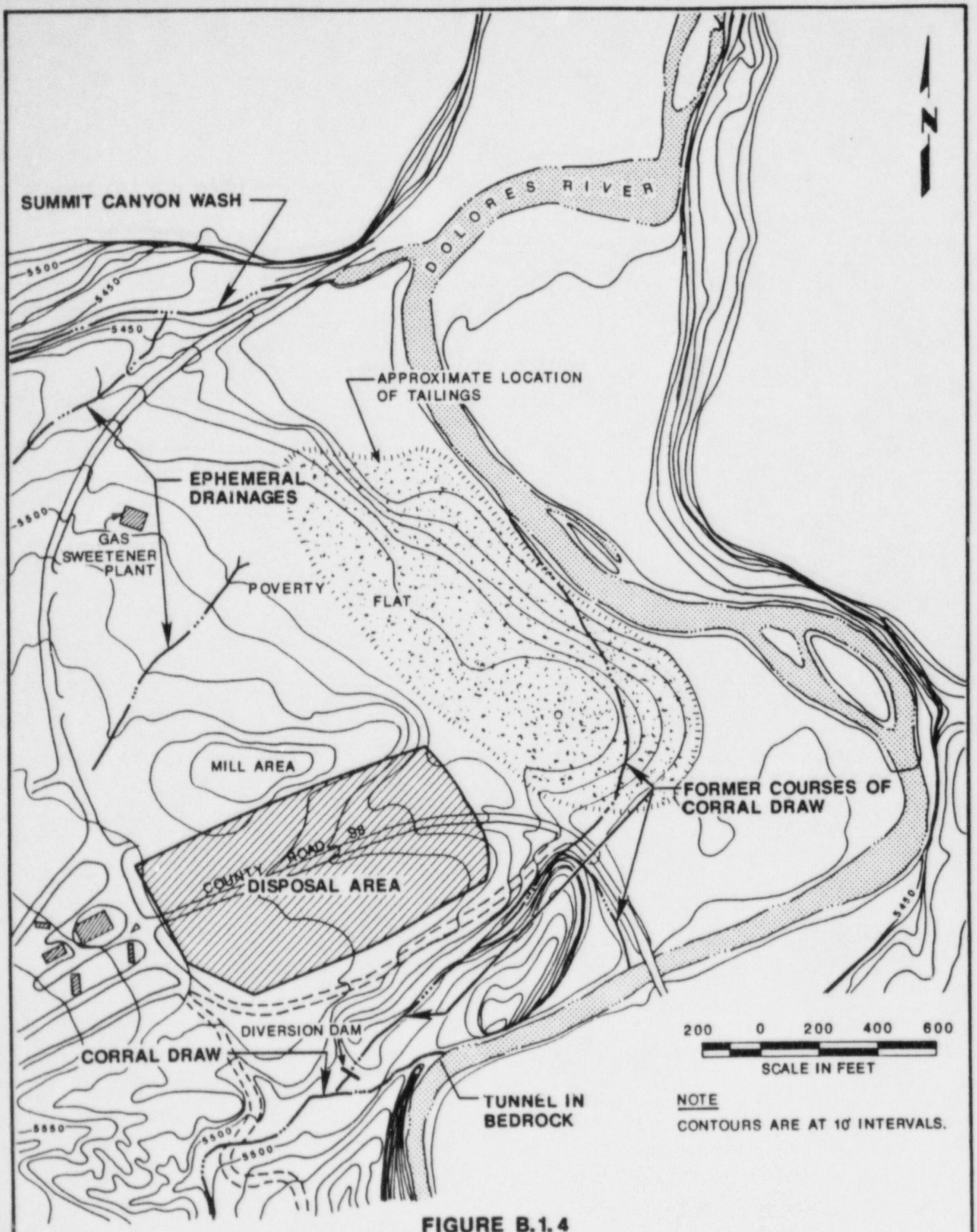

FIGURE B.1.4
SURFACE WATER FEATURES, UNION CARBIDE SITE
SLICK ROCK, COLORADO

An ephemeral gully, which drains a small area of Poverty Flat, impinges on the site from near the road southwest of the tailings pile and drains both to the northwest and southeast. The drainage basin for this small wash consists only of the site area east of the paved road to the gas sweetener plant and the small area of Poverty Flat. Runoff is concentrated in a shallow gully just west of the former mill site and in a broad, shallow wash between the mill site and the gas sweetener plant. A berm along the southwest side of the UC pile diverts surface water flow mainly to the northwest and into the deep wash leaving Summit Canyon (Figure B.1.4).

The area west of the former mill site and north of Poverty Flat drains to a small ephemeral channel which flows approximately 250 feet west of County Road S8 (CR-S8) and joins the Summit Canyon wash 600 feet north of the gas sweetener plant.

Geomorphology

The UC tailings pile rests on Entrada Sandstone bedrock, with a cover of terrace gravels and alluvium 15 to 30 feet thick. A small portion of the northern and eastern edges of the pile appears to overlap from the upper terrace level onto the lower terrace. The toe of the pile comes to within 15 feet of the river along the northeast side and rests on the lower terrace surface about eight to 10 feet above the modern channel. Some cover material from the pile has washed down

the slopes and forms small fans at the toe of the pile behind a sandstone berm. A few small gullies exist on the pile above these fans, but most have been graded smooth.

The lower terrace deposit below the pile is composed of silt and very fine to fine-grained sand and minor clay. It is slightly cemented by caliche but does not show a well developed soil profile, indicating a late Holocene age (less than 1000 years). Evidences of recent bank erosion are visible, including undercut banks, large slumped blocks, and undercut sagebrush and grasses. The overall age of this deposit may range from a few hundred to a few thousand years, and it is probably subject to periodic flooding and erosion. The banks are fairly straight and steep along the northeast side of the site and lower and less distinct on the southeast side. The southeast side may be subject to more frequent erosion.

While the area underlain by the lower terrace surface is evidently unstable and subject to future modification, the upper terrace surface appears to be more stable. This deposit is bordered by a prominent scarp along the north flank of the pile, where members of the Entrada Sandstone are exposed. The terrace surface is capped by a five- to eight-foot-thick layer of alluvial terrace gravels. The terrace gravels consist of well-rounded gravel, cobbles, and boulders composed of local

sandstones and igneous rocks possibly derived from the San Juan Mountains. The soil profile is disturbed; however, all of the gravel, cobbles, and boulders are coated with thin caliche coats, indicative of at least a late Pleistocene age. This surface appears to be fairly resistant to erosion.

The main channel of lower Corral Draw is incised into the three- to eight-foot thick sandy silt and terrace gravel deposits south and east of the trailer park. Erosion of the slightly to moderately carbonate cemented sandy silt deposits can be expected to continue for at least 1000 years. The rate of erosion is not known, but aerial photographs over a 40-year span show little to no headward or lateral extension of gullies within this deposit. Ephemeral flows of Corral Draw are constrained within the main channel by banks composed of well cemented terrace gravels overlying sandstone bedrock. These units are sufficiently erosion resistant to prevent encroachment of Corral Draw to the site within 1000 years.

The UC tailings pile has a gently rolling, sparsely vegetated surface with a thin cover of grass. The cover appears to be well maintained and no significant gullying is evident on the surface of the pile.

B.1.2.3 North Continent site

The NC tailings pile lies in the modern floodplain of the Dolores River within a large meander loop and is bordered by the river on the west, north, and east sides. The base of the tailings pile is approximately 5460 feet above MSL. The river varies in elevation from 5446 to 5438 feet above MSL as it flows past the site.

Hanks Pocket wash drains into the Dolores River approximately 1500 feet downstream of the tailings pile (see Figure B.1.2). Surface runoff across the site is limited to overland flow from precipitation events on or immediately above the site.

Erosion by wind, downhill creep, surface runoff, and possible flooding of the river has obscured the original outline of the tailings pile. The NC tailings appear to be concentrated along about a 15- to 18-foot-high slope that overlaps from the upper to the lower terrace deposits described in the previous section. The toe of the pile rests on the lower terrace about six to eight feet above the modern channel, and may have been subjected to periodic flooding in the past.

The surface of the tailings pile is partially vegetated and strongly gullied. Erosion by sheet wash, downhill creep,

and occasional surface flows is evident. Gullies and channels draining the surface of the pile have developed a small fan at the base of the slope. The fan surface does not show evidence of overbank flooding by the Dolores River, but may have been deposited over very recent overbank deposits and may conceal evidence of recent floods. The toe of the fan terminates abruptly at the edge of the lower terrace scarp above the river.

B.1.2.4 Borrow sites

The Dolores River borrow site lies in the modern floodplain of the Dolores River between the UC and NC tailings sites. No ephemeral channels cross the site or drain into the river in the site vicinity. Runoff across the site is limited to overland flows resulting from precipitation on the site and flows draining from the cliffs northeast of the site to the Dolores River.

The Disappointment Valley borrow site lies adjacent to an ephemeral tributary of Disappointment Creek. This ephemeral stream has a drainage area of 1.5 square miles and flows are typically the result of summer thunderstorms. A peak discharge of 260 cfs was recorded on this stream in 1971 at its confluence with Disappointment Creek (Pioneer, 1979).

Disappointment Creek, a major tributary to the Dolores River, flows within two miles of the borrow site. The creek has no flow at most times of the year with the majority of flow occurring from precipitation such as summer thunderstorms. There are several small reservoirs and ponds along Disappointment Creek as well as small diversions for irrigation. Flow records for Disappointment Creek near the borrow site are not available.

B.1.3 FLOOD ANALYSIS

B.1.3.1 Union Carbide site

A flood analysis has been performed to assure that the remedial action design for the uranium mill tailings sites at Slick Rock, Colorado, satisfactorily addresses short-term and long-term flood protection. Short-term flood protection defines the extent of the 100-year and 500-year floods and the impacts, if any, on the stabilized tailings or on remedial action construction activities. The primary purpose of this part of the analysis is to show compliance with floodplain and wetlands environmental review requirements in 10 CFR Part 1022.

To accomplish the objective of long-term flood protection, the magnitude and potential impacts resulting from a Probable Maximum Flood (PMF) event were determined and analyzed.

100-year and 500-year floods

Estimates for the 100-year and 500-year floods were determined using information obtained from the U.S. Army Corps of Engineers (COE) on cloudburst rainfall distributions, expressed as a percentage of the total rainfall, for the six-hour storm occurring over the Dolores River basin in the site vicinity (COE, 1986). The six-hour 100-year and six-hour 500-year precipitation values were determined from information in the NOAA Precipitation Frequency Atlas of the Western United States (Miller et al., 1973). This information was applied to the cloudburst rainfall distribution to obtain the incremental precipitation time distribution which is the primary input to the HEC-1 computer program (COE, 1981). In order to determine the maximum extent of the floodplains, conservative assumptions were used in estimating antecedent soil moisture conditions and lag times. The resulting peak discharges for the 100-year and 500-year floods are 84,200 cfs and 107,600 cfs, respectively. These peak discharges are higher than those presented in Table B.1.2. This is because the conservative flows used in this analysis were determined

by empirical methods while the values in the table were extrapolated from actual historical flows.

The results of these analyses indicate that the base of the UC tailings pile is within the 100-year floodplain. The maximum calculated water level at the UC site during a 100-year event varied from 5452 to 5446 feet above MSL along the pile. During a 500-year flood event, the water surface at the site varied from 5456 to 5448 feet above MSL along the pile.

The 100-year and 500-year floodplain boundaries, shown in Figure B.1.5, were determined using the HEC-2 computer model (COE, 1982). Surface-water profiles were estimated at cross sections extending from approximately 0.75 river mile downstream of the UC tailings pile to 0.5 river mile upstream of the NC tailings pile (Figure B.1.6). The hydraulic analysis used to determine floodplain boundaries is discussed in detail in the PMF hydraulic analysis discussion.

Probable Maximum Flood (PMF)

The first step in the PMF analysis requires the use of Hydrometeorological Report No. 49 (Hansen et al., 1977) to determine the appropriate Probable Maximum Precipitation (PMP) that could occur over the contributing drainage basins. The

Figure B.1.5 100 and 500-year floodplain boundaries at the UC site, Slick Rock, Colorado

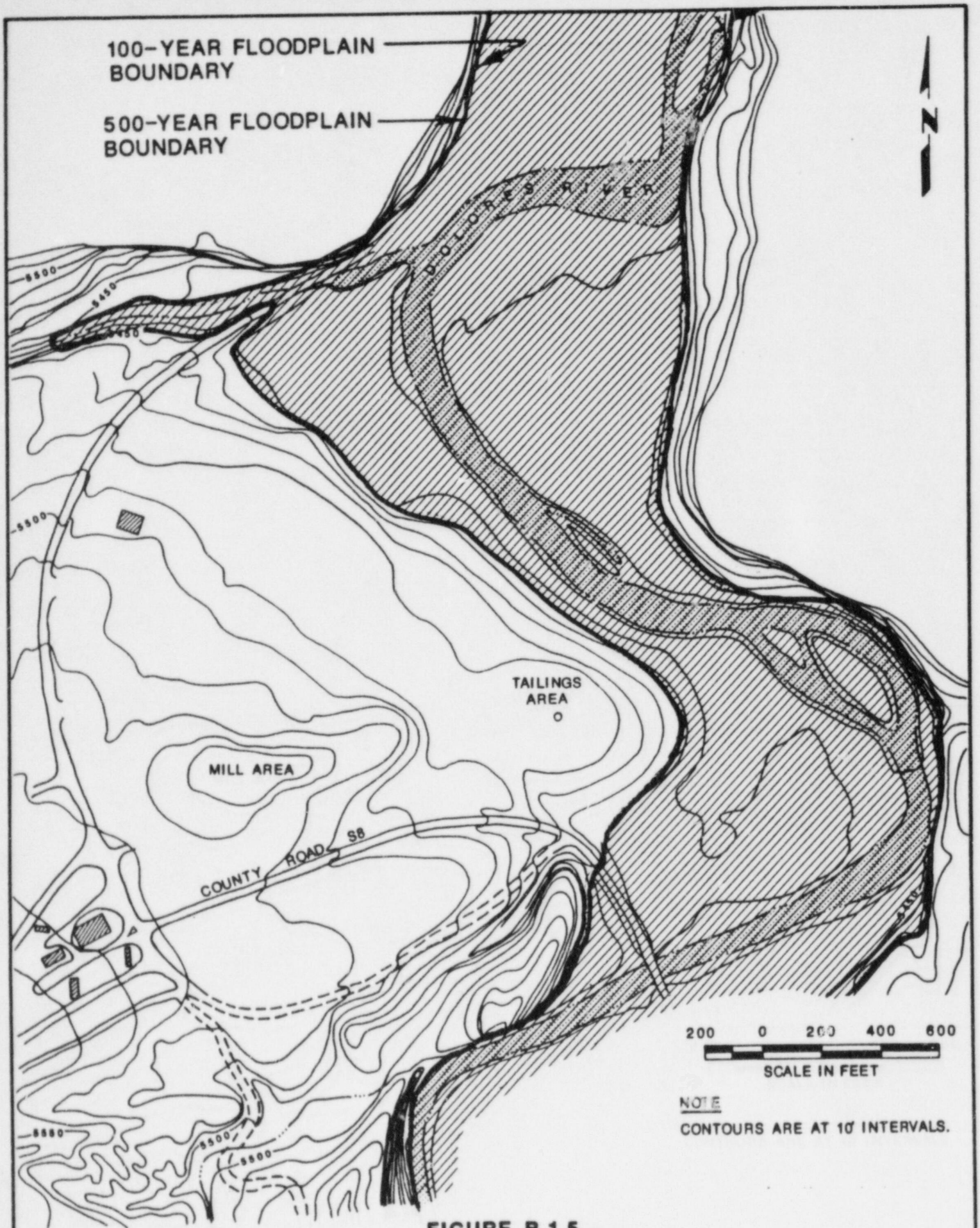

FIGURE B.1.5
100 AND 500-YEAR FLOODPLAIN BOUNDARIES AT THE UC SITE SLICK ROCK COLORADO

Figure B.1.6 Cross-section locations, HEC-2 analysis of the Dolores River near the Slick Rock, Colorado, tailings sites

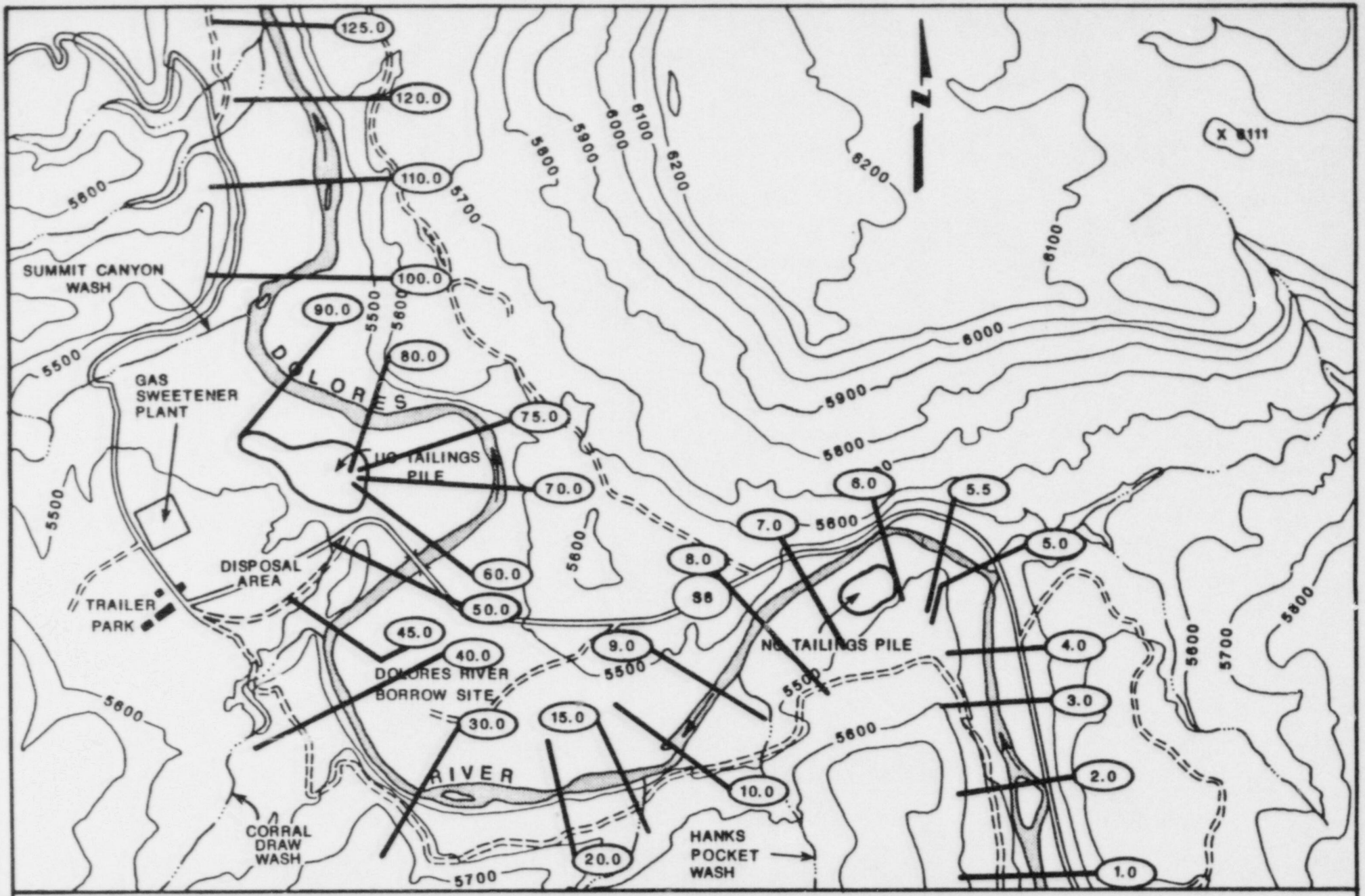

FIGURE B.1.6

CROSS-SECTION LOCATIONS HEC 2 ANALYSIS OF THE DOLORES RIVER NEAR THE SLICK ROCK COLORADO TAILINGS SITES

general (orographic and convergence) and local (thunderstorm) PMPs are then analyzed to determine the critical PMP discharge. Next, the analysis involves the consecutive use of the HEC-1 (COE, 1981) and HEC-2 (COE, 1982) models. The HEC-1 model is designed to simulate the runoff response (i.e., PMF) of a river basin to precipitation (i.e., PMP) by representing the basin as an interconnected system of hydrologic and hydraulic components. Then a determination of stream hydraulics, resulting in water-surface elevations and velocity gradients at the tailings site, is developed for the PMF flows using the dynamic HEC-2 model.

The PMF water-surface elevations were analyzed in order to determine the effects that flooding of the Dolores River would have on a stabilization in place design. In addition, the extent of the PMF floodplain was analyzed in order to ensure that the stabilization on site disposal area would not be affected by PMF flood flows.

Hydrologic analysis

The PMF estimate for the Dolores River at the UC tailings site is based on a HEC-1 model of the 1450-square-mile drainage basin upstream of the site. Four parameters were estimated to model the basin: (1) the amount and temporal

distribution of the Probable Maximum Precipitation (PMP); (2) the lag time of runoff within the basin; (3) computation interval for the hydrograph; and (4) loss rate of precipitation within the basin.

The drainage basin was divided into 13 subbasins for the HEC-1 model. Drainage areas, reach lengths, and channel slopes were taken from USGS topographic maps. The month with the highest 24-hour precipitation was August with 14.6 inches. The 72-hour PMP was areally reduced for the entire basin and distributed temporally by arranging six-hour incremental amounts in a sequence such that they decreased progressively to either side of the greatest six-hour increment for each subbasin.

Lag times were determined by assuming bank full velocities. Each subbasin was assumed to have four conveyance components:

- Overland flow with velocities ranging from two to 3.5 feet per second (fps) for slopes of less than eight percent to greater than 10 percent.

- Upland channels with velocities ranging from six to 14 fps as slopes varied from less than one percent to 12 percent.

- Secondary channels draining areas of 35 to 75 square miles with velocities of eight to 14 fps.

- Primary channels with velocities varying from eight to 20 fps.

Average slopes for each component were determined in order to select the appropriate velocity estimate. Lag times for each basin determined by the above were compared to values derived by using the equation presented in USBR (1977).

To account for severe hydrological conditions, which could be created by the presence of a snow pack, no initial loss of precipitation was assumed, and a very conservative uniform loss rate of 0.20 inch per hour was selected. This value was used by the Bureau of Reclamation in the PMF study for the McPhee Reservoir.

The PMF discharge of 410,000 cfs is approximately six times the maximum expected discharge estimated using methods developed by Crippen and Bue (1977), and approximately four times the 500-year flood.

The local (thunderstorm) PMP for the Dolores River in the Slick Rock area was also determined using HMR No. 49 and the HEC-1 computer model. The maximum expected flood from the

local PMP was approximately 200,000 cfs, or one-half of the discharge from the general PMP.

The PMF for the Summit Canyon Wash was estimated to be 11,000 cfs using the methods described above. The PMF for Corral Draw was estimated using the Linear Reservoir Routing Technique with Green-Ampt infiltration parameters as described in the Technical Approach Document (DOE, 1986). The resultant design discharge for the Corral Draw was 7800 cfs.

PMF hydraulic analysis

The physical characteristics of the Dolores River reach containing the UC tailings pile were modeled as follows. The river banks were extended beyond the normal bank locations to account for a dramatically different river regime during PMF conditions. The banks of the meander loops previously described would not be recognized as water would flow from canyon wall to canyon wall creating a confined system. The model reach extended from approximately one river mile downstream of the site to about 0.75 river mile upstream. Channel geometry was determined from two-foot-contour topographic maps.

Values of Manning's roughness coefficients, "n," were varied across the cross sections to account for conveyance

differences. In general, all cross sections exhibited a trapezoidal shape with the floodplain as the base and steep canyon walls on either side. Only at the pile were the overbank areas not steep. A value of 0.02 for "n" was used for the floodplains and midchannel islands and 0.05 was used for the overbank areas. Average values of 0.1 and 0.3 were used for the contraction and expansion coefficients, respectively.

The analysis showed two areas where floodway constrictions caused unstable flow conditions in the form of near-critical flows. These occurred at the UC pile and downstream of the pile. Each critical flow area was analyzed separately in order to confirm the reliability of the model. The floodway was plotted on topographic maps to confirm that the geometry was consistent. Areas of ineffective flow were eliminated by artificially raising the banks at certain sections. Finally, a sensitivity analysis was run at all natural constrictions on the contraction and expansion coefficients in an effort to moderate the steep energy grade slope and realistically simulate the effects of friction at these points.

The PMF floodplains for the Summit Canyon and Corral Draw Washes were determined by applying Manning's equation (COE, 1970) at cross sections along the channel reaches in the UC site vicinity.

The majority of the existing pile would be within the PMF floodplain of the Dolores River as elevations across the pile varied from 5480 to 5465 feet above MSL. However, the stabilization on site disposal area would not be affected by PMF flows of any of the surface-water bodies in the site vicinity (Figure B.1.7).

B.1.3.2 North Continent site

Flood analysis at the NC site was performed in order to address compliance with floodplain and wetlands environmental review requirements in 10 CFR Part 1022. Since the tailings would be removed from the NC site, a long-term flood analysis was not performed.

The methods used to determine the 100-year and 500-year floodplains are discussed in Section B.1.3. The outline of the tailings pile has been obscured by the effects of erosion on the site. However, contaminated materials, possibly tailings, lie within the 100-year floodplain of the Dolores River. Water levels across the pile would rise to a maximum elevation of 5465 feet above MSL during a 100-year flood event and 5467 feet above MSL during a 500-year flood event (Figure B.1.8).

Figure B.1.7 PMF floodplain boundary at the UC site, Slick Rock, Colorado

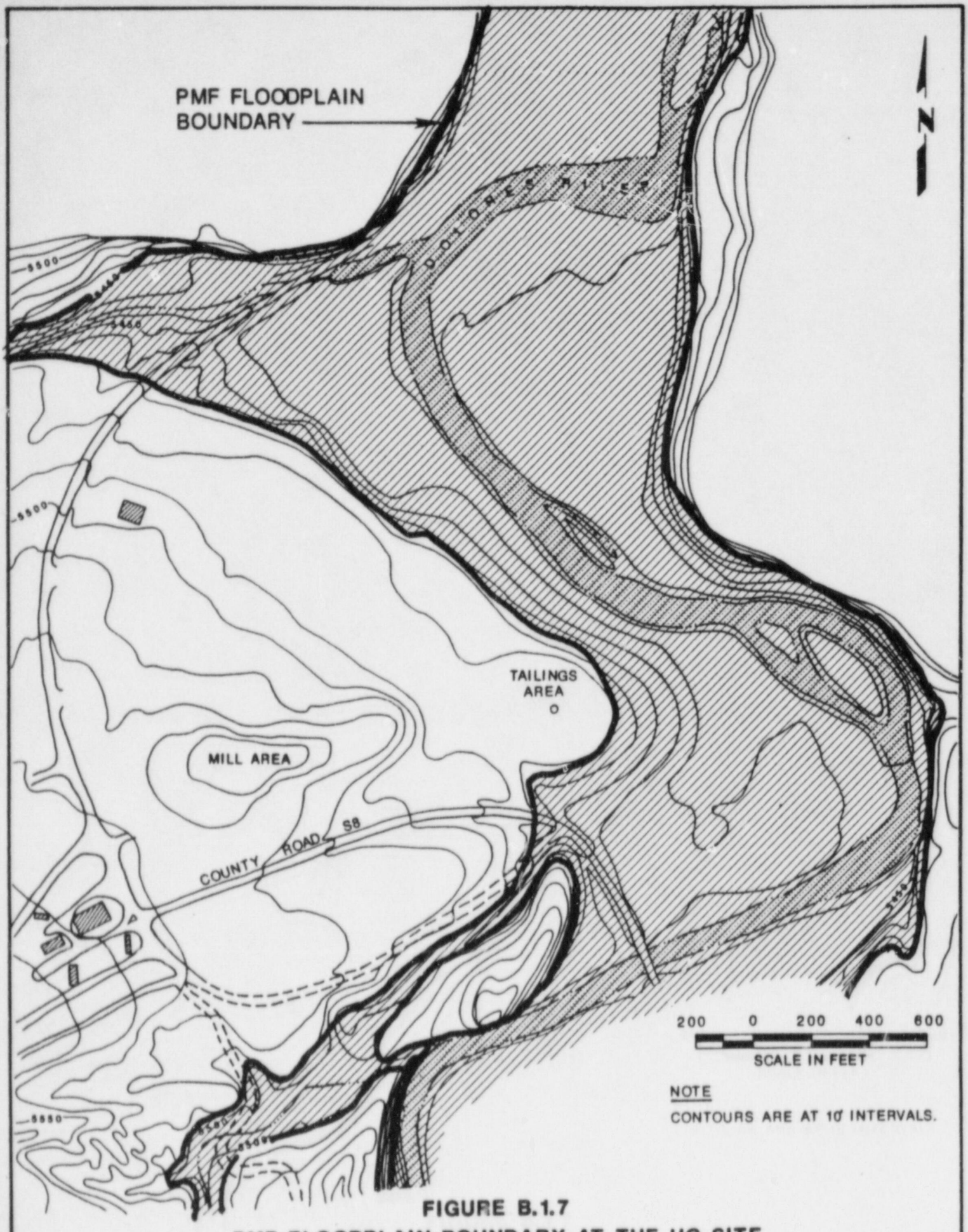

FIGURE B.1.7
PMF FLOODPLAIN BOUNDARY AT THE UC SITE,
SLICK ROCK, COLORADO

Figure 8.1.8 100 and 500-year floodplain boundaries at the NC site, Slick Rock, Colorado

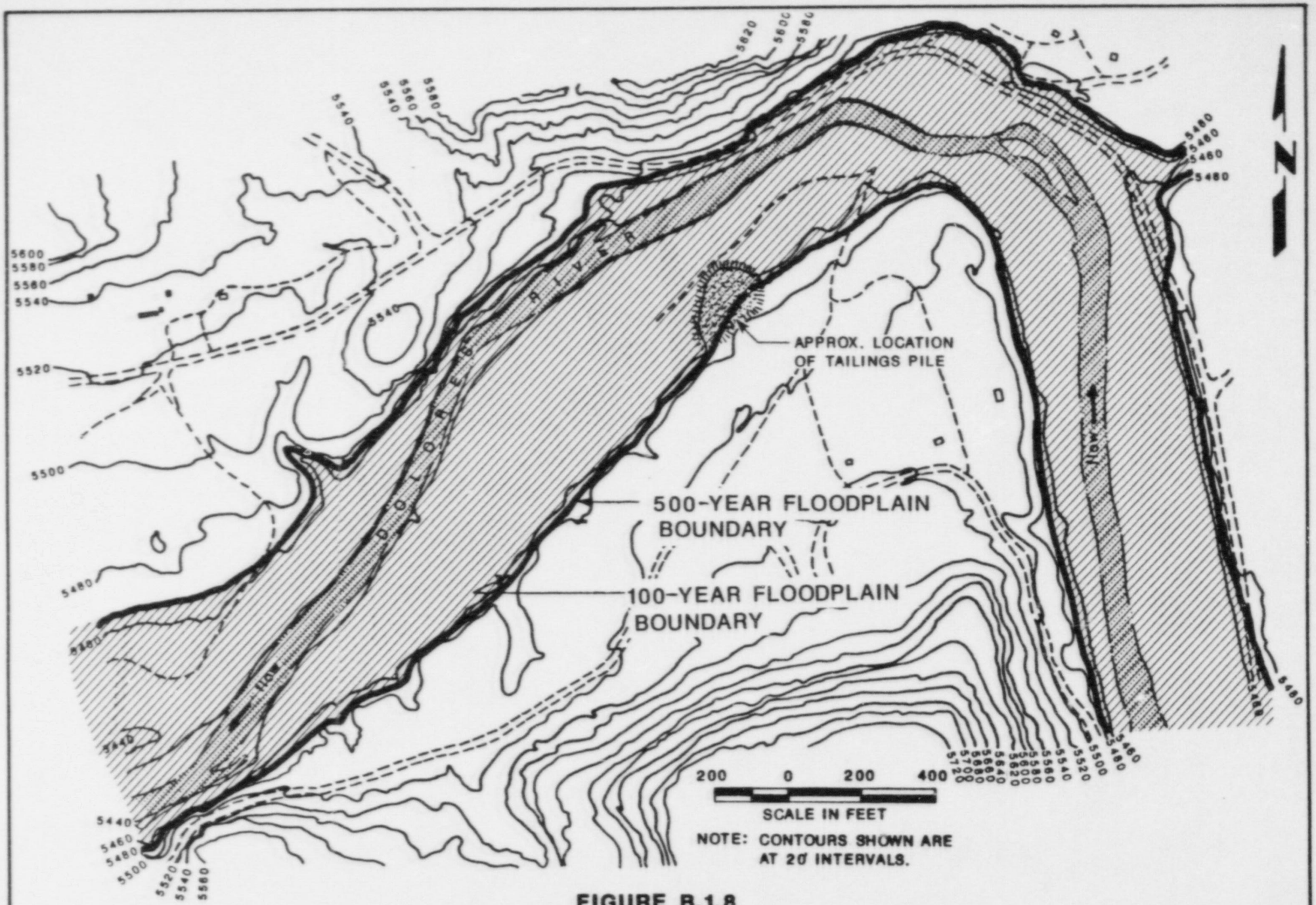

FIGURE B.1.8
100 AND 500-YEAR FLOODPLAIN BOUNDARIES AT THE NC SITE
SLICK ROCK, COLORADO

B.1.3.3 Borrow sites

As with the NC tailings site, analysis at the Dolores River borrow site was confined to addressing compliance with 10 CFR Part 1022. Areas within the 100-year and 500-year floodplains would likely be disturbed by borrow operations at this site.

A 100-year and PMF flood analyses for the washes near the Disappointment Valley borrow site indicated that construction activities would take place outside of the 100-year and PMF floodplain (Pioneer, 1979).

B.1.4 SURFACE-WATER QUALITY

B.1.4.1 Tailings sites

Eight sites were sampled to determine surface-water quality near the UC and NC sites during the fall of 1982 (DOE, 1983). These sites were located in the Dolores River and in some ephemeral bodies of water near the sites (Figure B.1.9). Several of the samples from ephemeral sites were collected from a thunderstorm and the total dissolved solids (TDS) concentration was approximately 250 milligrams per liter (mg/l). The ephemeral water was high in calcium and bicarbonate. Trace metal concentrations from the ephemeral

Figure B.1.9 Surface-water sample locations near the Slick Rock, Colorado, tailings sites

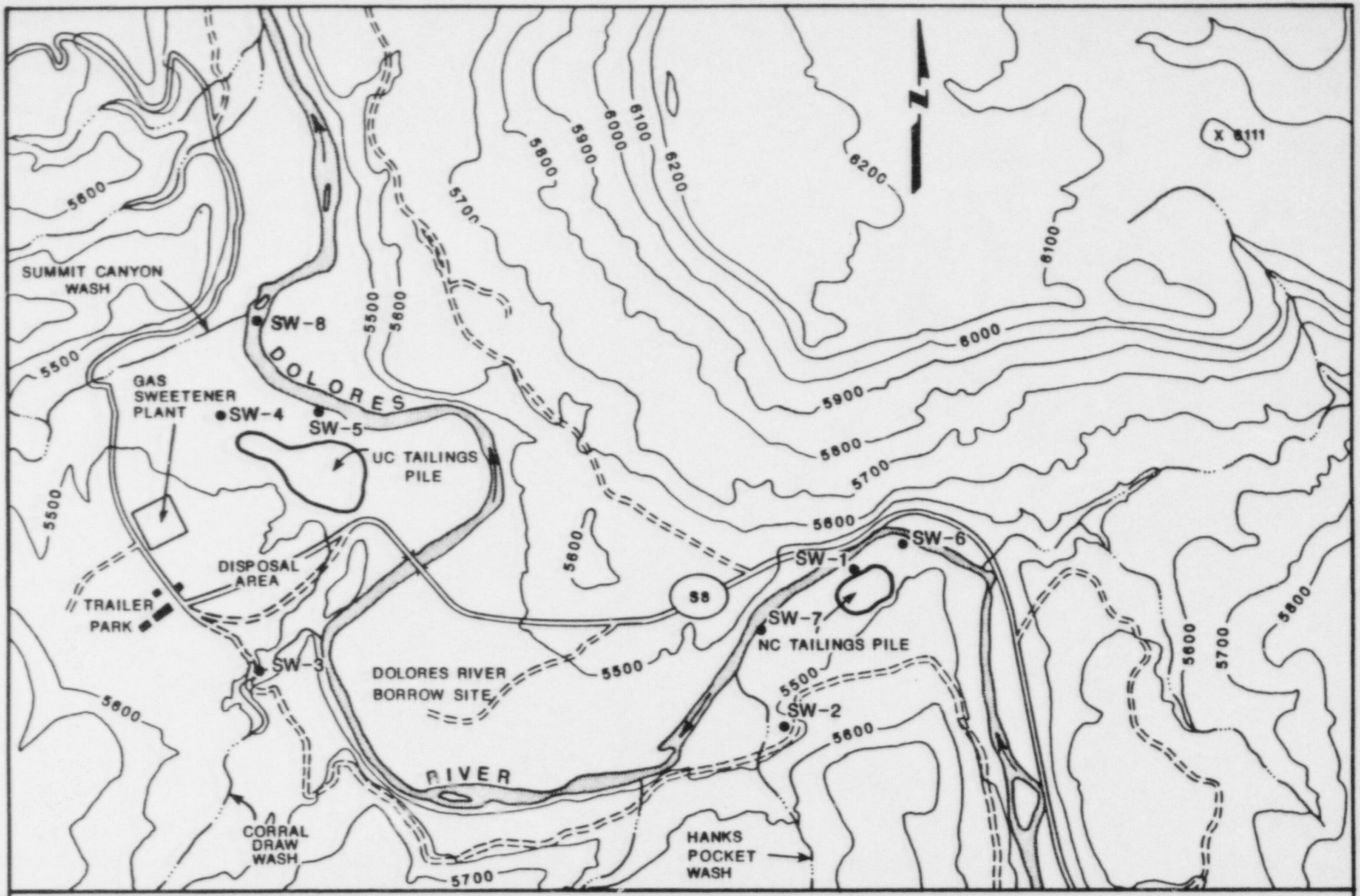

FIGURE B.1.9

SURFACE WATER SAMPLE LOCATIONS NEAR THE SLICK ROCK, COLORADO TAILINGS SITES

waters were below levels permitted by the Colorado Department of Health (CDH) except for selenium which had a concentration of 0.024 mg/l (sample point SW-5). Radium-226, uranium, and vanadium concentrations were highest in the ephemeral runoff that crossed the tailings piles (sampling stations SW-1, SW-4, and SW-5). The radium-226 values at these three sites ranged from 77 to 183 pCi/l, uranium ranged from 0.011 to 0.032 mg/l and vanadium ranged from 0.32 to 0.91 mg/l.

The Dolores River contained a TDS concentration of approximately 630 mg/l with calcium and sulfate being the dominant ions. Little change in the concentration of major constituents was noted between the Dolores River upstream (SW-6) and downstream (SW-8) stations.

B.1.4.2 Borrow sites

Water quality in the Dolores River near the Dolores River borrow site would be similar to that described for the tailings sites.

Chemical analyses of water samples from an ephemeral stream west of the Disappointment Valley borrow site indicate the water is alkaline and very hard (Pioneer, 1979). In addition, high concentrations of TDS and chlorides indicate that the water quality is generally poor and not potable.

B.1.5 SURFACE-WATER USES, STANDARDS, AND CLASSIFICATIONS

Withdrawals from the Dolores River for agricultural purposes are minimal downstream from the Slick Rock sites to Bedrock, Colorado (45 miles), and upstream to McPhee Reservoir (55 miles). The State of Colorado has classified the Dolores River in the area of the Slick Rock sites as suitable for domestic water supply and for agricultural purposes. In addition, the state has rated the Dolores River as Class 1 recreational waters (i.e., suitable for swimming) and as a Class 1 for cold-water aquatic life (CDH, 1986).

Agricultural use of the Disappointment Creek consists of several small ponds and limited diversions for irrigation. There are no users of the waters in the ephemeral wash that occurs near the Disappointment Valley borrow site. Based on the State of Colorado classification, Disappointment Creek and its tributaries are Class 2 recreational waters (i.e., waters suitable for activities that do not require primary contact) and are Class 2 warm water aquatic habitat (CDH, 1986).

B.2 GROUND WATER

B.2.1 INTRODUCTION

The EPA standards (40 CFR Part 192) require characterization of the hydrogeologic regime at and around each UMTRA Project site. These regulations state that "judgements on the possible need for remedial or protective actions for ground-water aquifers should be guided by relevant considerations described in EPA's hazardous waste management system (47 FR 32274)". Based on these two sets of requirements, it has been determined that the following 14 primary items must be addressed during ground-water characterization at an UMTRA Project site (Brinkman et al., 1985).

- Applicable water quality standards.
- Characterization of the potentially affected hydrogeologic environment.
- Proximity of the site to surface water.
- Physical and chemical characterization of waste in terms of contaminant migration in ground water and hydraulically connected surface water.

- Effect of climate on the movement of contaminants.

- Impact of contaminant sources other than those attributable to the UMTRA Project site.

- Proximity, withdrawal rates, uses, and sources of presently used water.

- Present value of affected water resource.

- Availability of alternative water supplies.

- Potential and expected use of affected resource.

- Future value of affected water resource.

- Potential health risks to humans and potential damage to crops, vegetation, and wildlife caused by exposure to contaminants in ground or surface water.

- Persistence and permanence of adverse effects.

- Aquifer restoration or protection.

The EPA standards recognized that the inactive mill tailings sites were not regulated and were not originally designed to protect ground-water resources. EPA also recognized that once an aquifer

becomes contaminated, it will remain polluted for a long period of time and it may be extremely difficult to restore the quality of the water in the aquifer (47 FR 32203). For these reasons, the EPA developed the inactive mill standards to allow decisions regarding the need for ground-water protection to be made based on such factors as technical feasibility of improving the aquifer in its hydrogeologic setting, the present and future value of the aquifer as a water resource, the availability of alternative water supplies, and the degree to which human exposure is likely to occur. Thus, rather than establish specific numerical limitations for contaminant discharges or ground-water quality, the EPA determined that the most appropriate course of action would be to require site-specific analyses of potential future contaminant discharge and a case-by-case evaluation of the significance of such a discharge. The implementation guidelines for the EPA standards call for adequate hydrological and geochemical surveys at each site as a basis for determining whether specific water-protection measures should be applied.

On September 3, 1985, the United States Tenth Circuit Court of Appeals set aside the EPA standard applicable to the protection of waterways and ground water, 40 CFR Part 192.20(a)(2)-(3). The water protection standard was remanded to the EPA for further consideration in light of the Court's opinion that the water standard promulgated by the EPA on March 7, 1983, was site specific rather than of general application as required by legislation. The EPA has not identified a date for reissuance of 40 CFR Part 192.20(a)(2)-(3), and such

reissuance may not occur until after remedial actions have been initiated at the Slick Rock tailings sites. The DOE has thoroughly characterized conditions at the Slick Rock sites and does not anticipate that any substantial changes to the remedial actions will be required. When the EPA issues revisions to the water protection standards (40 CFR Part 192.20 (a) (2)-(3)) that were remanded by the U.S. Tenth Circuit Court of Appeals, the ground-water issues at the Slick Rock sites will be re-evaluated to assure that the revised standards are met. Performing remedial actions to stabilize the tailings prior to the EPA issuing new standards will not affect the measures that are ultimately required to meet the revised EPA water protection standards. Conditions have been characterized at the Slick Rock sites and it is not anticipated that any substantial changes to the remedial actions will be required. However, after the EPA re-issues the water protection standards, the need for institutional controls, aquifer restoration, or other controls will be determined and appropriate action will be taken so as to comply with the re-issued standards.

B.2.2 APPLICABLE WATER-QUALITY STANDARDS

The water quality standards that have been used to evaluate affected or potentially affected ground-water systems at these sites are contained in the National Primary and Secondary Drinking Water Regulations (40 CFR Part 141 and 40 CFR Part 143, respectively). The primary standards are for contaminants in drinking water that affect

public health. The secondary standards are for contaminants in drinking water that primarily affect aesthetic qualities relating to the public acceptance of drinking water (e.g., odor, color). These drinking water standards are listed in Table B.2.1.

B.2.3 HYDROGEOLOGIC CHARACTERIZATION

B.2.3.1 Previous investigations

A number of reconnaissance-level, regional investigations have been conducted (Cater, 1955a,b, 1970; Pioneer, 1978, 1979; Weir et al., 1983). However, the information contained in these reports is outdated, is not sufficient to characterize the hydrology, or is not specific to the Slick Rock tailings sites. Site-specific investigations at the UC and NC sites includes water-quality analyses (DOE, 1983), surface and ground-water quality analyses (GECR, 1983), and radiologic characterization efforts (BFEC, 1986).

B.2.3.2 Present study

Hydrogeologic data including borehole logs, well completion data, ground-water levels, aquifer test data, and water-quality data were collected at the tailings sites. All field and laboratory procedures and calculations were performed according to standard operating procedures (DOE, 1985).

Table B.2.1 State of Colorado and Federal drinking-water standards

Contaminant	Units of measurement[a]	Standards
Primary		
Arsenic	mg/l	0.05
Barium	mg/l	1.0
Cadmium	mg/l	0.01
Chromium	mg/l	0.05
Fluoride	mg/l	4.0
Lead	mg/l	0.05
Mercury	mg/l	0.002
Nitrate (as N)[b]	mg/l	10.0
Selenium	mg/l	0.01
Silver	mg/l	0.05
Radium-226 and Radium-228	pCi/l	5.0
Gross alpha[c]	pCi/l	15.0
Endrin	ug/l	0.2
Lindane	ug/l	4.0
Methoxychlor	ug/l	100.00
Toxaphene	ug/l	5.0
2,4-D	ug/l	100.00
2,4,5-TP	ug/l	10.00
Trihalomethanes[d]	ug/l	100.00
Phenols	ug/l	1.00
Secondary		
Chloride	mg/l	250.0
Copper	mg/l	1.0
Iron	mg/l	0.3
Manganese	mg/l	0.05
pH	SU	6.5-8.5
Sulfate	mg/l	250.0
Total dissolved solids (TDS)	mg/l	500.0
Zinc	mg/l	5.0

[a]mg/l - milligrams per liter; pCi/l - picocuries per liter; ug/l - micrograms per liter; SU - Standard Units.

[b]Nitrate levels not to exceed 20 mg/l may be allowed in a non-community water system of the supplier of water at the discretion of the state. See 40 CFR Part 141 for details.

[c]Gross alpha particle activity includes radium-226 but excludes radon and uranium.

[d]Total trihalomethanes is the sum of the concentrations of bromodichlor-methane, (chloroform).

In 1986, six two-inch diameter polyvinyl chloride (PVC) monitor wells (wells 668, 669, 670, 684, 685, and 688), and three two-inch diameter PVC wells (wells 686, 687, and 690) were installed at the UC site and NC site, respectively (Figure B.2.1). The depths of these installations ranged from 19 to 195 feet below land surface. Prior to installation of the deepest monitor well, the borehole was advanced to a total depth of 249 feet below land surface and then grouted to the depth of the installed monitor well. Core samples were recovered from the total depth of the three deepest boreholes and lithologic logs were obtained to the total depth of all boreholes. Additional wells used for this analysis consisted of previously installed monitor wells (all 500 service wells on Figure B.2.1) (DOE, 1983) and private wells (634, 672, 675, and 805) (Figure B.2.1).

Slug withdrawal and slug injection tests to estimate the hydraulic properties of the aquifer material in the area of the screened intervals of the wells were performed on the wells installed during this study and on seven of the previously installed monitor wells (wells 501, 503, 504, 507, 509, and 510). All monitor wells were surveyed and static water elevations at the wells were measured to determine ground-water hydraulic gradients and directions of ground-water flow. Table B.2.2 summarizes monitor well information and Figure B.2.2 shows typical construction details of the installed wells.

Figure 8.2.1 Monitor well locations, Slick Rock, Colorado, tailings sites

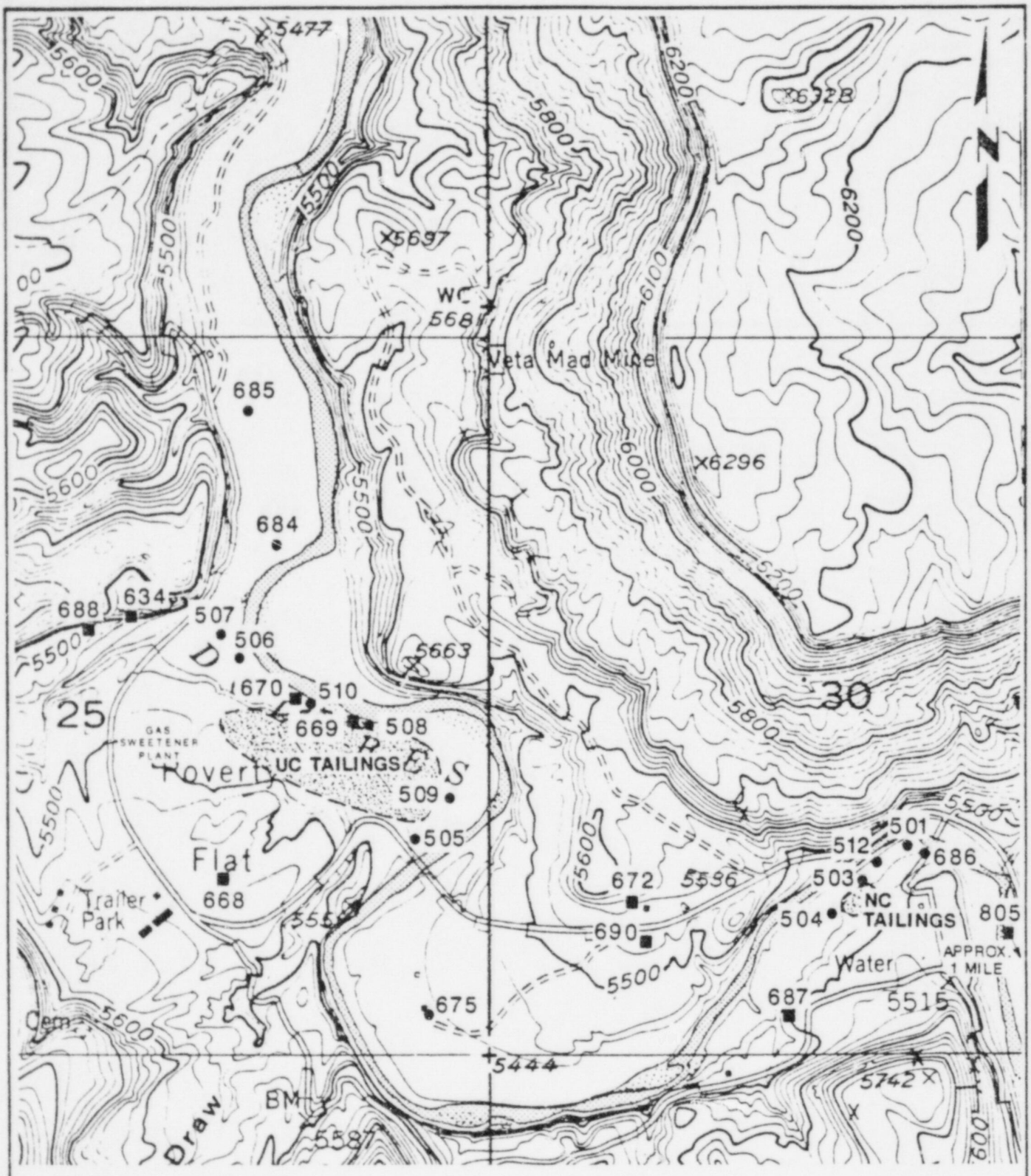

FIGURE B.2.1
MONITOR WELL LOCATIONS
SLICK ROCK, COLORADO TAILINGS SITES

Table B.2.2 Monitor well construction data, Slick Rock, Colorado, tailings sites

Well number	Well diameter (inches)	Land surface elevation (feet above MSL[a])	Total depth (feet)	Screened interval (feet above MSL)	Formation of completion
501	4.0	5454.0	22	5438-5429	Alluvium
503	4.0	5457.8	27	5438-5432	Alluvium
504	4.0	5448.4	19	5434-5430	Alluvium
505	4.0	5440.4	19	5429-5421	Alluvium
506	4.0	5430.1	21	5418-5411	Alluvium
507	4.0	5431.3	20	5421-5411	Alluvium
508	4.0	5437.2	20	5425-5418	Alluvium
509	4.0	5434.6	22	5423-5413	Alluvium
510	4.0	5436.2	26	5421-5412	Alluvium
512	4.0	5450.5	20	5438-5431	Alluvium
668	2.0	5524.9	155	5410-5370	Navajo Ss.[b]
669	2.0	5440.5	107	5341-5336	Navajo Ss.
670	2.0	5437.8	96	5354-5344	Navajo Ss.
684	2.0	5430.2	23	5419-5409	Alluvium
685	2.0	5426.3	27	5411-5401	Alluvium
686	2.0	5455.1	22	5440-5435	Alluvium
687	2.0	5492.8	195	5320-5300	Navajo Ss.
688	2.0	5453.6	70	5401-5386	Navajo Ss.
690	2.0	5506.9	182	5347-5327	Navajo Ss.

[a]MSL = Mean Sea Level
[b]Ss = Sandstone

Figure B.2.2 Configuration of typical DOE monitor wells

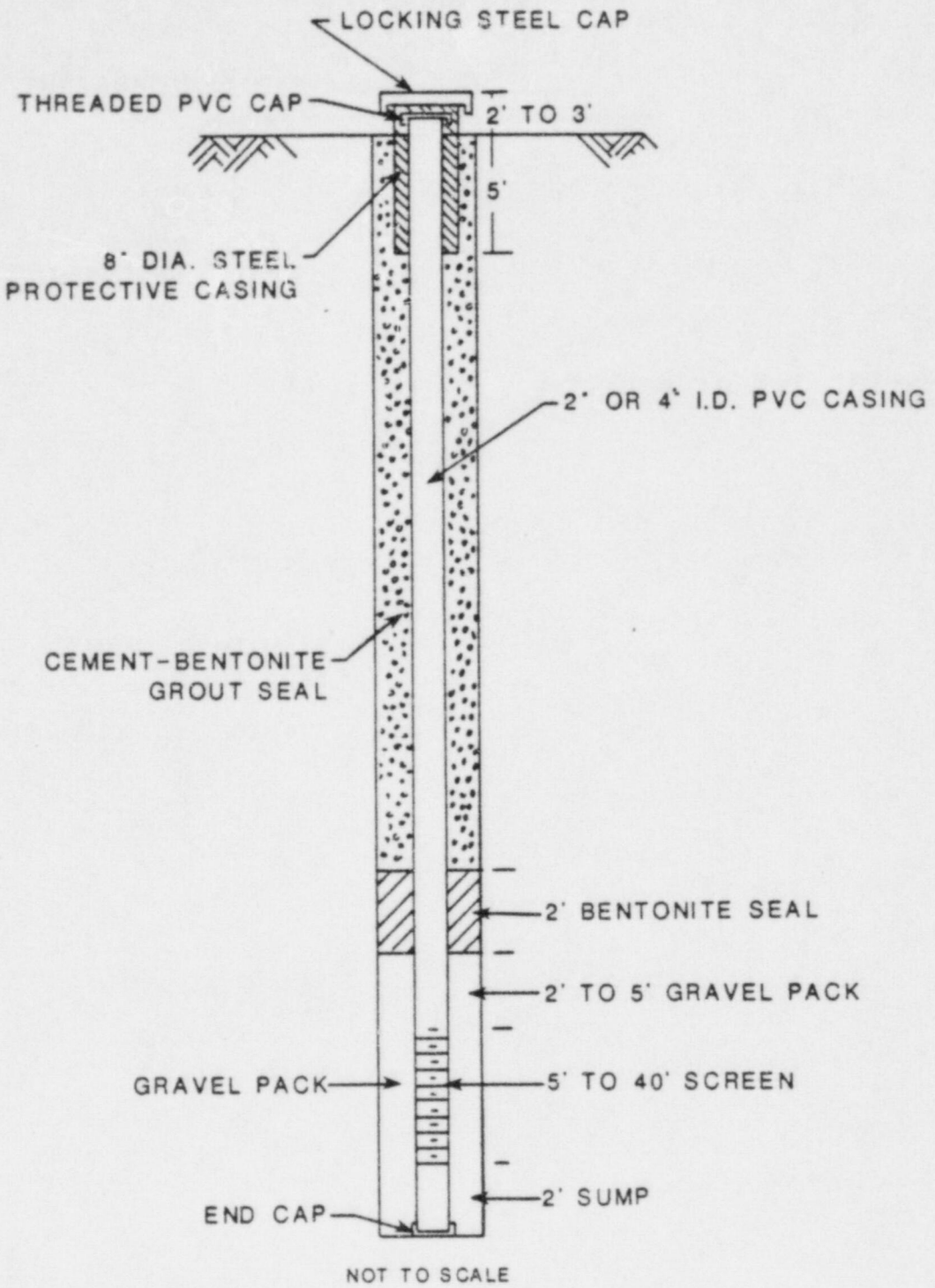

FIGURE B.2.2
CONFIGURATION OF TYPICAL DOE MONITOR WELL

B.2.3.3 Hydrostratigraphy

Ground water occurs in two distinct zones: the Dolores River alluvium and the Navajo Sandstone. These two water-bearing units are separated by the Entrada Sandstone. The Entrada Sandstone is not water-bearing as evidenced by the fact that water was not encountered in those wells that penetrated this unit.

The Dolores River alluvium consists of a mixture of sands, gravels, and cobbles and is the top hydrostratigraphic unit. The alluvium in the area of the sites is confined to the floodplain of the Dolores River and is incised into the underlying Entrada Sandstone. The modern channel of the river has divided the alluvium into discrete, lenticular bodies which vary between approximately 250 to 600 feet in width and 1000 to 4000 feet in length. The Dolores River alluvium ranges from 15 to 30 feet thick in the area of the tailings sites. The UC site rests upon an alluvial deposit with lateral dimensions of approximately 2400 feet by 600 feet and a depth of 25 feet; the alluvium underlying the NC tailings site is approximately 2400 feet by 300 feet by 25 feet. Ground water occurs under unconfined conditions at depths ranging from seven to 20 feet below land surface. There appears to be very limited hydraulic communication between the discrete alluvial deposits.

The Entrada Sandstone is present at the land surface across the sites and persists to depths of approximately 55 to 155 feet below land surface. This is the middle hydrostratigraphic unit and is reddish-brown, very fine grained, and contains predominantly silt and clay-sized particles in the lower sections of the unit. This unit is generally unsaturated except immediately below the Dolores River alluvium and immediately above the Navajo Sandstone. The Entrada Sandstone forms a barrier to downward movement of water from the alluvium, and also serves as a confining layer (aquitard) for the underlying saturated Navajo Sandstone.

The Navajo Sandstone is the bottom hydrostratigraphic unit and occurs at depths between 55 and 155 feet below land surface and is of an undetermined total thickness in the area of the tailings sites. This sandstone is light reddish-brown, massive to thinly-bedded, and fine grained and contains ground water under confined conditions which supplies all of the domestic water needs of the area.

The locations of hydrogeologic cross sections at the UC site is shown on Figure B.2.3 while actual cross sections are shown in Figures B.2.4 and B.2.5. The location of the NC site hydrogeologic cross sections are on Figure B.2.6 while the actual cross sections are on Figures B.2.7 and B.2.8. The surface topography shown on the cross sections was developed from a topographic survey of the sites. Subsurface

Figure B.2.3 Location of hydrogeologic cross sections at the UC site, Slick Rock, Colorado

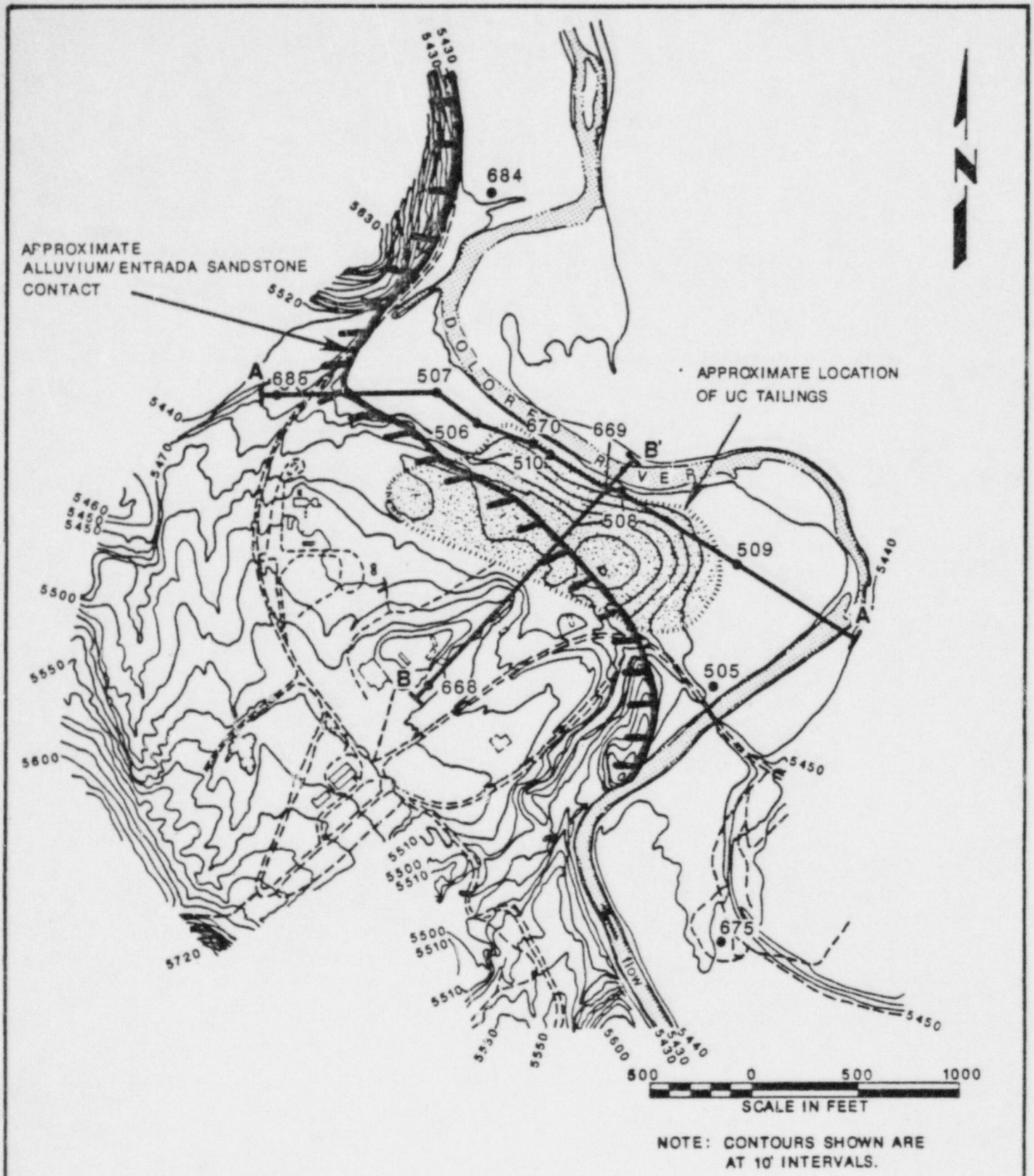

FIGURE B.2.3

LOCATION OF HYDROGEOLOGIC CROSS SECTIONS AT THE UC SITE
SLICK ROCK, COLORADO

Figure B.2.4 Hydrogeologic cross section A–A' at the UC site, Slick Rock, Colorado

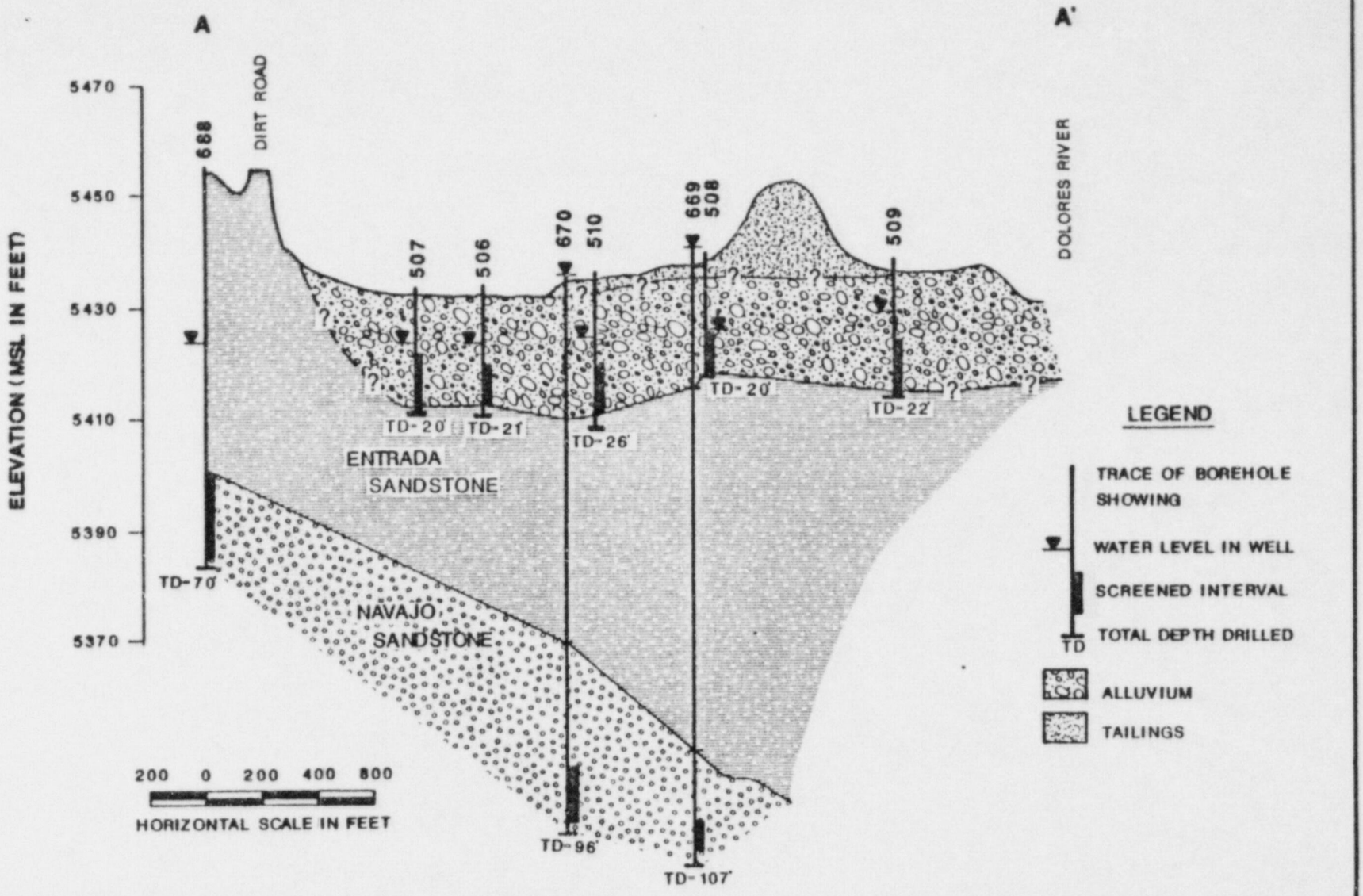

FIGURE B.2.4
HYDROGEOLOGIC CROSS SECTION A-A' AT THE UC SITE
SLICK ROCK, COLORADO

Figure 8.2.5 Hydrogeologic cross section B-B' at the UC site, Slick Rock, Colorado

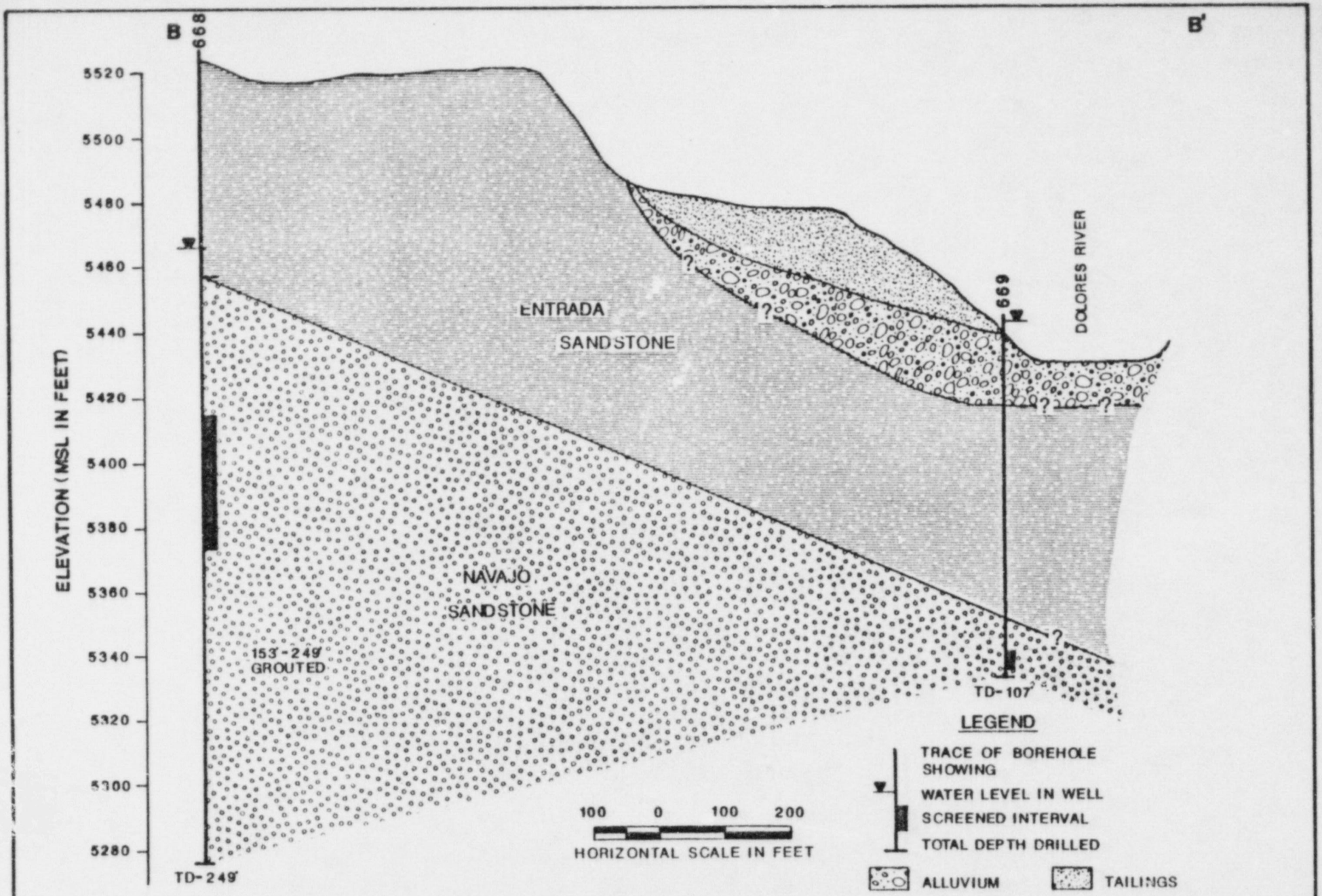

FIGURE B.2.5

HYDROGEOLOGIC CROSS SECTION B-B' AT THE UC SITE, SLICK ROCK, COLORADO

Figure 8.2.6 Location of hydrogeologic cross sections at the NC site, Slick Rock, Colorado

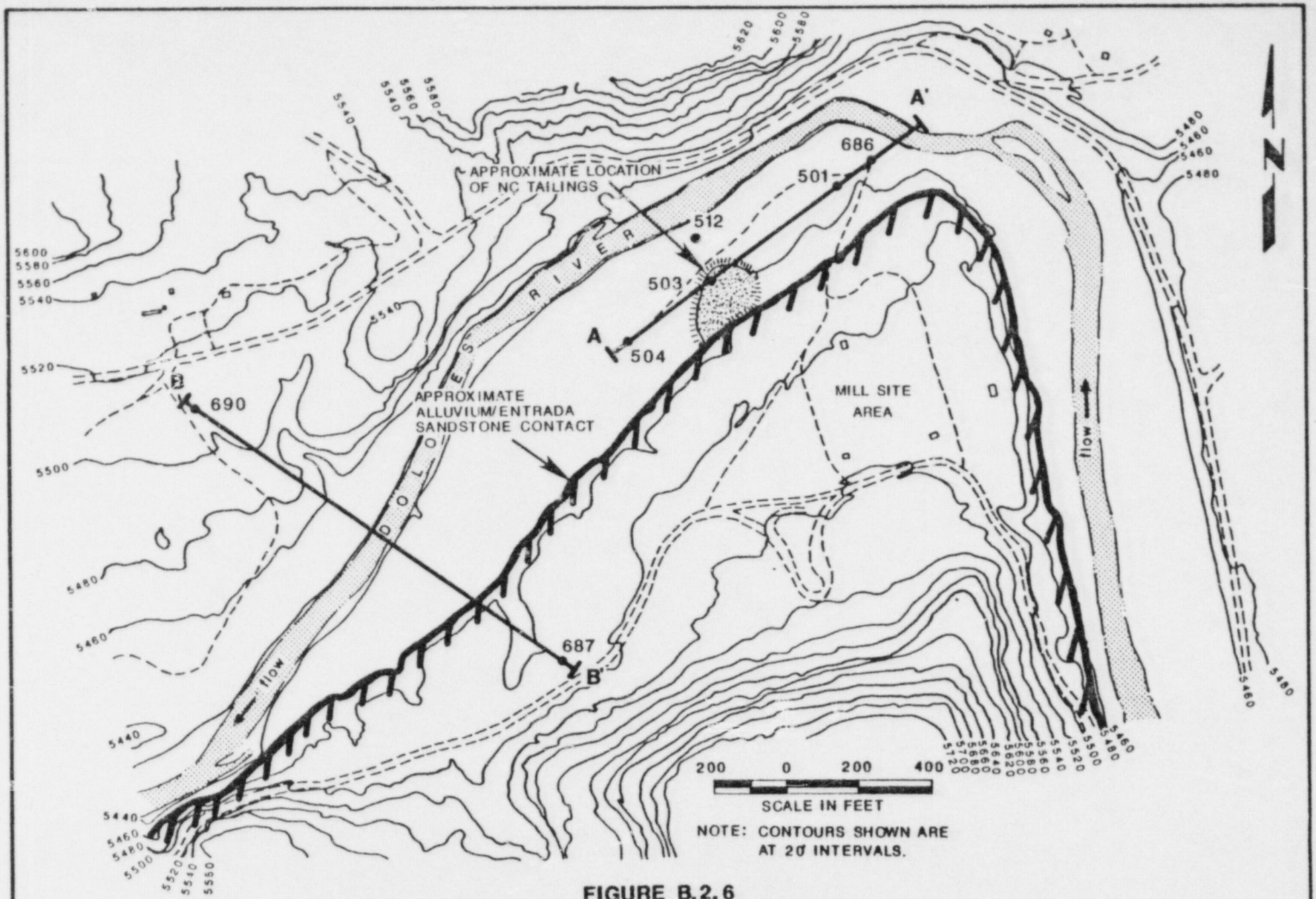

FIGURE B.2.6

LOCATION OF HYDROGEOLOGIC CROSS SECTIONS AT THE NC SITE
SLICK ROCK, COLORADO

Figure B.2.7 Hydrogeologic cross section A-A', at the NC site, Slick Rock, Colorado

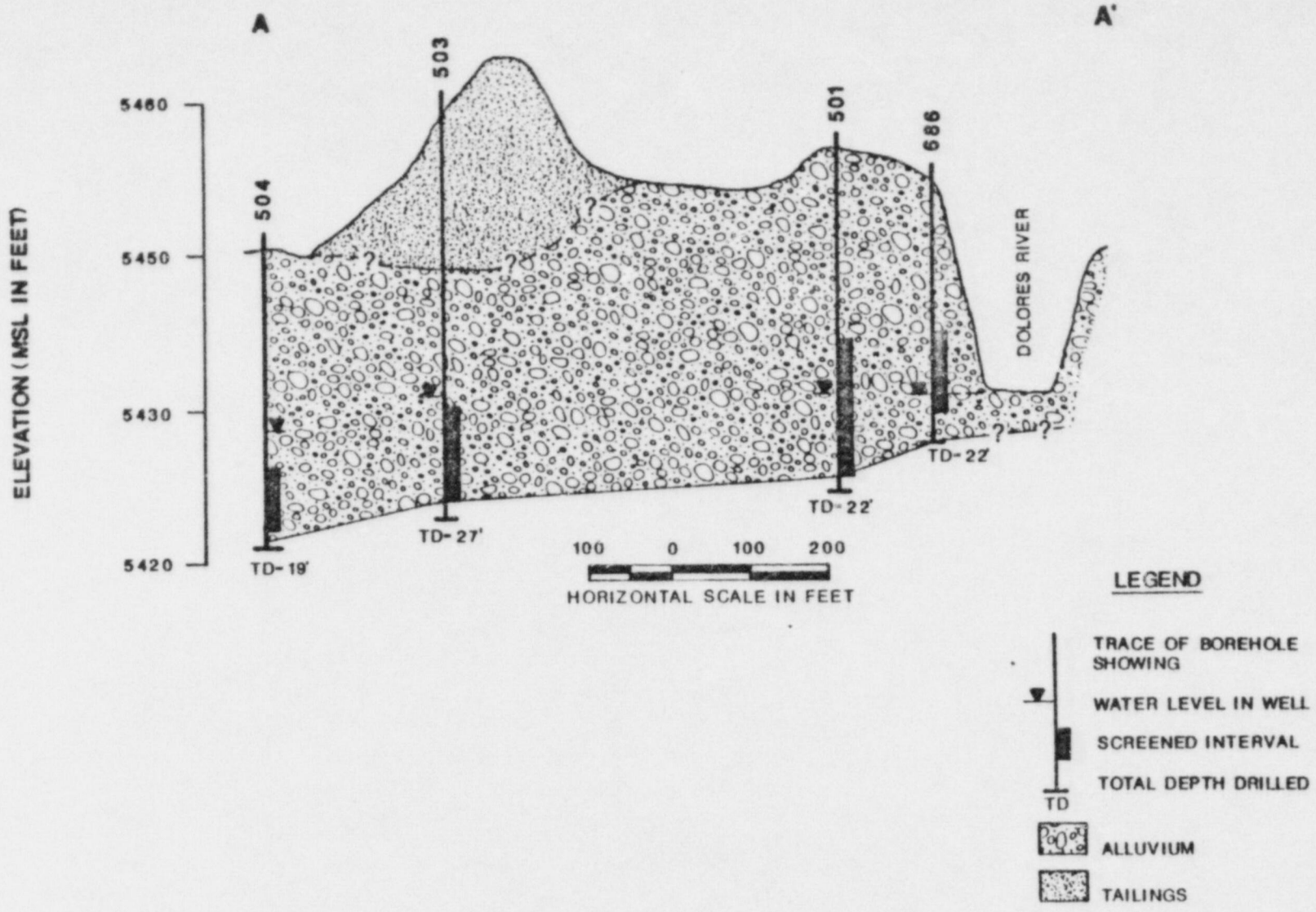

FIGURE B.2.7
HYDROGEOLOGIC CROSS SECTION A-A' AT THE NC SITE
SLICK ROCK, COLORADO

Figure 8.2.8 Hydrogeologic cross section 8-8' at the NC site, Slick Rock, Colorado

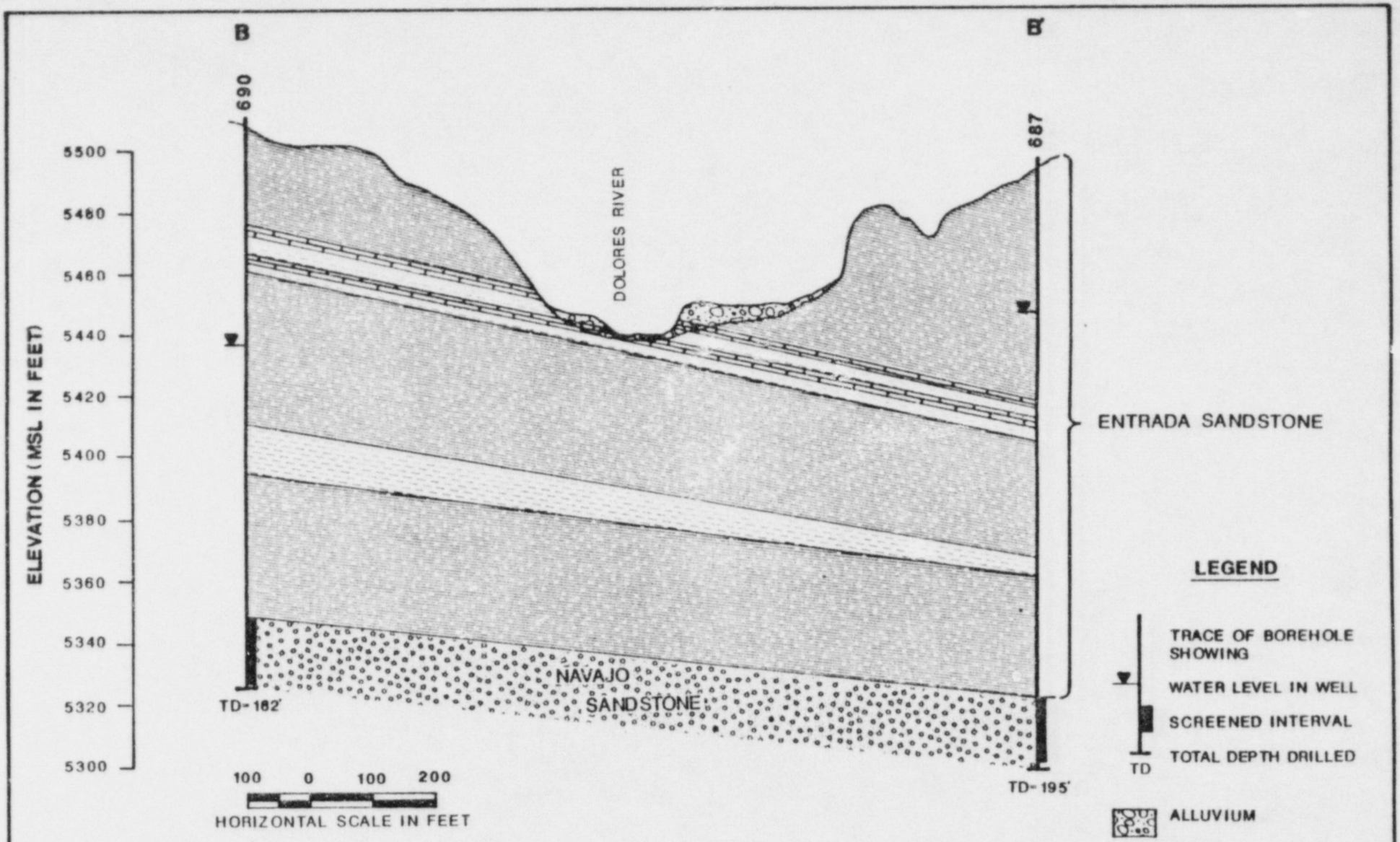

FIGURE B.2.8

HYDROGEOLOGIC CROSS SECTION B-B' AT THE NC SITE
SLICK ROCK, COLORADO

lithologies were drawn from borehole logs, visual inspection of core samples, and correlation of subsurface data with surface geology.

B.2.3.4 Saturated zone hydraulics

DOE (1983) presented hydraulic data and analyses for one alluvial well at the UC site and five alluvial wells at the NC site. Slug withdrawal or injection tests were performed within ten alluvial monitor wells during the present study. In addition five monitor wells were completed within the Navajo Sandstone.

The water table in the alluvium ranges from about seven to 20 feet below land surface near both tailings sites. Water levels taken between February and July, 1986, (Table B.2.3) indicate that the water table at both sites slopes from the upstream Dolores River-alluvium contact toward the downstream extent of the alluvium (Figures B.2.9 through B.2.12). Alluvial ground water is recharged by the river at the upstream aquifer boundaries and is discharged into the river in the downstream portions of the alluvial aquifers.

Average linear velocities within the alluvium were calculated with Darcy's Law:

Table B.2.3 Potentiometric surface elevations from February through July, 1986, at the Slick Rock, Colorado, tailings sites

Well number	Water level elevation in feet above mean sea level				Maximum fluctuation (feet)
	Feb 86	May 86	Jun 86	Jul 86	
Alluvium					
501	5439.65	5441.20	5441.13	[a]	1.55
503	5438.84	5439.57	5440.51		1.67
504	5437.99	5438.37	5439.27		1.28
505	5430.64	5431.14	5431.96	5431.55	1.32
506	5421.72	5422.23	5422.46		0.74
507	5423.16	5423.68	5423.41		0.52
508	5424.29	5425.37	5424.96		1.08
509	5425.66	5426.29	5427.38	5427.60	1.94
510	5422.66	5423.50	5423.75		1.09
512	5439.23	5440.63	5439.95		1.40
684			5419.57		
685			5417.08	5416.81	0.27
686			5443.51	5440.74	2.77
675[b]		5430.77	5431.72		0.95
Navajo Sandstone					
668	5465.71	5465.64	5465.83		0.19
669	5439.75	5440.17	5440.41		0.66
670	5434.91	5435.42	5435.04		0.51
687			5447.16	5438.24	8.92
688			5424.94	5423.90	1.04
690			5436.86	5436.78	0.08

[a]Blanks indicate levels not taken.
[b]Well number 675 is a private, hand-dug alluvial well.

Figure B.2.9 Alluvial ground-water flow directions during February, 1986, at the UC site, Slick Rock, Colorado

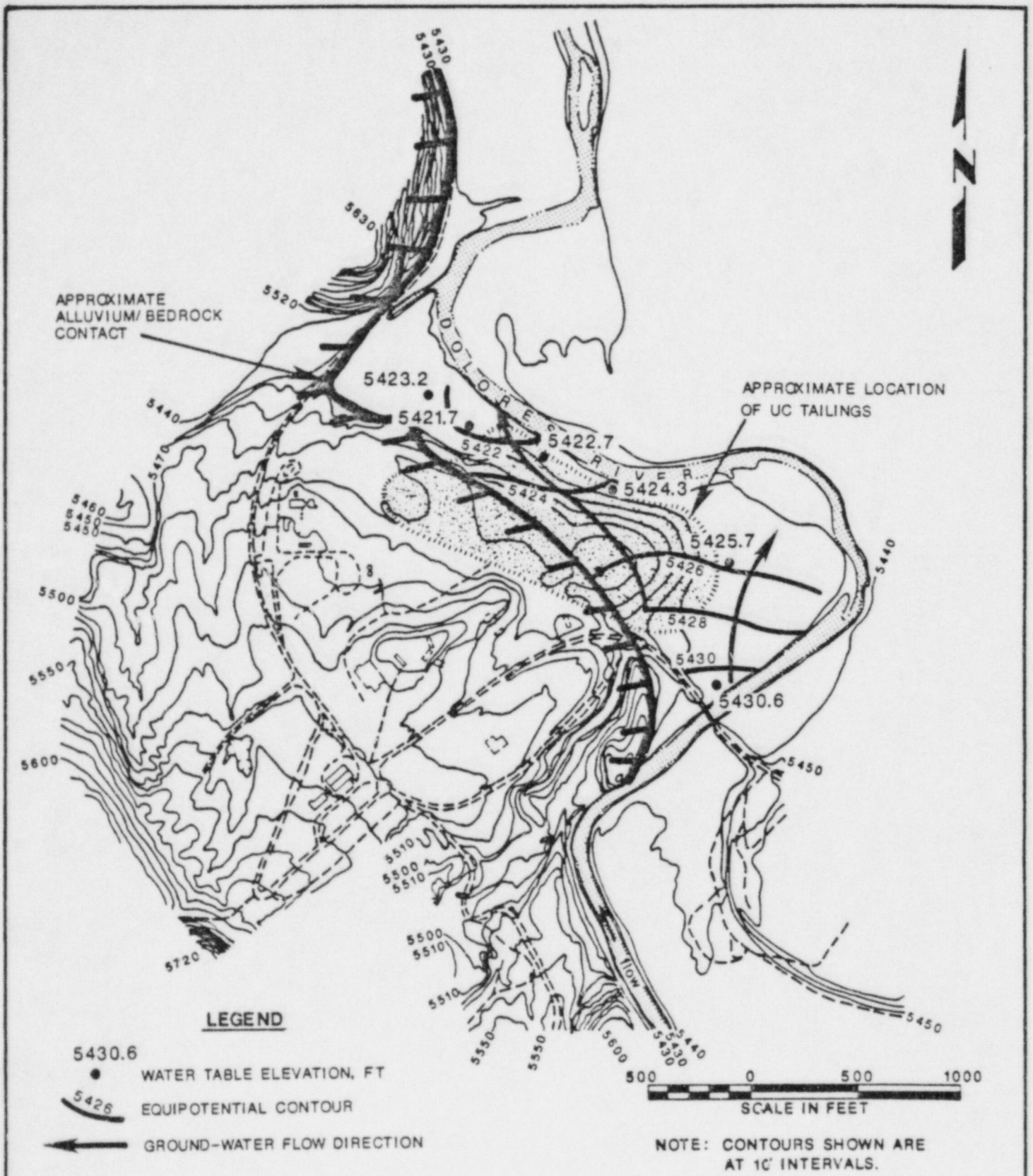

FIGURE B.2.9

ALLUVIAL GROUND-WATER FLOW DIRECTIONS DURING FEBRUARY, 1986 AT THE UC SITE, SLICK ROCK, COLORADO

Figure B.2.10 Alluvial ground-water flow directions during June, 1986, at the UC site, Slick Rock, Colorado

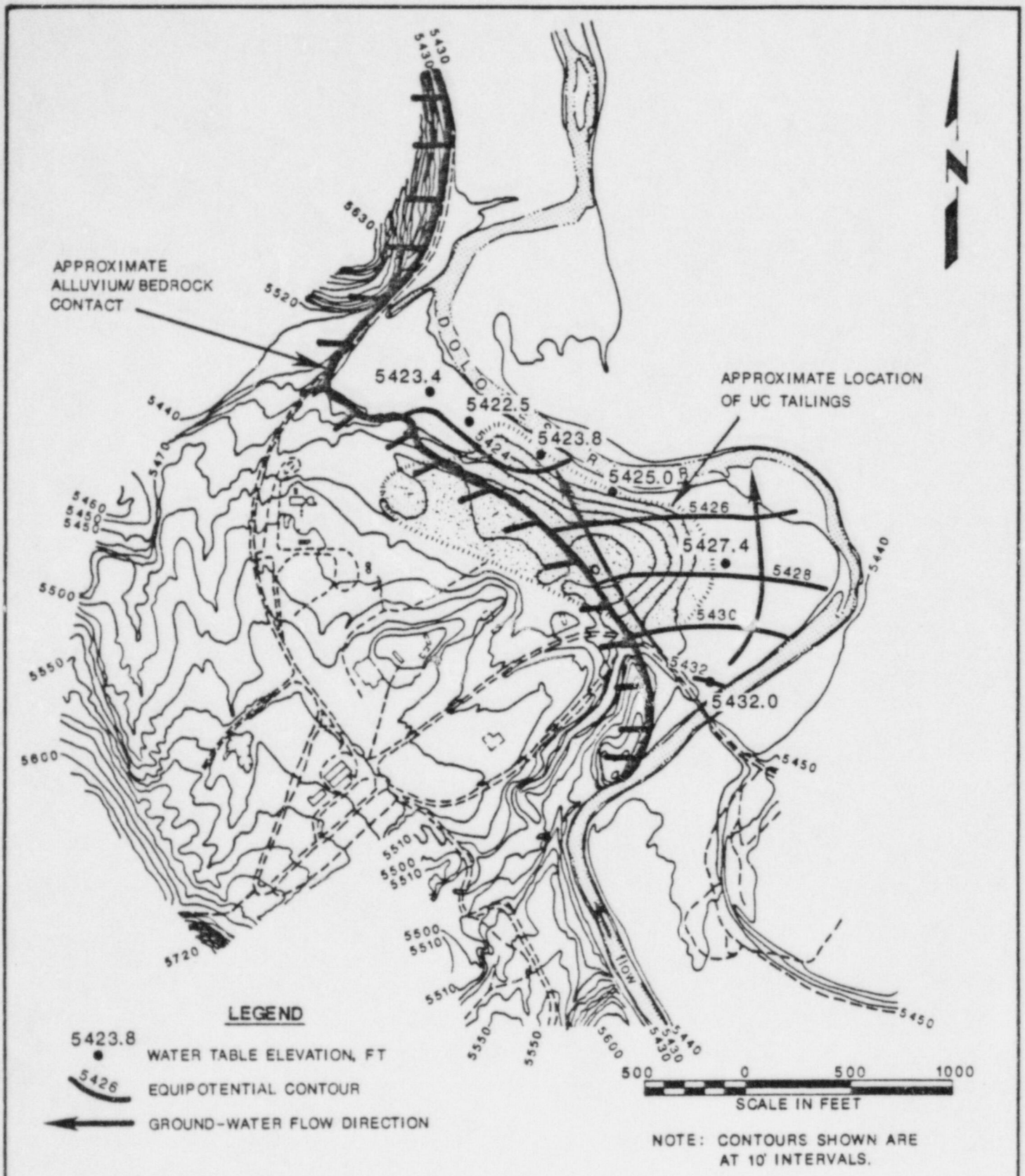

FIGURE B.2.10

ALLUVIAL GROUND-WATER FLOW DIRECTIONS DURING JUNE, 1986 AT THE UC SITE, SLICK ROCK, COLORADO

Figure B.2.11 Alluvial ground-water flow directions during February, 1986, at the NC site, Slick Rock, Colorado

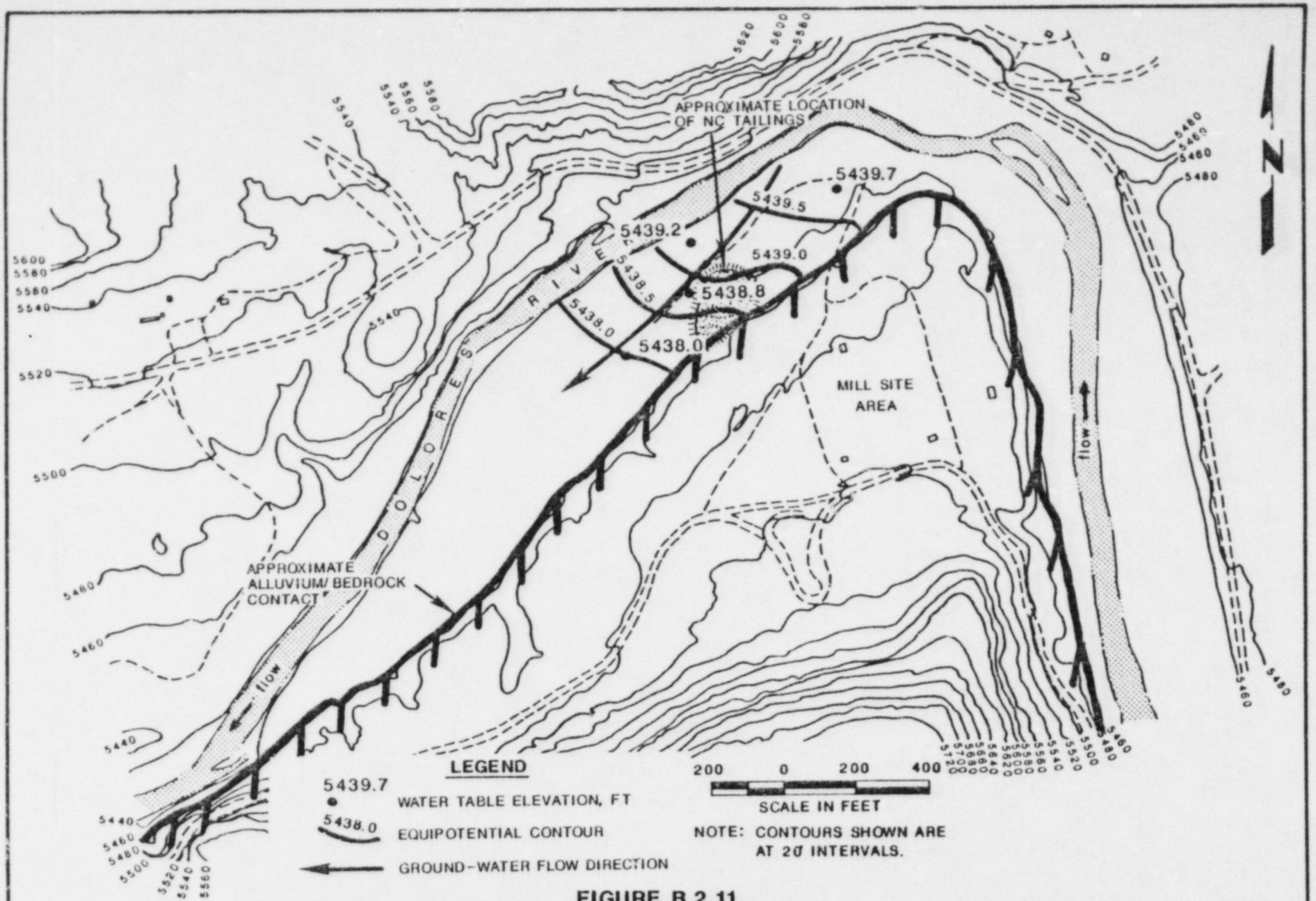

FIGURE B.2.11

ALLUVIAL GROUND-WATER FLOW DIRECTIONS DURING FEBRUARY, 1986 AT THE NC SITE SLICK ROCK, COLORADO

Figure B.2.12 Alluvial ground-water flow directions during June, 1986, at the NC site, Slick Rock, Colorado

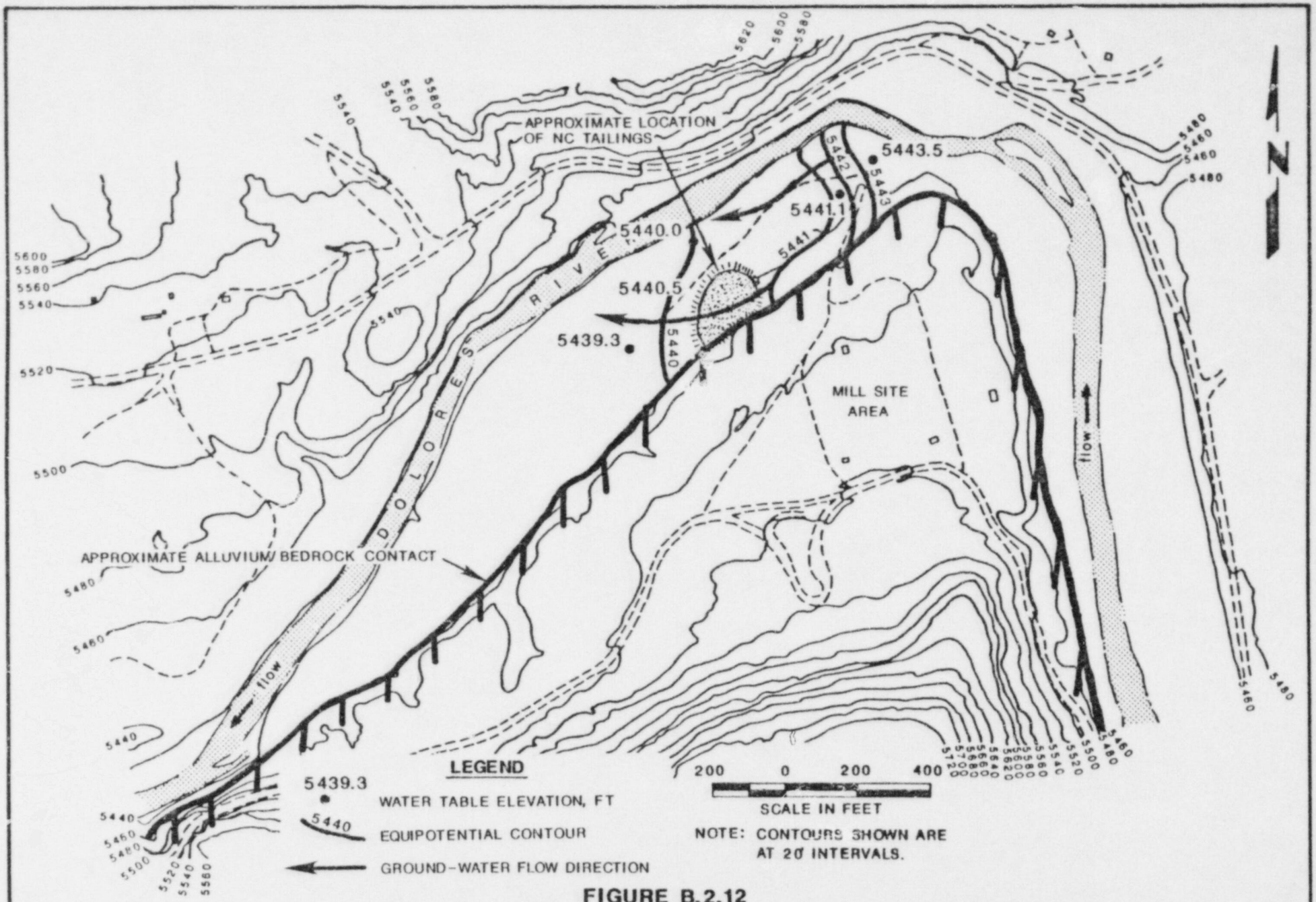

FIGURE B.2.12

ALLUVIAL GROUND-WATER FLOW DIRECTIONS DURING JUNE, 1986 AT THE NC SITE SLICK ROCK, COLORADO

$$q_n = \frac{K\Delta h/\Delta l}{n_e}$$

where:

q_n = average linear velocity

K = hydraulic conductivity

$\Delta h/\Delta l$ = hydraulic gradient

n_e = effective porosity

The hydraulic gradient was calculated using values shown on Figure B.2.11.

$$\frac{\Delta h}{\Delta l} = \frac{h_1 - h_2}{\Delta l}$$

where:

h_1 = 5432 feet

h_2 = 5426 feet

Δl = 775 feet, distance between points where water levels were measured (h_1 and h_2).

Analysis of data obtained from slug tests performed in the alluvial and Navajo Sandstone monitor wells at the Slick

Rock sites was used to calculate hydraulic conductivities (Table B.2.4). Porosity was assumed to range from 25 to 50 percent in the alluvium and 25 to 35 percent in the Navajo Sandstone (Freeze and Cherry, 1979; Cooley et al, 1969). These values were assumed to equal the effective porosity. Other hydraulic characteristics, including hydraulic gradient and average linear velocity, appear in Table B.2.5.

Ground water, which is contained in the Navajo Sandstone, was encountered at depths ranging from about 55 to 155 feet below land surface. The upward hydraulic gradient of ground water in this unit was examined by a comparison of the potentiometric surfaces as exhibited in adjacent monitor wells completed within both the alluvial and Navajo Sandstone aquifers. At the monitor well pairs 510/670 and 508/669, the difference in elevation between the centers of each pairs' screened interval is about 70 and 85 feet, respectively. The difference in the elevation of the potentiometric surface in February, 1986, was about 12 feet at pair 510/670 and about 16 feet at pair 508/669, with the potentiometric surface of the ground water in the Navajo Sandstone higher in elevation in both pairs. The upward hydraulic gradient at monitor well pairs 510/670 and 508/669 is equal to about 0.17 and 0.19, respectively.

Table B.2.4 Hydraulic conductivity calculated from slug test data from the alluvium and Navajo Sandstone beneath the Slick Rock tailings sites, Slick Rock, Colorado

Alluvium well number	Hydraulic conductivity-K (feet per year)	
	Bouwer-Rice method	Hvorslev method
501	660.0	12,785.0
503	124.0	5,272.0
504	—[a]	6,073.0
505	905.0	—
507	365.0	12,468.0
509	2,073.0	10,132.0
510	—	11,000.0
684	—	6,678.0

Navajo Sandstone well number	Hydraulic conductivity-K (feet per year)		
	Skibitzke method	Ferris-Knowles method	Cooper-Bredehoeft-Papadopulos method
668	5.1	6.4	5.1
669	5.0	9.0	15.0
670	2.5	4.5	11.0
687	9.4	—	—
690	63.0	41.0	36.0

a. analysis invalid.

Ref. Bouwer, 1978; Hvorslev, 1951; Skibitzke, 1963; Ferris and Knowles, 1963; Lohman, 1972.

Table B.2.5 Range of hydraulic characteristics calculated from slug test data at the Slick Rock, Colorado, tailings sites

	Formation well number	Hydraulic conductivity (feet per year)	Hydraulic gradient	Effective porosity[b]	Average linear velocity (feet per year)
	Alluvium				
Minimum	503	124.0	8×10^{-3}	0.50	2.0
Geometric mean	—[a]	2780.0	8×10^{-3}	0.39	57.0
Maximum	501	12785.0	8×10^{-3}	0.25	409.1
	Navajo Sandstone				
Minimum	670	2.5	2×10^{-2}	0.35	0.1
Geometric mean	—	10.2	2×10^{-2}	0.30	0.7
Maximum	690	63.0	2×10^{-2}	0.25	5.0

[a]"—" = not applicable.
[b]Porosity for the alluvium is from Freeze and Cherry (1979) and the Navajo Sandstone is from Cooley et al (1969). Porosity is assumed to equal effective porosity.

Water levels within the Navajo Sandstone taken between February, 1986, and July, 1986, were presented in Table B.2.3. The potentiometric surface of ground water in the Navajo Sandstone slopes toward the north and northeast (Figure B.2.13).

Average linear velocities within the Navajo Sandstone were calculated with Darcy's Law and the hydraulic gradient was calculated using values shown on Figure B.2.13.

B.2.3.5 Ground-water quality

Ground-water quality in the vicinity of the UC and NC sites was characterized by sampling 14 alluvial and nine Navajo Sandstone monitor wells (see Figure B.2.1). The samples were withdrawn with a bladder pump or a submersible pump and preserved in accordance with EPA recommendations (EPA, 1983). The temperature, pH, electrical conductivity, and alkalinity of each sample were measured in the field in accordance with approved procedures (DOE, 1985).

Results of the water-quality analyses used to define background concentrations in the alluvial and Navajo Sandstone aquifers are presented in Tables B.2.6 and B.2.7, respectively. Table B.2.8 presents water-quality data for alluvial monitoring wells that were found to be contaminated.

Figure 8.2.13 Navajo Sandstone ground-water flow directions during June, 1986, at the Slick Rock, Colorado, tailings sites

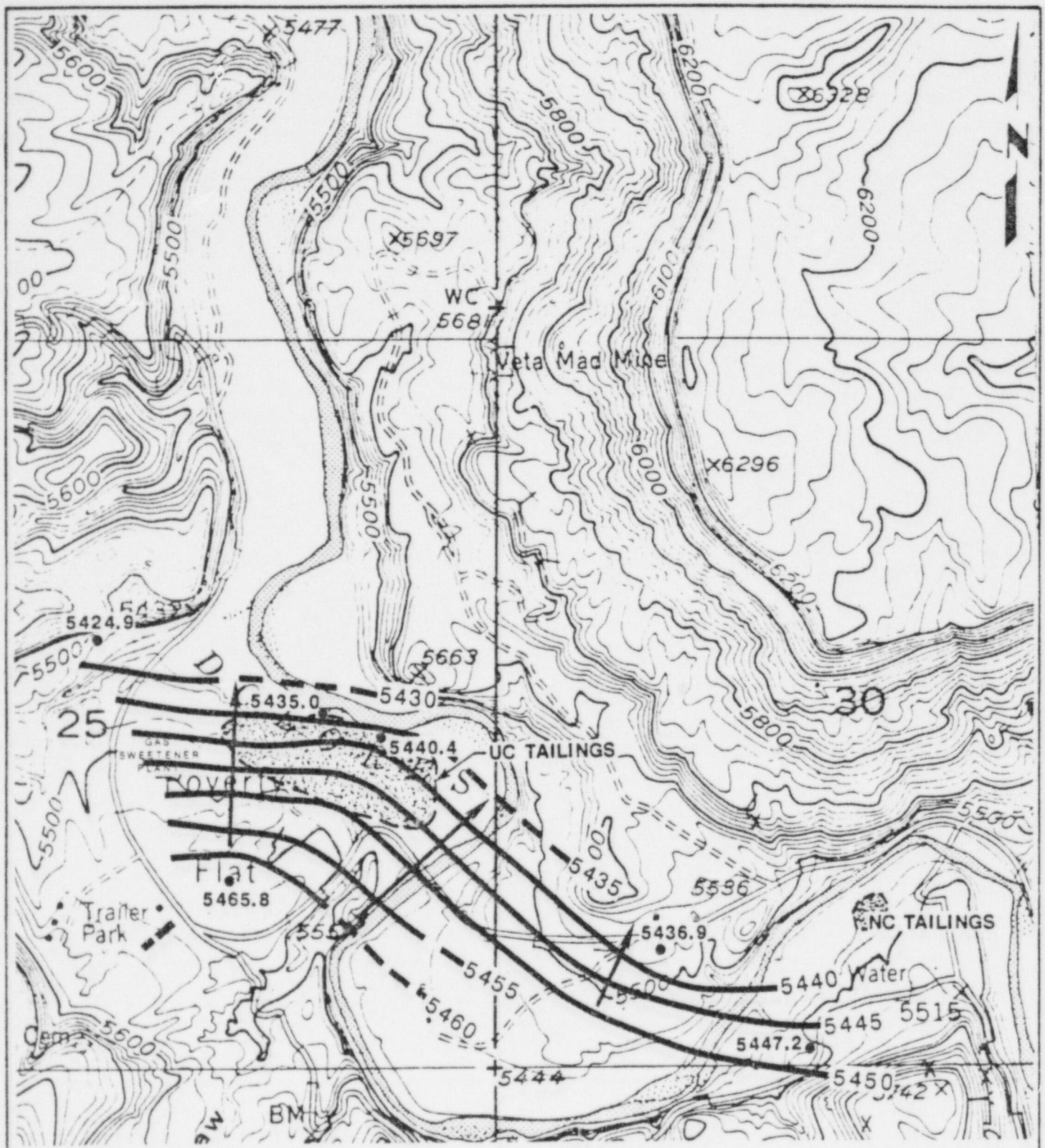

FIGURE B.2.13
NAVAJO SANDSTONE GROUND-WATER FLOW DIRECTIONS DURING JUNE, 1986 AT THE SLICK ROCK, COLORADO TAILINGS SITES

Table B.2.6 Background alluvial ground-water quality analyses for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites

Table B.2.6 Background alluvial ground-water quality analyses for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites

PARAMETER	UNIT OF MEASURE	LOCATION ID - SAMPLE ID AND LOG DATE: 501-01 02/18/86	501-02 02/18/86	501-03 02/18/86	501-04 02/18/86	501-05 02/18/86
		PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY
ALKALINITY	MG/L CACO3	951.	951.	951.	951.	951.
ALUMINUM	MG/L	-	-	-	-	-
AMMONIUM	MG/L	0.6	0.6	0.6	0.5	0.5
ANTIMONY	MG/L	-	-	-	-	-
ARSENIC	MG/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
BARIUM	MG/L	-	-	-	-	-
BORON	MG/L	-	-	-	-	-
CADMIUM	MG/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
CALCIUM	MG/L	163.	163.	163.	163.	163.
CHLORIDE	MG/L	81.	81.	82.	82.	82.
CHROMIUM	MG/L	-	-	-	-	-
CONDUCTANCE	UMHO/CM	1000.	1000.	1000.	1000.	1000.
COPPER	MG/L	-	-	-	-	-
FLUORIDE	MG/L	-	-	-	-	-
IRON	MG/L	0.25	0.25	0.25	0.25	0.25
LEAD	MG/L	-	-	-	-	-
MAGNESIUM	MG/L	46.7	46.7	46.7	46.7	46.7
MANGANESE	MG/L	0.26	0.26	0.26	0.26	0.26
MERCURY	MG/L	-	-	-	-	-
MOLYBDENUM	MG/L	0.13	0.12	0.13	0.13	0.13
NICKEL	MG/L	-	-	-	-	-
NITRATE	MG/L	< 1.	< 1.	< 1.	< 1.	< 1.
PB-210	PCI/L	-	-	-	-	-
PH	SU	7.2	7.2	7.2	7.2	7.2
PHOSPHATE	MG/L	-	-	-	-	-
PO-210	PCI/L	-	-	-	-	-
POTASSIUM	MG/L	5.72	5.73	5.71	5.72	5.72
RA-226	PCI/L	-	-	-	-	-
RA-228	PCI/L	-	-	-	-	-
SELENIUM	MG/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
SILICA	MG/L	-	-	-	-	-
SILVER	MG/L	-	-	-	-	-
SODIUM	MG/L	470.	470.	470.	470.	470.
SULFATE	MG/L	521.	522.	519.	520.	521.
SULFIDE	MG/L	-	-	-	-	-
TEMPERATURE	C - DEGREE	12.	12.	12.	12.	12.
TH-230	PCI/L	-	-	-	-	-
TIN	MG/L	-	-	-	-	-
TOTAL SOLIDS	MG/L	1160.	1170.	1160.	1170.	1160.
URANIUM	MG/L	0.0498	0.0668	0.591	0.0534	0.0565
VANADIUM	MG/L	-	-	-	-	-
ZINC	MG/L	-	-	-	-	-

Table B.2.6 Background alluvial ground-water quality analyses for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (continued)

Table B.2.6 Background alluvial ground-water quality analyses for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (Continued)

		LOCATION ID - SAMPLE ID AND LOG DATE									
		501-01 07/01/86		505-01 02/18/86		505-01 07/17/86		509-01 02/18/86		509-01 07/17/86	
PARAMETER	UNIT OF MEASURE	PARAMETER VALUE	+/-UNCERTAINTY	PARAMETER VALUE	+/-UNCERTAINTY	PARAMETER VALUE	+/-UNCERTAINTY	PARAMETER VALUE	+/-UNCERTAINTY	PARAMETER VALUE	+/-UNCERTAINTY
ALKALINITY	MG/L CACO3	231.		301.		298.		280.		291.	
ALUMINUM	MG/L	0.4		-		0.2		-		0.2	
AMMONIUM	MG/L	-		4.6		5.2		80.		-	
ANTIMONY	MG/L	-		-		< 0.003		-		-	
ARSENIC	MG/L	< 0.01		< 0.01		< 0.01		< 0.01		< 0.01	
BARIUM	MG/L	-		-		0.1		-		-	
BORON	MG/L	-		-		< 0.1		-		-	
CADMIUM	MG/L	-		< 0.001		< 0.001		< 0.001		-	
CALCIUM	MG/L	99.6		137.		113.		182.		138.	
CHLORIDE	MG/L	64.		74.		77.		100.		71.	
CHROMIUM	MG/L	-		-		0.07		-		-	
CONDUCTANCE	UMHO/CM	790.		1150.		1000.		1900.		1000.	
COPPER	MG/L	-		-		0.03		-		-	
FLUORIDE	MG/L	-		-		0.3		-		-	
IRON	MG/L	0.05		0.16		0.31		0.07		0.05	
LEAD	MG/L	-		-		< 0.01		-		-	
MAGNESIUM	MG/L	29.		65.7		52.2		88.8		49.	
MANGANESE	MG/L	0.04		0.32		0.38		0.4		0.12	
MERCURY	MG/L	-		-		< 0.0002		-		-	
MOLYBDENUM	MG/L	0.11		0.14		0.14		0.44		0.38	
NICKEL	MG/L	-		-		< 0.04		-		-	
NITRATE	MG/L	< 1.		< 1.		< 1.		< 1.		5.	
PB-210	PCI/L	-		-		0.7	1.3	-		-	
PH	SU	7.16		6.62		6.98		6.94		6.9	
PHOSPHATE	MG/L	-		-		< 0.1		-		-	
PO-210	PCI/L	-		-		0.	0.5	-		-	
POTASSIUM	MG/L	4.75		10.2		6.64		17.5		7.56	
RA-226	PCI/L	-		-		0.2	0.2	-		-	
RA-228	PCI/L	-		-		0.	0.9	-		-	
SELENIUM	MG/L	< 0.005		< 0.005		< 0.005		< 0.005		< 0.005	
SILICA	MG/L	-		-		4.		-		-	
SILVER	MG/L	-		-		< 0.01		-		-	
SODIUM	MG/L	125.		185.		186.		212.		171.	
SULFATE	MG/L	336.		619.		524.		1160.		532.	
SULFIDE	MG/L	< 0.1		-		< 0.1		-		< 0.1	
TEMPERATURE	C - DEGREE	12.5		10.		11.5		11.		14.	
TH-230	PCI/L	-		-		0.5	0.4	-		-	
TIN	MG/L	-		-		< 0.005		-		-	
TOTAL SOLIDS	MG/L	819.		1350.		1180.		1940.		1140.	
URANIUM	MG/L	0.0334		0.0398		0.0304		0.0242		0.0287	
VANADIUM	MG/L	0.23		-		0.24		-		0.43	
ZINC	MG/L	-		-		0.013		-		-	

Table B.2.6 Background alluvial ground-water quality analyses for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (concluded)

Table B.2.6 Background alluvial ground-water quality analyses for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (Concluded)

PARAMETER	UNIT OF MEASURE	LOCATION ID - SAMPLE ID AND LOG DATE: 675-01 06/30/86 PARAMETER VALUE +/- UNCERTAINTY	684-01 06/30/86 PARAMETER VALUE +/- UNCERTAINTY	685-01 07/17/86 PARAMETER VALUE +/- UNCERTAINTY	686-01 07/17/86 PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY
ALKALINITY	MG/L CACO3	487.	223.	336.	435.	
ALUMINUM	MG/L	0.3	0.3	0.4	0.3	
AMMONIUM	MG/L	-	1.	-	< 0.1	
ANTIMONY	MG/L	-	< 0.003	-	< 0.003	
ARSENIC	MG/L	< 0.01	< 0.01	< 0.01	< 0.01	
BARIUM	MG/L	-	0.1	-	0.2	
BORON	MG/L	-	< 0.1	-	0.3	
CADMIUM	MG/L	-	< 0.001	-	< 0.001	
CALCIUM	MG/L	108.	82.6	119.	73.8	
CHLORIDE	MG/L	140.	32.	87.0	40.	
CHROMIUM	MG/L	-	0.05	-	0.04	
CONDUCTANCE	UMHO/CM	1800.	650.	970.	600.	
COPPER	MG/L	-	0.04	-	0.05	
FLUORIDE	MG/L	-	0.4	-	0.4	
IRON	MG/L	0.24	0.05	0.29	0.07	
LEAD	MG/L	-	< 0.01	-	< 0.01	
MAGNESIUM	MG/L	111.	29.7	65.3	20.9	
MANGANESE	MG/L	0.3	0.31	0.72	1.27	
MERCURY	MG/L	-	< 0.0002	-	< 0.0002	
MOLYBDENUM	MG/L	0.12	0.08	0.15	0.24	
NICKEL	MG/L	-	< 0.04	-	< 0.04	
NITRATE	MG/L	< 1.	< 1.	< 1.	< 1.	
PB-210	PCI/L	-	0. 1.1	-	-	
PH	SU	7.34	7.3	6.97	7.55	
PHOSPHATE	MG/L	-	< 0.1	-	< 0.1	
PO-210	PCI/L	-	0. 0.6	-	-	
POTASSIUM	MG/L	27.9	11.9	12.3	6.08	
RA-226	PCI/L	-	0.1 0.1	-	-	
RA-228	PCI/L	-	0. 0.8	-	-	
SELENIUM	MG/L	< 0.005	< 0.005	< 0.005	< 0.005	
SILICA	MG/L	-	4.	-	4.	
SILVER	MG/L	-	< 0.01	-	< 0.01	
SODIUM	MG/L	345.	83.6	132.	195.	
SULFATE	MG/L	840.	272.	424.	223.	
SULFIDE	MG/L	< 0.1	< 0.1	< 0.1	< 0.1	
TEMPERATURE	C - DEGREE	16.	12.5	11.5	13.5	
TH-230	PCI/L	-	0. 0.1	-	-	
TIN	MG/L	-	< 0.005	-	< 0.005	
TOTAL SOLIDS	MG/L	1950.	655.	1030.	622.	
URANIUM	MG/L	0.0246	0.009	0.0188	0.0404	
VANADIUM	MG/L	0.42	0.44	0.33	0.39	
ZINC	MG/L	-	0.014	-	0.011	

Table B.2.7 Background Navajo Sandstone ground-water quality analysis for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites

Table B.2.7 Background Navajo Sandstone ground-water quality analyses for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites

PARAMETER	UNIT OF MEASURE	LOCATION ID - SAMPLE ID AND LOG DATE: 634-01 02/01/86 PARAMETER VALUE +/- UNCERTAINTY	634-01 06/30/86 PARAMETER VALUE +/- UNCERTAINTY	668-01 02/02/86 PARAMETER VALUE +/- UNCERTAINTY	668-01 06/30/86 PARAMETER VALUE +/- UNCERTAINTY	669-01 02/04/86 PARAMETER VALUE +/- UNCERTAINTY
ALKALINITY	MG/L CACO3	319.	347.	268.	261.	140.
ALUMINUM	MG/L	-	0.3	-	0.3	-
AMMONIUM	MG/L	< 0.1	-	< 0.1	-	< 0.1
ANTIMONY	MG/L	-	-	-	-	-
ARSENIC	MG/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
BARIUM	MG/L	-	-	-	-	-
BORON	MG/L	-	-	-	-	-
CADMIUM	MG/L	< 0.001	-	< 0.001	-	< 0.001
CALCIUM	MG/L	59.4	63.7	26.7	28.1	22.
CHLORIDE	MG/L	28.	47.	18.	15.	39.
CHROMIUM	MG/L	-	-	-	-	-
CONDUCTANCE	UMHO/CM	470.	600.	435.	390.	190.
COPPER	MG/L	-	-	-	-	-
FLUORIDE	MG/L	-	-	-	-	-
IRON	MG/L	0.04	< 0.03	< 0.03	< 0.03	< 0.03
LEAD	MG/L	-	-	-	-	-
MAGNESIUM	MG/L	39.8	41.2	50.4	44.4	18.7
MANGANESE	MG/L	< 0.01	0.03	0.03	0.04	0.02
MERCURY	MG/L	-	-	-	-	-
MOLYBDENUM	MG/L	0.09	0.16	0.08	0.17	0.09
NICKEL	MG/L	-	-	-	-	-
NITRATE	MG/L	1.	< 1.	1.	< 1.	< 1.
PB-210	PCI/L	-	-	-	-	-
PH	SU	7.46	7.52	8.22	7.47	10.45
PHOSPHATE	MG/L	-	-	-	-	-
PO-210	PCI/L	-	-	-	-	-
POTASSIUM	MG/L	5.22	5.52	13.9	9.12	14.
RA-226	PCI/L	-	-	-	-	-
RA-228	PCI/L	-	-	-	-	-
SELENIUM	MG/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
SILICA	MG/L	-	-	-	-	-
SILVER	MG/L	-	0.3	-	0.3	-
SODIUM	MG/L	31.7	45.3	48.6	41.1	20.5
SULFATE	MG/L	58.	44.9	55.	14.8	34.
SULFIDE	MG/L	-	< 0.1	-	< 0.1	-
TEMPERATURE	C - DEGREE	9.5	17.5	14.	15.5	12.
TH-230	PCI/L	-	-	-	-	-
TIN	MG/L	-	-	-	-	-
TOTAL SOLIDS	MG/L	417.	521.	214.	355.	162.
URANIUM	MG/L	0.0113	0.0114	0.0078	0.0028	0.0013
VANADIUM	MG/L	-	0.63	-	0.44	-
ZINC	MG/L	-	-	-	-	-

Table 8.2.7 Background Navajo Sandstone ground-water quality analysis for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (continued)

Table B.2.7 Background Navajo Sandstone ground-water quality analyses for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (Continued)

PARAMETER	UNIT OF MEASURE	LOCATION ID - SAMPLE ID AND LOG DATE: 669-01 06/30/86 PARAMETER VALUE +/- UNCERTAINTY	670-01 02/03/86 PARAMETER VALUE +/- UNCERTAINTY	670-01 07/19/86 PARAMETER VALUE +/- UNCERTAINTY	672-01 02/01/86 PARAMETER VALUE +/- UNCERTAINTY	672-01 07/19/86 PARAMETER VALUE +/- UNCERTAINTY
ALKALINITY	MG/L CACO3	205.	184.	225.	265.	273.
ALUMINUM	MG/L	0.4	-	0.3	-	0.4
AMMONIUM	MG/L	-	0.3	-	0.3	-
ANTIMONY	MG/L	-	-	-	-	-
ARSENIC	MG/L	< 0.01	0.01	< 0.01	< 0.01	< 0.01
BARIUM	MG/L	-	-	-	-	-
BORON	MG/L	-	-	-	-	-
CADMIUM	MG/L	-	< 0.001	-	< 0.001	-
CALCIUM	MG/L	31.9	25.5	34.8	21.1	20.8
CHLORIDE	MG/L	9.8	8.	18.	8.	15.
CHROMIUM	MG/L	-	-	-	-	-
CONDUCTANCE	UMHO/CM	250.	290.	320.	350.	380.
COPPER	MG/L	-	-	-	-	-
FLUORIDE	MG/L	-	-	-	-	-
IRON	MG/L	0.06	0.06	< 0.03	< 0.03	< 0.03
LEAD	MG/L	-	-	-	-	-
MAGNESIUM	MG/L	22.3	25.4	29.7	43.	42.8
MANGANESE	MG/L	0.13	0.02	0.12	0.01	0.03
MERCURY	MG/L	-	-	-	-	-
MOLYBDENUM	MG/L	0.17	0.13	0.14	0.09	0.14
NICKEL	MG/L	-	-	-	-	-
NITRATE	MG/L	< 1.	< 1.	< 1.	< 1.	< 1.
PB-210	PCI/L	-	-	-	-	-
PH	SU	8.85	9.39	7.32	7.7	7.6
PHOSPHATE	MG/L	-	-	-	-	-
PO-210	PCI/L	-	-	-	-	-
POTASSIUM	MG/L	16.3	1.79	14.2	9.56	9.99
RA-226	PCI/L	-	-	-	-	-
RA-228	PCI/L	-	-	-	-	-
SELENIUM	MG/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
SILICA	MG/L	-	-	-	-	-
SILVER	MG/L	-	-	-	-	-
SODIUM	MG/L	9.38	14.	15.5	16.2	20.5
SULFATE	MG/L	19.3	23.	16.5	13.	9.5
SULFIDE	MG/L	< 0.1	-	< 0.1	-	< 0.1
TEMPERATURE	C - DEGREE	13.5	11.5	13.	14.	17.
TH-230	PCI/L	-	-	-	-	-
TIN	MG/L	-	-	-	-	-
TOTAL SOLIDS	MG/L	288.	201.	322.	261.	361.
URANIUM	MG/L	0.002	0.0048	0.0045	0.003	0.0034
VANADIUM	MG/L	0.43	-	0.34	-	0.24
ZINC	MG/L	-	-	-	-	-

Table B.2.7 Background Navajo Sandstone ground-water quality analysis for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (continued)

Table B.2.7 Background Navajo Sandstone ground-water quality analyses for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (Continued)

		LOCATION ID - SAMPLE ID AND LOG DATE									
		687-01 07/18/86		687-02 07/18/86		687-03 07/18/86		687-04 07/18/86		687-05 07/18/86	
PARAMETER	UNIT OF MEASURE	PARAMETER VALUE+/-UNCERTAINTY		PARAMETER VALUE+/-UNCERTAINTY		PARAMETER VALUE+/-UNCERTAINTY		PARAMETER VALUE+/-UNCERTAINTY		PARAMETER VALUE+/-UNCERTAINTY	
ALKALINITY	MG/L CACO3	418.		418.		418.		418.		418.	
ALUMINUM	MG/L	0.3		0.3		0.3		0.3		0.3	
AMMONIUM	MG/L	< 0.1		< 0.1		< 0.1		< 0.1		< 0.1	
ANTIMONY	MG/L	< 0.003		< 0.003		< 0.003		< 0.003		< 0.003	
ARSENIC	MG/L	0.01		0.01		0.01		0.01		0.01	
BARIUM	MG/L	0.2		0.2		0.2		0.3		0.3	
BORON	MG/L	< 0.1		1.7		1.6		1.6		1.6	
CADMIUM	MG/L	< 0.001		< 0.001		< 0.001		< 0.001		< 0.001	
CALCIUM	MG/L	28.1		28.4		28.4		28.4		28.4	
CHLORIDE	MG/L	45.		18.		19.		18.		19.	
CHROMIUM	MG/L	0.05		0.04		0.04		0.04		0.04	
CONDUCTANCE	UMHO/CM	500.		500.		500.		500.		500.	
COPPER	MG/L	0.03		0.03		0.03		0.03		0.03	
FLUORIDE	MG/L	0.7		0.8		0.8		0.8		0.8	
IRON	MG/L	0.04		0.05		0.05		0.05		0.05	
LEAD	MG/L	< 0.01		< 0.01		< 0.01		< 0.01		< 0.01	
MAGNESIUM	MG/L	19.3		19.5		19.2		19.2		19.3	
MANGANESE	MG/L	0.08		0.05		0.05		0.05		0.05	
MERCURY	MG/L	< 0.0002		< 0.0002		< 0.0002		< 0.0002		< 0.0002	
MOLYBDENUM	MG/L	0.16		0.09		0.09		0.1		0.1	
NICKEL	MG/L	0.06		< 0.04		< 0.04		< 0.04		< 0.04	
NITRATE	MG/L	80.0		< 1.		< 1.		< 1.		< 1.	
PB-210	PCI/L	0.4	0.9	0.2	1.7	1.1	1.2	0.2	0.9	0.2	1.1
PH	SU	7.24		7.24		7.24		7.24		7.24	
PHOSPHATE	MG/L	< 0.1		< 0.1		< 0.1		< 0.1		< 0.1	
PO-210	PCI/L	0.	0.5	0.	0.6	0.	0.4	0.7	0.7	0.	0.5
POTASSIUM	MG/L	30.1		29.8		29.8		29.8		29.8	
RA-226	PCI/L	0.6	0.3	0.6	0.3	0.5	0.3	0.5	0.3	0.8	0.4
RA-228	PCI/L	0.	1.3	0.	1.	0.5	1.2	0.	1.	0.	1.2
SELENIUM	MG/L	< 0.005		< 0.005		< 0.005		< 0.005		< 0.005	
SILICA	MG/L	4.		4.		4.		4.		4.	
SILVER	MG/L	< 0.01		< 0.01		< 0.01		< 0.01		< 0.01	
SODIUM	MG/L	177.		154.		154.		154.		154.	
SULFATE	MG/L	63.8		62.7		62.7		62.6		62.9	
SULFIDE	MG/L	< 0.1		< 0.1		< 0.1		< 0.1		< 0.1	
TEMPERATURE	C - DEGREE	19.		19.		19.		19.		19.	
TH-230	PCI/L	0.	0.1	0.	0.1	0.	0.1	0.	0.1	0.1	0.2
TIN	MG/L	< 0.005		< 0.005		< 0.005		< 0.005		< 0.005	
TOTAL SOLIDS	MG/L	886.		676.		680.		674.		679.	
URANIUM	MG/L	0.003		0.0033		0.0033		0.0039		0.0036	
VANADIUM	MG/L	0.43		0.25		0.23		0.24		0.43	
ZINC	MG/L	0.021		0.018		0.021		0.02		0.018	

Table B.2.7 Background Navajo Sandstone ground-water quality analysis for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (continued)

Table B.2.7 Background Navajo Sandstone ground-water quality analyses for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (Continued)

PARAMETER	UNIT OF MEASURE	LOCATION ID - SAMPLE ID AND LOG DATE				
		688-01 07/17/86	688-02 07/17/86	688-03 07/17/86	688-04 07/17/86	688-05 07/17/86
		PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY
ALKALINITY	MG/L CACO3	329.	329.	329.	329.	329.
ALUMINUM	MG/L	0.2	0.2	0.2	0.2	0.2
AMMONIUM	MG/L	-	-	-	-	-
ANTIMONY	MG/L	-	-	-	-	-
ARSENIC	MG/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
BARIUM	MG/L	-	-	-	-	-
BORON	MG/L	-	-	-	-	-
CADMIUM	MG/L	-	-	-	-	-
CALCIUM	MG/L	58.4	58.4	58.4	58.4	58.4
CHLORIDE	MG/L	48.	48.	48.	48.	48.
CHROMIUM	MG/L	-	-	-	-	-
CONDUCTANCE	UMHO/CM	475.	475.	475.	475.	475.
COPPER	MG/L	-	-	-	-	-
FLUORIDE	MG/L	-	-	-	-	-
IRON	MG/L	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
LEAD	MG/L	-	-	-	-	-
MAGNESIUM	MG/L	38.6	38.6	38.6	38.6	38.6
MANGANESE	MG/L	0.01	0.02	0.02	0.02	0.02
MERCURY	MG/L	-	-	-	-	-
MOLYBDENUM	MG/L	0.15	0.15	0.15	0.15	0.14
NICKEL	MG/L	-	-	-	-	-
NITRATE	MG/L	< 1.	< 1.	< 1.	< 1.	< 1.
PB-210	PCI/L	-	-	-	-	-
PH	SU	7.1	7.1	7.1	7.1	7.1
PHOSPHATE	MG/L	-	-	-	-	-
PO-210	PCI/L	-	-	-	-	-
POTASSIUM	MG/L	5.65	5.65	5.65	5.65	5.65
RA-226	PCI/L	-	-	-	-	-
RA-228	PCI/L	-	-	-	-	-
SELENIUM	MG/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
SILICA	MG/L	-	-	-	-	-
SILVER	MG/L	-	-	-	-	-
SODIUM	MG/L	52.1	52.1	52.1	52.1	52.1
SULFATE	MG/L	36.3	36.3	36.3	36.3	36.3
SULFIDE	MG/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
TEMPERATURE	C - DEGREE	14.	14.	14.	14.	14.
TH-230	PCI/L	-	-	-	-	-
TIN	MG/L	-	-	-	-	-
TOTAL SOLIDS	MG/L	409.	410.	411.	413.	407.
URANIUM	MG/L	0.0083	0.0093	0.0078	0.008	0.0083
VANADIUM	MG/L	0.33	0.32	0.32	0.32	0.32
ZINC	MG/L	-	-	-	-	-

Table B.2.7 Background Navajo Sandstone ground-water quality analysis for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (continued)

Table B.2.7 Background Navajo Sandstone ground-water quality analyses for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (Continued)

		LOCATION ID - SAMPLE ID AND LOG DATE				
		690-01 07/19/86	805-01 02/03/86	805-02 02/03/86	805-03 02/03/86	805-04 02/03/86
PARAMETER	UNIT OF MEASURE	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY
ALKALINITY	MG/L CACO3	253.	343.	343.	343.	343.
ALUMINUM	MG/L	0.2	-	-	-	-
AMMONIUM	MG/L	-	< 0.1	< 0.1	< 0.1	< 0.1
ANTIMONY	MG/L	-	-	-	-	-
ARSENIC	MG/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
BARIUM	MG/L	-	-	-	-	-
BORON	MG/L	-	-	-	-	-
CADMIUM	MG/L	-	< 0.001	< 0.001	< 0.001	< 0.001
CALCIUM	MG/L	20.5	35.8	35.8	35.8	35.8
CHLORIDE	MG/L	18.	38.	39.	39.	39.
CHROMIUM	MG/L	-	-	-	-	-
CONDUCTANCE	UMHO/CM	370.	600.	600.	600.	600.
COPPER	MG/L	-	-	-	-	-
FLUORIDE	MG/L	-	-	-	-	-
IRON	MG/L	0.03	0.04	0.04	0.04	0.04
LEAD	MG/L	-	-	-	-	-
MAGNESIUM	MG/L	38.9	38.5	38.5	38.5	38.4
MANGANESE	MG/L	0.03	0.02	0.02	0.02	0.02
MERCURY	MG/L	-	-	-	-	-
MOLYBDENUM	MG/L	0.12	0.09	0.09	0.09	0.09
NICKEL	MG/L	-	-	-	-	-
NITRATE	MG/L	< 1.	1.	1.	1.	1.
PB-210	PCI/L	-	-	-	-	-
PH	SU	7.45	7.19	7.19	7.19	7.19
PHOSPHATE	MG/L	-	-	-	-	-
PO-210	PCI/L	-	-	-	-	-
POTASSIUM	MG/L	9.19	18.2	18.2	18.2	18.1
RA-226	PCI/L	-	-	-	-	-
RA-228	PCI/L	-	-	-	-	-
SELENIUM	MG/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
SILICA	MG/L	-	-	-	-	-
SILVER	MG/L	-	-	-	-	-
SODIUM	MG/L	26.9	85.3	85.4	85.3	85.3
SULFATE	MG/L	9.5	89.	89.	89.	89.
SULFIDE	MG/L	< 0.1	-	-	-	-
TEMPERATURE	C - DEGREE	15.	14.	14.	14.	14.
TH-230	PCI/L	-	-	-	-	-
TIN	MG/L	-	-	-	-	-
TOTAL SOLIDS	MG/L	268.	486.	484.	488.	493.
URANIUM	MG/L	0.0034	0.0128	0.0166	0.0139	0.0135
VANADIUM	MG/L	0.3	-	-	-	-
ZINC	MG/L	-	-	-	-	-

Table B.2.7 Background Navajo Sandstone ground-water quality analysis for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (continued)

Table B.2.7 Background Navajo Sandstone ground-water quality analyses for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (Concluded)

		LOCATION ID - SAMPLE ID AND LOG DATE				
		805-05 02/03/86				
PARAMETER	UNIT OF MEASURE	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY
ALKALINITY	MG/L CACO3	313.				
ALUMINUM	MG/L	-				
AMMONIUM	MG/L	< 0.1				
ANTIMONY	MG/L	-				
ARSENIC	MG/L	< 0.01				
BARIUM	MG/L	-				
BORON	MG/L	-				
CADMIUM	MG/L	< 0.001				
CALCIUM	MG/L	35.8				
CHLORIDE	MG/L	39.				
CHROMIUM	MG/L	-				
CONDUCTANCE	UMHO/CM	600.				
COPPER	MG/L	-				
FLUORIDE	MG/L	-				
IRON	MG/L	0.04				
LEAD	MG/L	-				
MAGNESIUM	MG/L	38.3				
MANGANESE	MG/L	0.02				
MERCURY	MG/L	-				
MOLYBDENUM	MG/L	0.09				
NICKEL	MG/L	-				
NITRATE	MG/L	1.				
PB-210	PCI/L	-				
PH	SU	7.19				
PHOSPHATE	MG/L	-				
PO-210	PCI/L	-				
POTASSIUM	MG/L	18.2				
RA-226	PCI/L	-				
RA-228	PCI/L	-				
SELENIUM	MG/L	< 0.005				
SILICA	MG/L	-				
SILVER	MG/L	-				
SODIUM	MG/L	85.3				
SULFATE	MG/L	89.				
SULFIDE	MG/L	-				
TEMPERATURE	C - DEGREE	14.				
TH-230	PCI/L	-				
TIN	MG/L	-				
TOTAL SOLIDS	MG/L	490.				
URANIUM	MG/L	0.0149				
VANADIUM	MG/L	-				
ZINC	MG/L	-				

Table B.2.8 Water quality analyses of contaminated ground-water for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites

Table B.2.8 Contaminated alluvial ground-water quality analyses for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites

		LOCATION ID - SAMPLE ID AND LOG DATE				
		503-01 02/18/86	503-01 06/30/86	504-01 02/04/86	504-01 07/01/86	506-01 02/05/86
PARAMETER	UNIT OF MEASURE	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY
ALKALINITY	MG/L CACO3	440.	410.	506.	441.	754.
ALUMINUM	MG/L	-	0.4	-	0.3	-
AMMONIUM	MG/L	0.5	< 0.1	< 0.1	-	115.
ANTIMONY	MG/L	-	< 0.003	-	-	-
ARSENIC	MG/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
BARIUM	MG/L	-	< 0.1	-	-	-
BORON	MG/L	-	< 0.1	-	-	-
CADMIUM	MG/L	< 0.001	< 0.001	< 0.001	-	< 0.001
CALCIUM	MG/L	225.	264.	222.	226.	415.
CHLORIDE	MG/L	340.	380.	360.	360.	430.
CHROMIUM	MG/L	-	0.05	-	-	-
CONDUCTANCE	UMHO/CM	2900.	2650.	3800.	3000.	4400.
COPPER	MG/L	-	0.05	-	-	-
FLUORIDE	MG/L	-	0.3	-	-	-
IRON	MG/L	2.45	3.2	9.32	6.06	8.82
LEAD	MG/L	-	< 0.01	-	-	-
MAGNESIUM	MG/L	126.	127.	218.	161.	363.
MANGANESE	MG/L	0.75	0.68	0.8	0.83	4.73
MERCURY	MG/L	-	< 0.0002	-	-	-
MOLYBDENUM	MG/L	0.15	0.07	0.13	0.06	0.15
NICKEL	MG/L	-	< 0.04	-	-	-
NITRATE	MG/L	< 1.	< 1.	< 1.	< 1.	27.
PB-210	PCI/L	-	33. 2.	-	-	-
PH	SU	7.05	7.	7.2	7.22	6.84
PHOSPHATE	MG/L	-	0.1	-	-	-
PO-210	PCI/L	-	0.8 0.7	-	-	-
POTASSIUM	MG/L	54.1	44.7	13.3	12.4	39.2
RA-226	PCI/L	-	2.4 0.6	-	-	-
RA-228	PCI/L	-	1.1 1.2	-	-	-
SELENIUM	MG/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
SILICA	MG/L	-	7.	-	-	-
SILVER	MG/L	-	< 0.01	-	-	-
SODIUM	MG/L	646.	637.	933.	774.	608.
SULFATE	MG/L	1600.	1650.	2470.	2130.	2930.
SULFIDE	MG/L	-	< 0.1	-	< 0.1	-
TEMPERATURE	C - DEGREE	12.	15.	11.	12.	10.5
TH-230	PCI/L	-	0.3 0.3	-	-	-
TIN	MG/L	-	< 0.005	-	-	-
TOTAL SOLIDS	MG/L	3330.	3400.	4770.	3950.	5630.
URANIUM	MG/L	3.9	3.78	2.29	2.66	0.0591
VANADIUM	MG/L	-	0.53	-	0.33	-
ZINC	MG/L	-	0.028	-	-	-

Table B.2.8 Water quality analyses of contaminated ground-water for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (continued)

Table 3.2.8 Contaminated ground-water quality analyses for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (Continued)

		LOCATION ID - SAMPLE ID AND LOG DATE				
		506-01 07/01/86	507-01 02/05/86	507-01 06/30/86	508-01 02/18/86	508-01 06/30/86
PARAMETER	UNIT OF MEASURE	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY
ALKALINITY	MG/L CACO3	645.	493.	461.	418.	406.
ALUMINUM	MG/L	0.2	-	0.2	-	0.3
AMMONIUM	MG/L	-	66.	-	170.	-
ANTIMONY	MG/L	-	-	-	-	-
ARSENIC	MG/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
BARIUM	MG/L	-	-	-	-	-
BORON	MG/L	-	-	-	-	-
CADMIUM	MG/L	-	< 0.001	-	0.004	-
CALCIUM	MG/L	593.	178.	173.	383.	541.
CHLORIDE	MG/L	810.	130.	200.	160.	210.
CHROMIUM	MG/L	-	-	-	-	-
CONDUCTANCE	UMHO/CM	3950.	1650.	1500.	4150.	3550.
COPPER	MG/L	-	-	-	-	-
FLUORIDE	MG/L	-	-	-	-	-
IRON	MG/L	6.23	2.28	2.11	0.27	0.08
LEAD	MG/L	-	-	-	-	-
MAGNESIUM	MG/L	339.	84.5	81.4	264.	258.
MANGANESE	MG/L	6.12	1.36	1.39	6.63	7.49
MERCURY	MG/L	-	-	-	-	-
MOLYBDENUM	MG/L	0.17	0.13	0.14	2.2	2.43
NICKEL	MG/L	-	-	-	-	-
NITRATE	MG/L	< 1.	< 1.	< 1.	800.	290.
PB-210	PCI/L	-	-	-	-	-
PH	SU	6.76	7.08	7.01	6.62	6.73
PHOSPHATE	MG/L	-	-	-	-	-
PO-210	PCI/L	-	-	-	-	-
POTASSIUM	MG/L	36.9	19.8	16.7	25.1	21.1
RA-226	PCI/L	-	-	-	-	-
RA-228	PCI/L	-	-	-	-	-
SELENIUM	MG/L	< 0.005	< 0.005	< 0.005	0.012	0.035
SILICA	MG/L	-	-	-	-	-
SILVER	MG/L	-	-	-	-	-
SODIUM	MG/L	970.	172.	322.	226.	160.
SULFATE	MG/L	3160.	808.	733.	1700.	1920.
SULFIDE	MG/L	< 0.1	-	< 0.1	-	< 0.1
TEMPERATURE	C - DEGREE	13.	10.	12.	12.	13.
TH-230	PCI/L	-	-	-	-	-
TIN	MG/L	-	-	-	-	-
TOTAL SOLIDS	MG/L	5370.	1460.	1520.	4790.	4420.
URANIUM	MG/L	0.0439	0.0262	0.0309	0.106	0.115
VANADIUM	MG/L	0.33	-	0.23	-	1.04
ZINC	MG/L	-	-	-	-	-

Table B.2.8 Water quality analyses of contaminated ground-water for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (concluded)

Table B.2.8 Contaminated ground-water quality analyses for the period February, 1986, into July, 1986, at the Slick Rock, Colorado, tailings sites (Concluded)

PARAMETER	UNIT OF MEASURE	LOCATION ID - SAMPLE ID AND LOG DATE: 540-01 02/18/86 PARAMETER VALUE +/- UNCERTAINTY	540-01 06/30/86 PARAMETER VALUE +/- UNCERTAINTY	542-01 02/04/86 PARAMETER VALUE +/- UNCERTAINTY	542-01 07/01/86 PARAMETER VALUE +/- UNCERTAINTY	PARAMETER VALUE +/- UNCERTAINTY
ALKALINITY	MG/L CACO3	399.	374.	303.	252.	
ALUMINUM	MG/L	-	0.2	-	0.2	
AMMONIUM	MG/L	120.	80.	< 0.1	-	
ANTIMONY	MG/L	-	< 0.003	-	-	
ARSENIC	MG/L	< 0.01	< 0.01	< 0.01	< 0.01	
BARIUM	MG/L	-	0.1	-	-	
BORON	MG/L	-	< 0.1	-	-	
CADMIUM	MG/L	< 0.001	< 0.001	< 0.001	-	
CALCIUM	MG/L	453.	590.	232.	240.	
CHLORIDE	MG/L	140.	150.	110.	80.	
CHROMIUM	MG/L	-	0.05	-	-	
CONDUCTANCE	UMHO/CM	3750.	3300.	140.	1050.	
COPPER	MG/L	-	0.06	-	-	
FLUORIDE	MG/L	-	0.4	-	-	
IRON	MG/L	0.42	0.07	0.3	0.07	
LEAD	MG/L	-	< 0.01	-	-	
MAGNESIUM	MG/L	269.	200.	65.2	48.1	
MANGANESE	MG/L	7.49	4.66	0.25	0.09	
MERCURY	MG/L	-	< 0.0002	-	-	
MOLYBDENUM	MG/L	1.22	1.09	0.08	0.11	
NICKEL	MG/L	-	0.09	-	-	
NITRATE	MG/L	610.	1000.	< 1.	< 1.	
PB-210	PCI/L	-	1.9 1.1	-	-	
PH	SU	6.44	6.6	6.99	7.04	
PHOSPHATE	MG/L	-	< 0.1	-	-	
PO-210	PCI/L	-	0. 0.6	-	-	
POTASSIUM	MG/L	22.6	12.9	27.7	13.3	
RA-226	PCI/L	-	1.1 0.4	-	-	
RA-228	PCI/L	-	0.3 0.8	-	-	
SELENIUM	MG/L	< 0.005	< 0.005	< 0.005	< 0.005	
SILICA	MG/L	-	7.	-	-	
SILVER	MG/L	-	< 0.01	-	-	
SODIUM	MG/L	155.	177.	206.	135.	
SULFATE	MG/L	1730.	1540.	916.	653.	
SULFIDE	MG/L	-	< 0.1	-	< 0.1	
TEMPERATURE	C - DEGREE	12.	13.	11.	11.5	
TH-230	PCI/L	-	0.1 0.2	-	-	
TIN	MG/L	-	< 0.005	-	-	
TOTAL SOLIDS	MG/L	4780.	4180.	4850.	1340.	
URANIUM	MG/L	0.199	0.195	3.95	2.92	
VANADIUM	MG/L	-	0.36	-	0.53	
ZINC	MG/L	-	0.06	-	-	

Two values in these tables appear to be inaccurate. The background uranium concentration of 0.591 milligrams per liter determined from a sample of well 501 appears to be inaccurate because uranium was determined to be an order of magnitude less in four replicate samples taken at the same time for this well (Table 8.2.6). The nitrate concentration of 80 milligrams per liter from a sample o well 687 appears to be inaccurate because nitrate was not detected in four replicate samples taken at the same time from this well (Table 8.2.8).

The samples were analyzed by EDA Instruments, Inc. of Denver, Colorado, using EPA-approved analytical methods (EPA, 1983) or methods approved by DOE. The analytical results submitted by the laboratory were subjected to quality assurance checks.

Fourteen wells yield water from the alluvial aquifer; one well (675) is privately owned and the remaining wells are DOE installed monitor wells. Six DOE installed monitor wells and three privately owned wells (634, 672, and 805) yield water from the Navajo Sandstone.

Alluvial aquifer

Background water quality

Water samples from seven alluvial wells (501, 505, 509, 675, 684, 685, and 686) represent background water quality (Table B.2.9) as defined by the draft Nuclear Regulatory Commission Standard Review Plan for UMTRA Project Sites (NRC, 1985). The plan defines background water quality as ". . . the quality of water that would be expected at a site if contamination had not occurred from the designated facility." These wells were unaffected by the tailings because they were upgradient of the sites (501, 505, 509, and 686) or far enough downgradient (675, 684, and 685) not to be affected. The calculated concentration ranges for background water quality were determined in accordance with the Technical Approach Document (DOE, 1986).

The trilinear diagrams (Figures B.2.14 and B.2.15) and chemical analyses of background samples show that the uncontaminated alluvial ground water is classified as a calcium/sodium-sulfate type water and is fresh to slightly brackish in quality, with a mean total dissolved solids content of 1185 milligrams per liter. Most background samples are essentially neutral with pH values near 7.0.

Table 8.2.9 Summary of background alluvial ground-water quality near the Slick Rock, Colorado, tailings sites

Constituent	Observed concentration range[a]	Number of analyses	Mean concentration	Two standard deviations	Calculated concentration range[c]
Sodium	83.6-470	10	210.5	229.1	<0.002-470
Potassium	4.75-27.9	10	11.1	14.2	<0.01-27.9
Magnesium	20.9-111	10	55.8	56.1	<0.001-111.9
Calcium	73.8-182	10	121.6	68.1	53.5-189.7
Ammonium	<0.1-80	7	13.1	59.2	<0.1-80
Chloride	32-140	10	76.6	60.4	16.2-140
Sulfate	272-1160	10	545.1	561.1	<0.1-1160
Nitrate	<1-5	10	<1	3.2	<1-5
Alkalinity (as $CaCo_3$)	223-951	10	383.3	432.1	0-951
Aluminum	0.2-0.4	7	0.3	0.2	0.1-0.5
Manganese	0.04-1.27	10	0.41	0.70	<0.01-1.27
Iron	0.05-0.31	10	0.15	0.22	<0.03-0.37
Nickel	<0.04	3	<0.04	ND	<0.04
Arsenic	<0.01	10	<0.01	ND	<0.01
Barium	0.1-0.2	3	0.13	0.12	0.01-0.25
Cadmium	<0.001	6	<0.001	ND	<0.001
Chromium	0.04-0.07	3	0.05	0.03	0.02-0.08
Molybdenum	0.08-0.44	10	0.19	0.25	<0.01-0.44
Lead	<0.01	3	<0.01	ND	<0.01
Selenium	<0.005	10	<0.005	ND	<0.005
Uranium	0.009-0.0498	10	0.0299	0.0235	0.009-0.0534
pH	6.62-7.75	10	ND[b]	ND	ND
TDS	622-1950	10	1185	929	256-2114

[a]Units in mg/l except pH which is in standard pH units.
[b]ND = Not determined.
[c]Calculated ranges determined in accordance with methods in DOE, 1986.

Figure B.2.14 Trilinear diagram for February, 1986, water quality data at the Slick Rock, Colorado, tailings sites

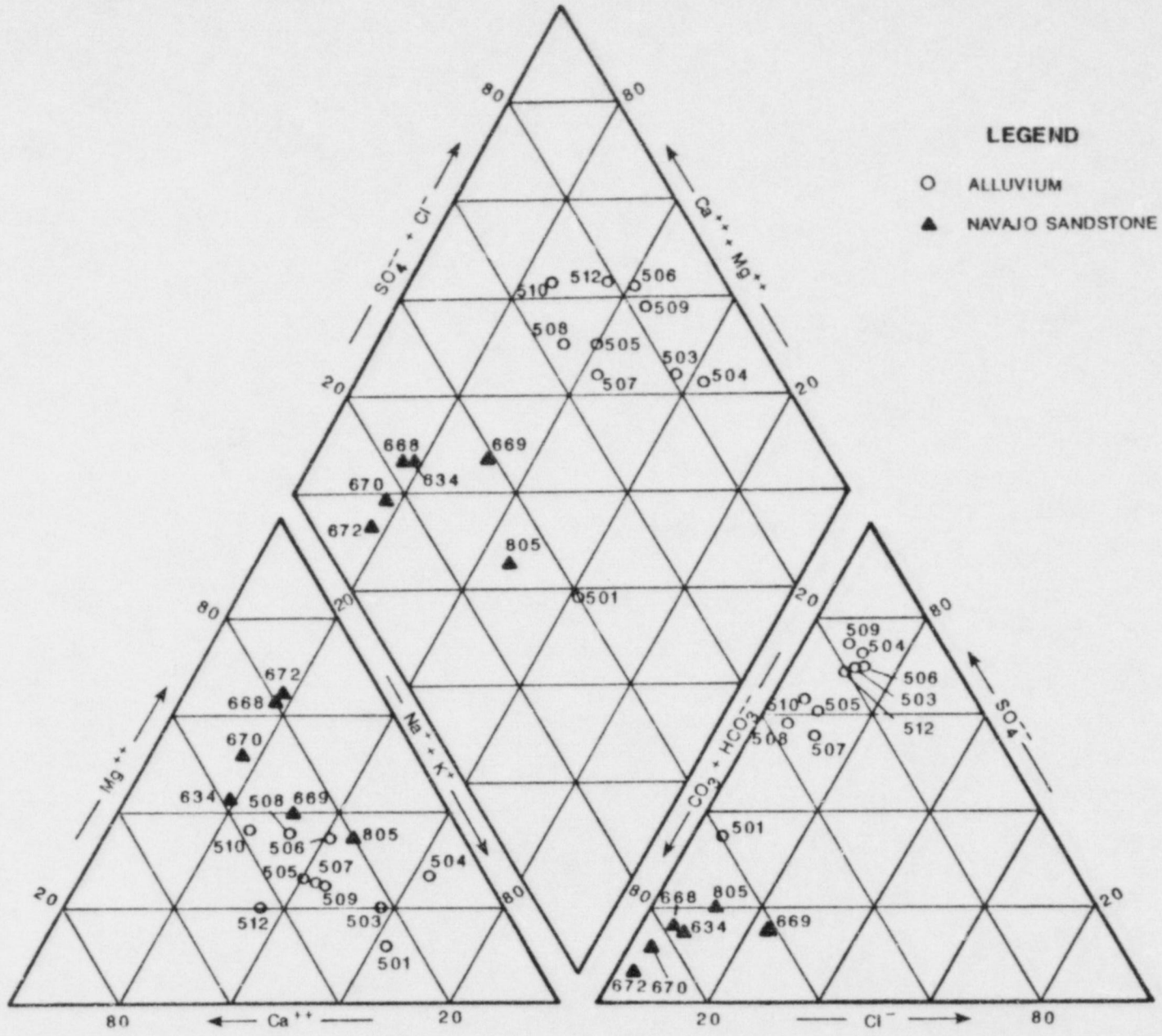

FIGURE B.2.14

TRILINEAR DIAGRAM FOR FEBRUARY, 1986 WATER-QUALITY DATA AT THE SLICK ROCK, COLORADO TAILINGS SITES

Figure 8.2.15 Trilinear diagram for June-July, 1986, water quality data at the Slick Rock, Colorado, tailings sites

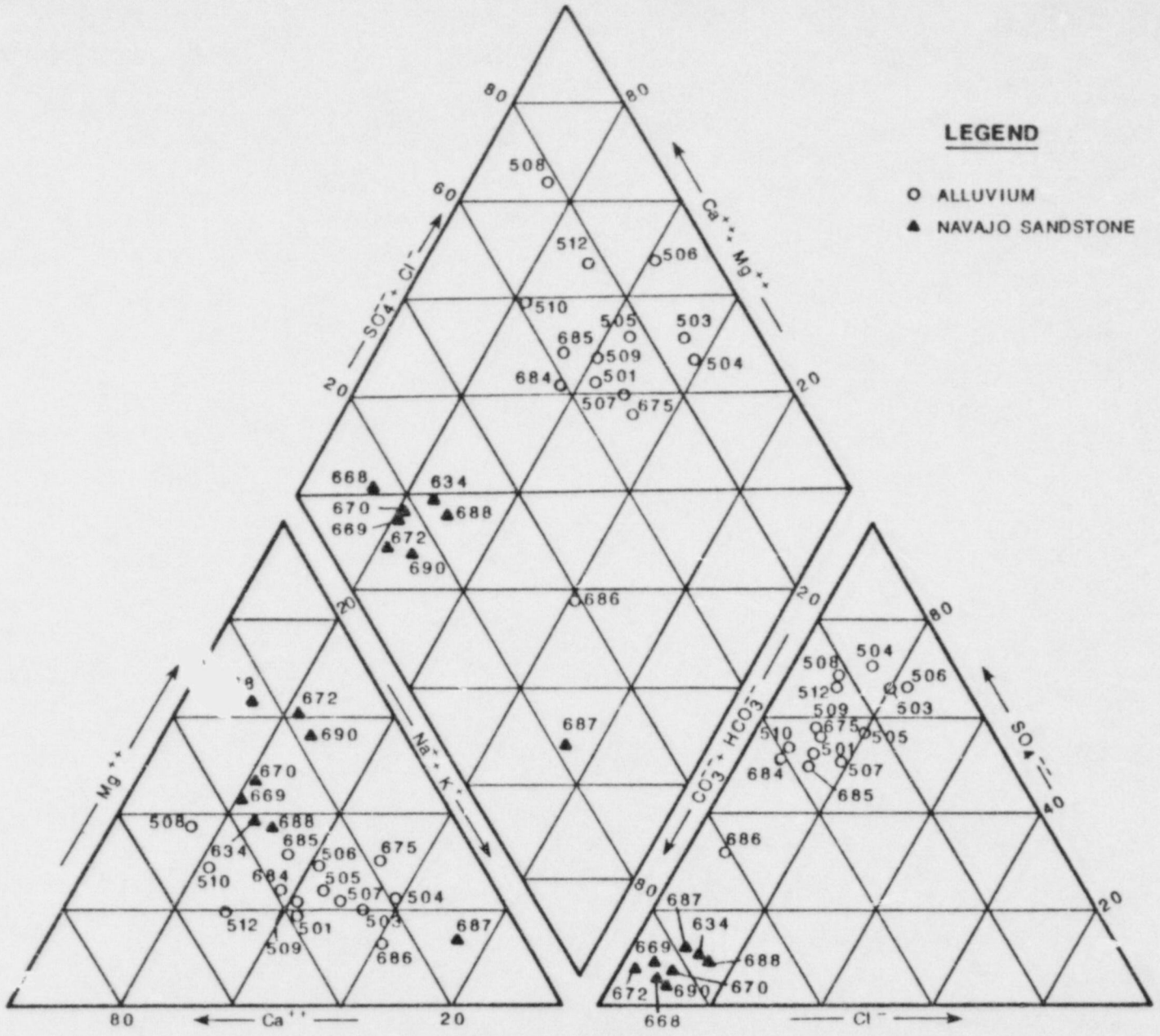

FIGURE B.2.15

TRILINEAR DIAGRAM FOR JUNE – JULY, 1986 WATER-QUALITY DATA AT THE SLICK ROCK, COLORADO TAILINGS SITES

The only primary drinking water standard exceeded by the alluvial background samples was a minor exceedance of the standard for chromium at well 505. The secondary drinking water standards for manganese and total dissolved solids was exceeded by every alluvial background sample. The secondary standard for sulfate was exceeded by all but one alluvial sample, as was the proposed health advisory level for uranium (0.015 mg/l natural uranium) (Cothern et al, 1982). The secondary standard for iron was exceeded by samples from wells 503, 504, 505, and 507. The secondary standard for chloride was exceeded by samples from wells 503, 504, and 506, while samples from wells 508 and 510 exceeded the secondary standard for nitrate.

Contaminated water quality

Concentrations of the major contaminants common at the UC and NC sites (i.e., sodium, potassium, magnesium, calcium, chloride, sulfate, iron, uranium, and total dissolved solids) are higher in the contaminated samples than in the background samples (Tables B.2.10 and B.2.11). The contaminated ground water below the UC pile contains appreciably higher concentrations of ammonium, nitrate, manganese, and molybdenum than the contaminated ground water below the NC pile.

Table B.2.10 Summary of contaminated alluvial ground-water quality at the UC pile, Slick Rock, Colorado

Constituent	Observed concentration range[a]	Number of analyses	Mean concentration
Sodium	155–970	8	349
Potassium	12.9–39.2	8	24.3
Magnesium	81.4–363	8	232.4
Calcium	173–593	8	416
Ammonium	66–170	5	110
Chloride	130–810	8	279
Sulfate	733–3160	8	1815
Nitrate	<1–1000	8	341
Alkalinity (as $CaCO_3$)	374–754	8	494
Aluminum	0.2–0.3	4	0.2
Manganese	1.36–7.49	8	4.98
Iron	0.07–8.82	8	2.50
Nickel	0.09	1	ND[b]
Arsenic	<0.01	8	<0.01
Barium	0.1	1	ND
Cadmium	<0.001–0.004	5	0.0008
Chromium	0.05	1	ND
Molybdenum	0.13–2.43	8	0.94
Lead	<0.01	1	ND
Selenium	<0.005–0.035	8	0.006
Uranium	0.0139–0.199	8	0.093
pH	6.44–7.08	8	ND
TDS	1460–5630	8	4019

[a]Units in mg/l except pH which is in standard pH units.
[b]ND = Not determined.

Table B.2.11 Summary of contaminated alluvial ground-water quality at the NC pile, Slick Rock, Colorado

Constituent	Observed concentration range[a]	Number of analyses	Mean concentration
Sodium	135–933	6	555
Potassium	12.4–54.1	6	27.6
Magnesium	48.1–218	6	124.2
Calcium	210–264	6	230
Ammonium	0.1–0.5	4	0.1
Chloride	80–380	6	309
Sulfate	653–2470	6	1570
Nitrate	<1	6	<1
Alkalinity (as $CaCO_3$)	252–506	6	392
Aluminum	0.2–0.4	3	0.3
Manganese	0.09–0.83	6	0.57
Iron	0.07–9.32	6	3.57
Nickel	<0.04	1	ND[b]
Arsenic	<0.01	6	<0.01
Barium	<0.1	1	ND
Cadmium	<0.001	4	<0.001
Chromium	0.05	1	ND
Molybdenum	0.06–0.15	6	0.10
Lead	<0.01	1	ND
Selenium	<0.005	6	<0.005
Uranium	2.29–3.95	6	3.25
pH	6.99–7.27	6	ND
TDS	1310–4770	6	3102

[a]Units in mg/l except pH which is in standard pH units.
[b]ND = Not determined.

The differences between background and contaminated samples are also seen in bivariate plots (Figures B.2.16 and B.2.17). The background samples are narrowly distributed and do not, in general, infringe on the areas occupied by the contaminated samples. If the background samples were affected by the tailings, they would either plot in the area occupied by contaminated samples or plot along mixing lines between the two sample types. Based on the data distribution on the bivariate plots, the summarized differences between background and contaminated samples, and the location of monitor wells, none of the background samples have been affected by the piles.

Navajo Sandstone aquifer

None of the wells completed in the Navajo Sandstone aquifer (634, 668, 669, 670, 672, 687, 688, 690, and 805) are affected by contaminants emanating from the piles because, as explained in Section B.2.3.5, these wells are hydraulically upgradient of the contaminated ground water. Chemical analyses of water samples from these wells represent background water quality of the Navajo Sandstone (Table B.2.12) and the data are plotted on the trilinear diagrams (Figures B.2.14 and B.2.15).

These data indicate that the Navajo Sandstone is classified as a calcium-bicarbonate type water and is fresh

Figure B.2.16 Bivariate plot-sum of alkali and alkaline earth metals vs. uranium at the Slick Rock, Colorado, tailings sites

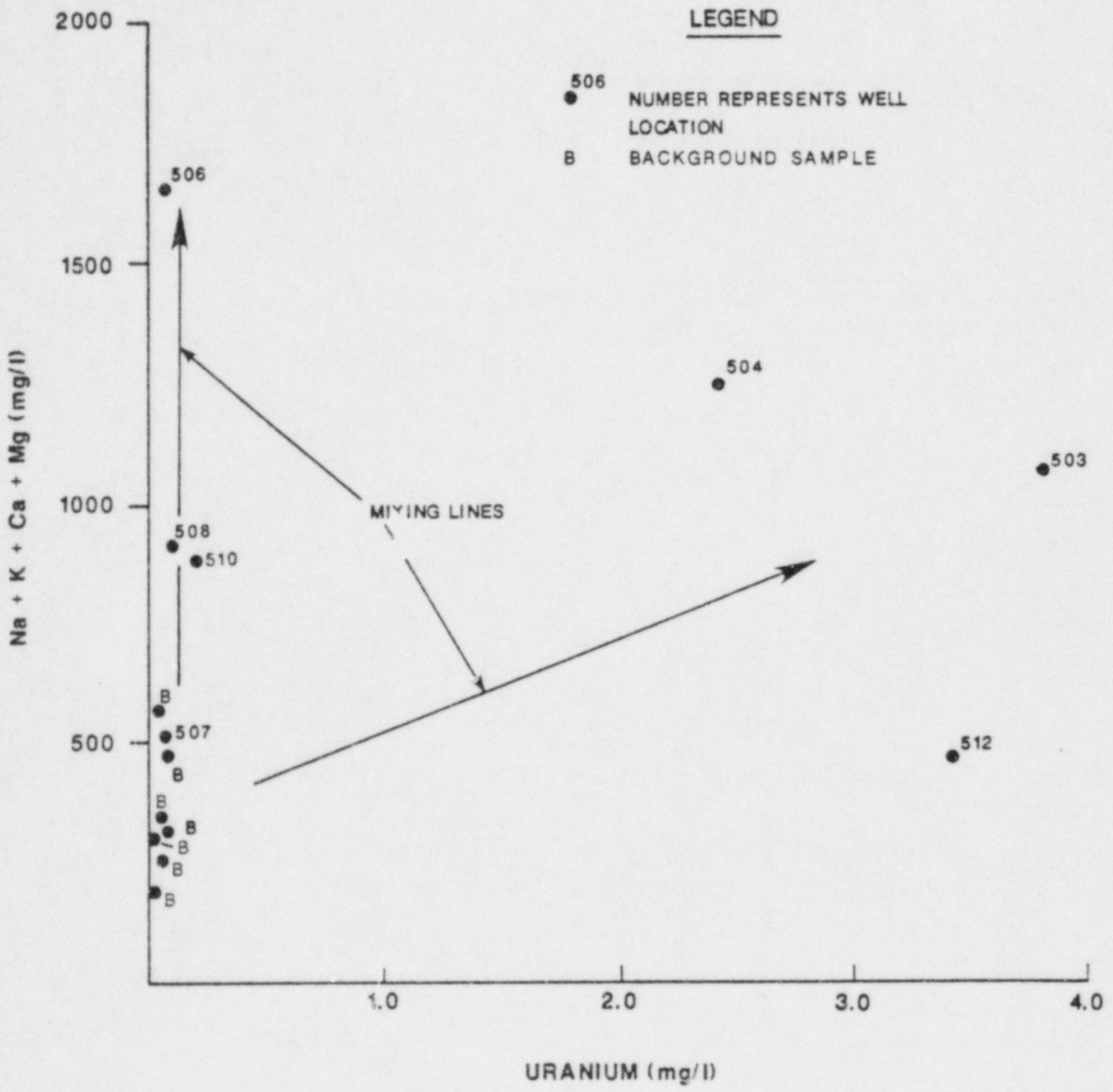

FIGURE B.2.16
BIVARIATE PLOT
SUM OF AKALI AND ALKALINE-EARTH METALS vs. URANIUM
AT THE SLICK ROCK, COLORADO TAILINGS SITES

Figure B.2.17 Bivariate plot-chloride vs. sulfate at the Slick Rock, Colorado, tailings sites

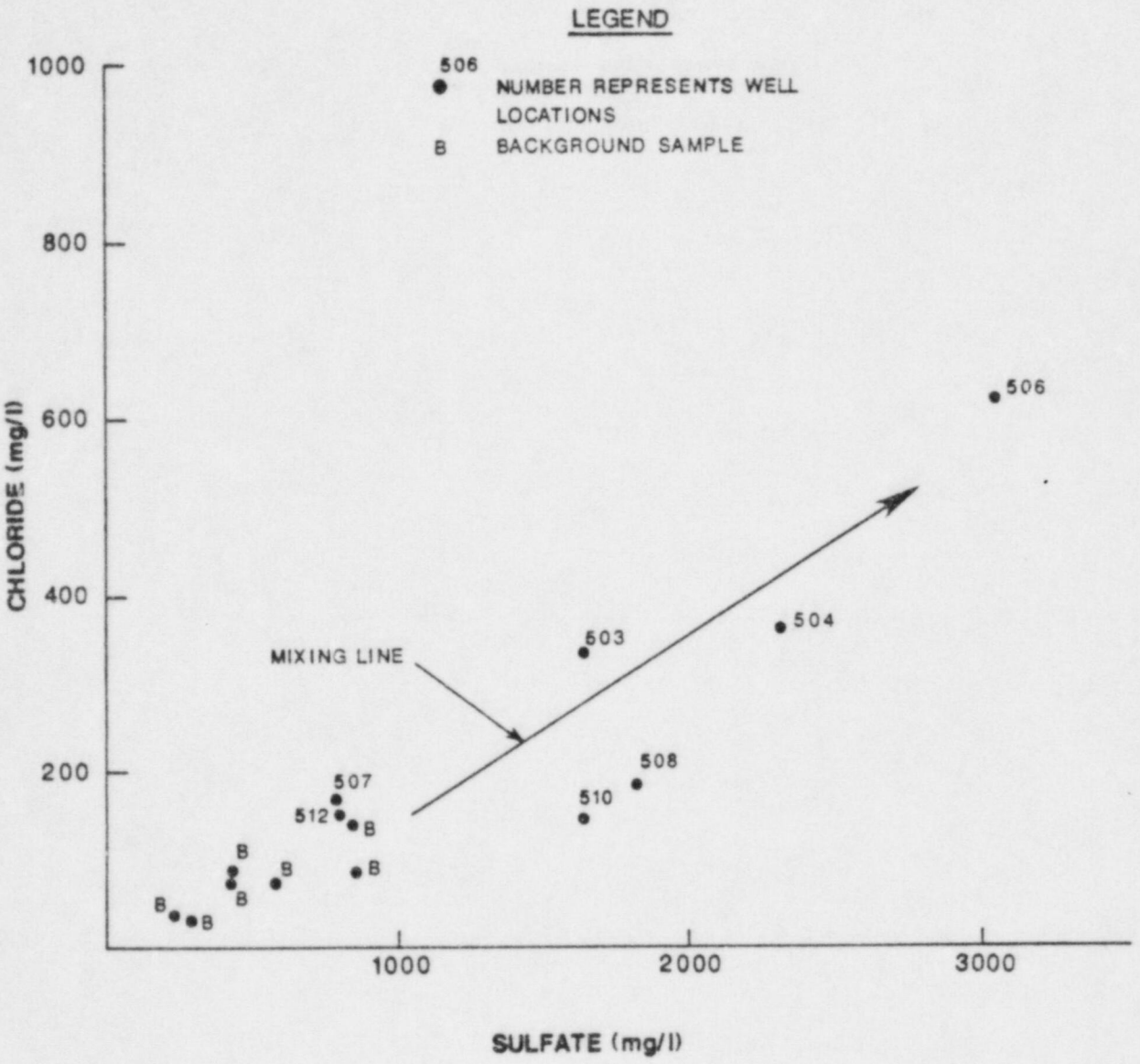

FIGURE B.2.17
BIVARIATE PLOT
CHLORIDE vs. SULFATE
AT THE SLICK ROCK, COLORADO TAILINGS SITES

Table B.2.12 Summary of background Navajo Sandstone ground-water quality near the Slick Rock, Colorado, tailings sites

Constituent	Observed concentration range[a]	Number of analyses	Mean concentration	Two standard deviations	Calculated concentration range[a,c]
Sodium	9.38–177	14	38.9	89.5	<0.002–177
Potassium	1.79–30.1	14	11.6	14.2	<0.01–30.1
Magnesium	18.7–50.4	14	35.2	20.4	14.8–55.6
Calcium	20.5–63.7	14	34.1	30.4	3.7–64.5
Ammonium	<0.1–0.3	7	0.1	0.3	<0.1–0.4
Chloride	8–48	14	25	30	<1–55
Sulfate	9.5–89	14	35	49	<0.1–89
Nitrate	<1–80	14	6	43	<1–80
Alkalinity (as $CaCO_3$)	140–418	14	271	143	128–418
Aluminum	0.2–0.4	8	0.3	0.2	0.1–0.5
Manganese	<0.01–0.13	14	0.04	0.08	<0.01–0.13
Iron	<0.03–0.06	14	0.02	0.05	<0.03–0.07
Nickel	0.06	1	ND	ND	ND
Arsenic	<0.01–0.01	14	<0.01	0.01	<0.01–0.01
Barium	0.2	1	ND[b]	ND	ND
Cadmium	<0.001	7	<0.001	0	<0.001
Chromium	0.05	1	ND	ND	ND
Molybdenum	0.08–0.17	14	0.13	0.07	0.06–0.20
Lead	<0.01	1	ND	ND	ND
Selenium	<0.005	14	<0.005	0	<0.005
Uranium	0.0013–0.0128	14	0.0053	0.0083	<0.003–0.0136
pH	7.1–10.45	14	ND	ND	ND
TDS	162–886	14	368	365	3–886

[a]Units in mg/l except pH which is in standard pH units.
[b]ND - Not determined.
[c]Calculated ranges determined in accordance with methods in DOE, 1986.

water quality. The average total dissolved solids content is 368 milligrams per liter and the waters are neutral to slightly alkaline. Wells 669 and 670 exhibited pH values higher than the other Navajo Sandstone wells; these elevated pH values were probably due to incomplete initial development of the wells since there was a drop in pH values by two units during the five-month period between sampling of these two wells.

The Primary Drinking Water Standards for silver were exceeded by samples from wells 634 and 668. The Secondary Drinking Water Standards for other constituents are exceeded in a few instances. Samples from wells 634 and 687 exceeded the secondary standard for TDS. Samples from wells 669, 670, and 687 exceeded the secondary standard for manganese.

B.2.3.6 Proximity of site to surface water

Both Slick Rock tailings piles are within the modern floodplain of the Dolores River. In the present locations, both piles are subject to potential tailings dispersal due to flooding and the continued leaching of contaminants into the underlying Dolores River alluvial ground water.

B.2.4 PHYSICAL AND CHEMICAL CHARACTERIZATION OF WASTE AND CONTAMINANT TRANSPORT

The physical and chemical characterization of waste and the determination of the extent of contaminant transport have several purposes:

- Identification of the potential contaminants.
- Determination of which contaminants have migrated from the tailings.
- Identification of the extent and relative concentration of contamination (e.g., the contaminant plume).
- Determination of the rate of contaminant migration.
- Determination of the extent to which contaminated ground water is discharging to hydraulically connected surface water.
- Separation of the contamination due to mill tailings from other contaminant sources.

B.2.4.1 Extent of contamination

The extent of alluvial ground-water contamination resulting from tailings seepage is defined from plume maps,

and by comparing on-site and downgradient alluvial water quality to background alluvial water quality and U.S. EPA drinking water standards. Exceedences of water quality standards in the alluvium and Navajo Sandstone at the Slick Rock sites appear in Table B.2.13.

UC site

Alluvial ground water present below and downgradient of the UC tailings pile has been affected by tailings seepage, and the highest concentrations of contaminants, relative to background concentrations, were exhibited by nitrate, manganese, and iron. Plume maps for nitrate, uranium and iron are shown in Figures B.2.18 through B.2.20. Other contaminants exceeding drinking water standards were chloride, sulfate, and total dissolved solids. Elevated concentrations of uranium and ammonium, for which no drinking water standards presently exist, were also detected.

NC site

Alluvial ground water present below and downgradient of the NC tailings pile has been affected by tailings seepage and the highest concentrations of contaminants, relative to background concentrations, were exhibited by chloride, iron, and uranium. Plume maps for chloride, iron, and uranium are

Table B.2.13 Monitor wells where Primary and/or Secondary drinking water quality standards are exceeded at the Slick Rock, Colorado, tailings sites[a]

	Primary standard[b]	Secondary standard[b]	Exceedences at monitor wells	
			Alluvium	Navajo Sandstone
Arsenic	0.05		None	None
Barium	1.0		None	None
Cadmium	0.01		None	None
Chloride		250.0	503, 504, 506	None
Chromium	0.05		505	None
Copper		1.0	None	None
Gross alpha[c,d]	15		NA[g]	NA[f]
Iron		0.3	503, 504, 505, 506, 507	None
Lead	0.05		None	None
Manganese		0.05	All wells	669, 670, 687
Mercury	0.002		None	None
Nitrate	44		508, 510	None
pH[e]	6.5–8.5		None	669, 670
Radium-226 + Radium-228[c]	5.0		None	None
Selenium	0.01		None	None
Silver	0.05		None	634, 668
Sulfate		250.0	All wells, except 686	None
Total dissolved solids		500	All wells	634, 687
Uranium[f]	0.015		All wells, except 684	None
Zinc		5.0	None	None

[a]EPA and State of Colorado drinking water standards are the same.
[b]Units in mg/l except where otherwise noted.
[c]picocuries per liter.
[d]Excluding uranium and radon.
[e]Standard units.
[f]Health advisory level.
[g]NA = Not analyzed.

Figure B.2.18 Nitrate plume during June-July, 1986 at the UC site, Slick Rock, Colorado

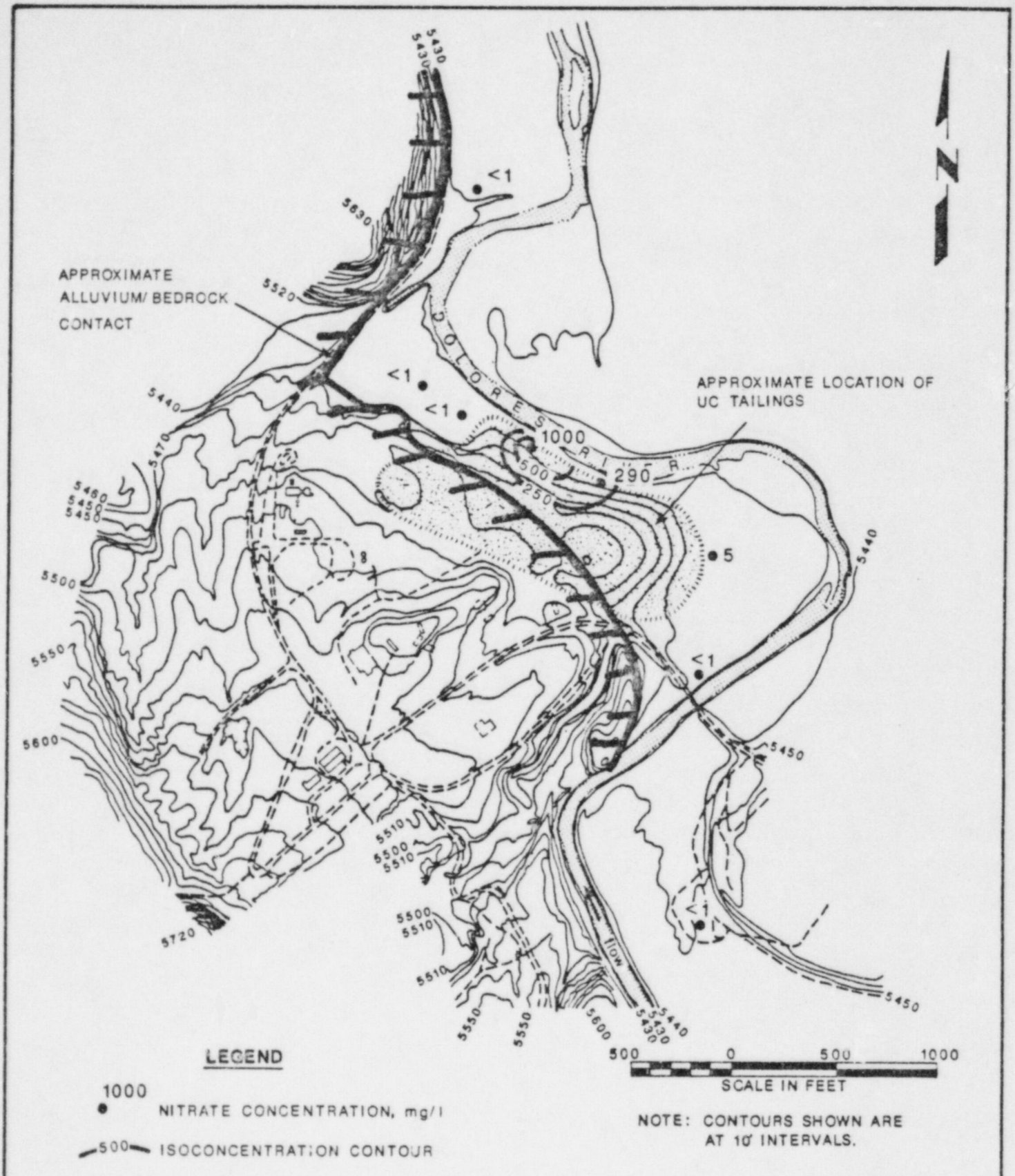

FIGURE B.2.18

NITRATE PLUME DURING JUNE - JULY, 1986, AT THE UC SITE SLICK ROCK, COLORADO

Figure 8.2.19 Uranium plume during June-July, 1986 at the UC site, Slick Rock, Colorado

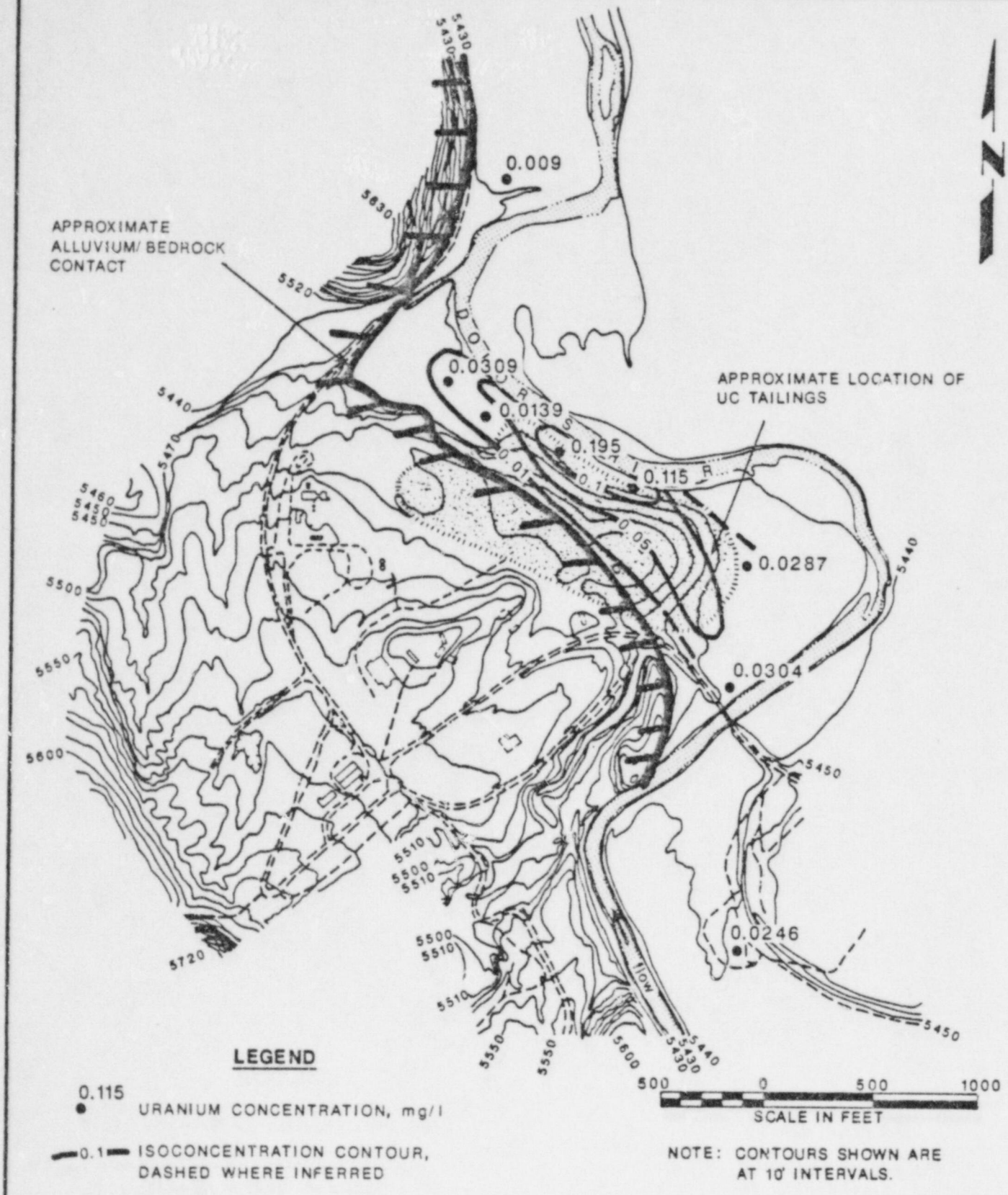

FIGURE B.2.19

URANIUM PLUME DURING JUNE - JULY, 1986, AT THE UC SITE SLICK ROCK, COLORADO

Figure B.2.20 Iron plume during June-July, 1986 at the UC site, Slick Rock, Colorado

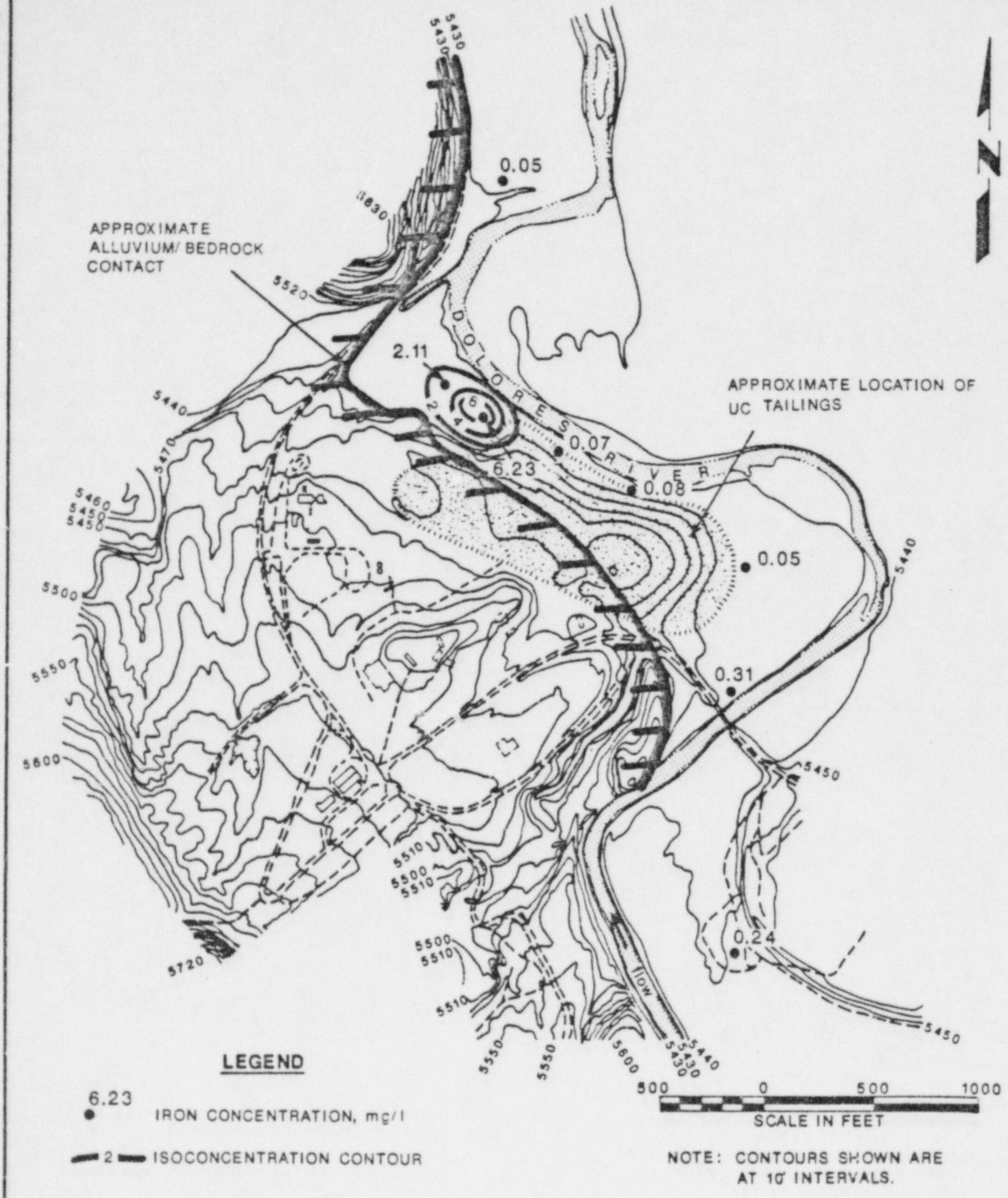

FIGURE B.2.20
IRON PLUME DURING JUNE - JULY, 1986, AT THE UC SITE
SLICK ROCK, COLORADO

shown in Figures B.2.21 through B.2.23. Other contaminants exceeding drinking water standards are manganese, sulfate, and total dissolved solids.

Summary

Tailings-related contamination exists within the alluvium beneath and for a distance downgradient of both the UC and NC tailings piles. Contamination is present at each site over the full vertical extent of the alluvium, approximately 25 feet, and persists downgradient for a distance of approximately 500 feet from the UC pile and NC piles, respectively. Tailings-related contamination was not detected past the limits of either alluvial aquifer. The vertical migration of contaminants into the underlying Navajo Sandstone aquifer is minimized by the upward vertical hydraulic gradient within this unit and the thick sequence of low permeability deposits which separates the contaminated alluvium from the uncontaminated Navajo Sandstone.

B.2.4.2 Discharge of plumes to surface water

It is evident from the ground-water flow maps (Figures B.2.9 through B.2.12) that alluvial ground water at the UC and NC sites discharges into the Dolores River downstream from

Figure B.2.21 Chloride plume during June-July, 1986 at the NC site, Slick Rock, Colorado

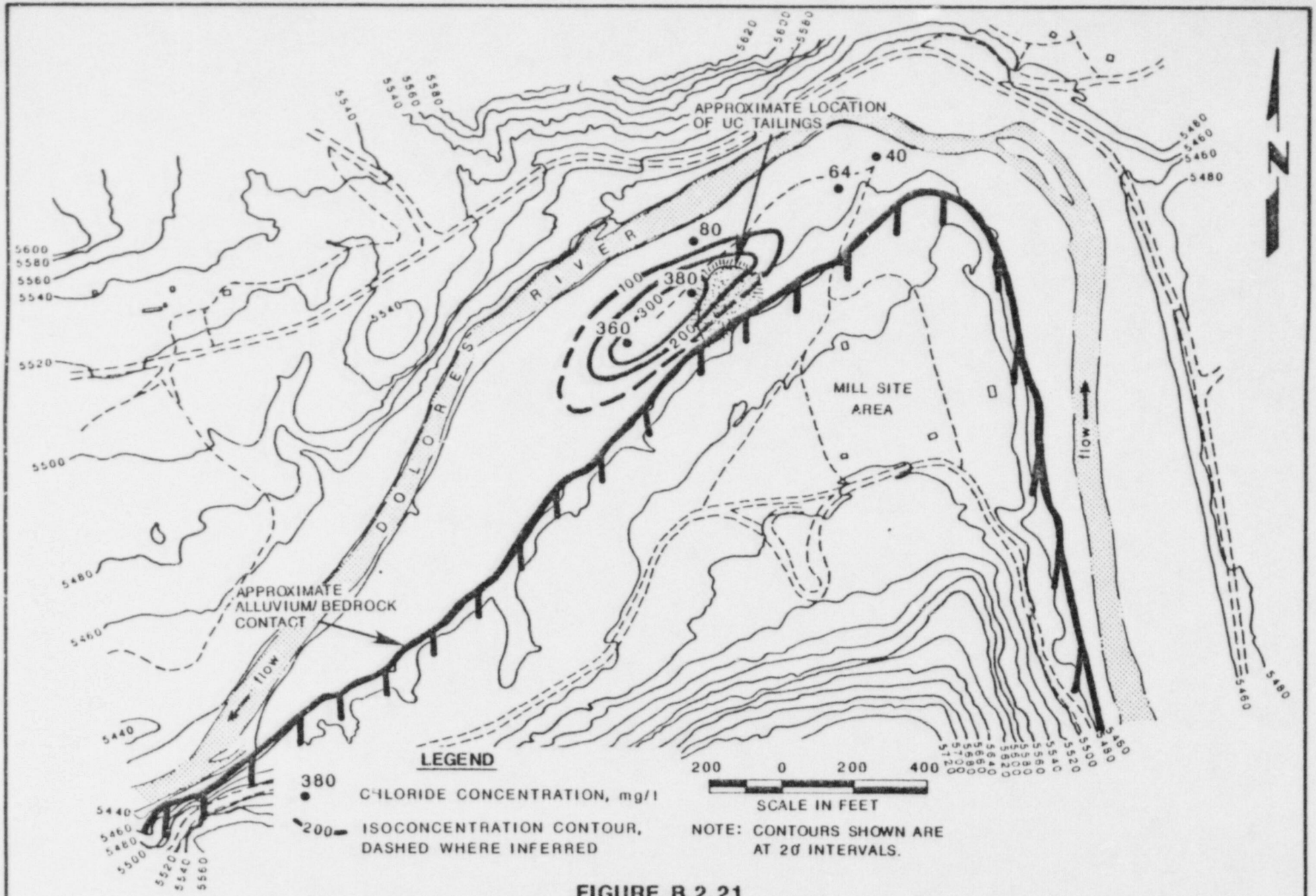

FIGURE B.2.21

CHLORIDE PLUME DURING JUNE - JULY, 1986, AT THE NC SITE
SLICK ROCK, COLORADO

Figure B.2.22 Iron plume during June-July, 1986 at the NC site, Slick Rock, Colorado

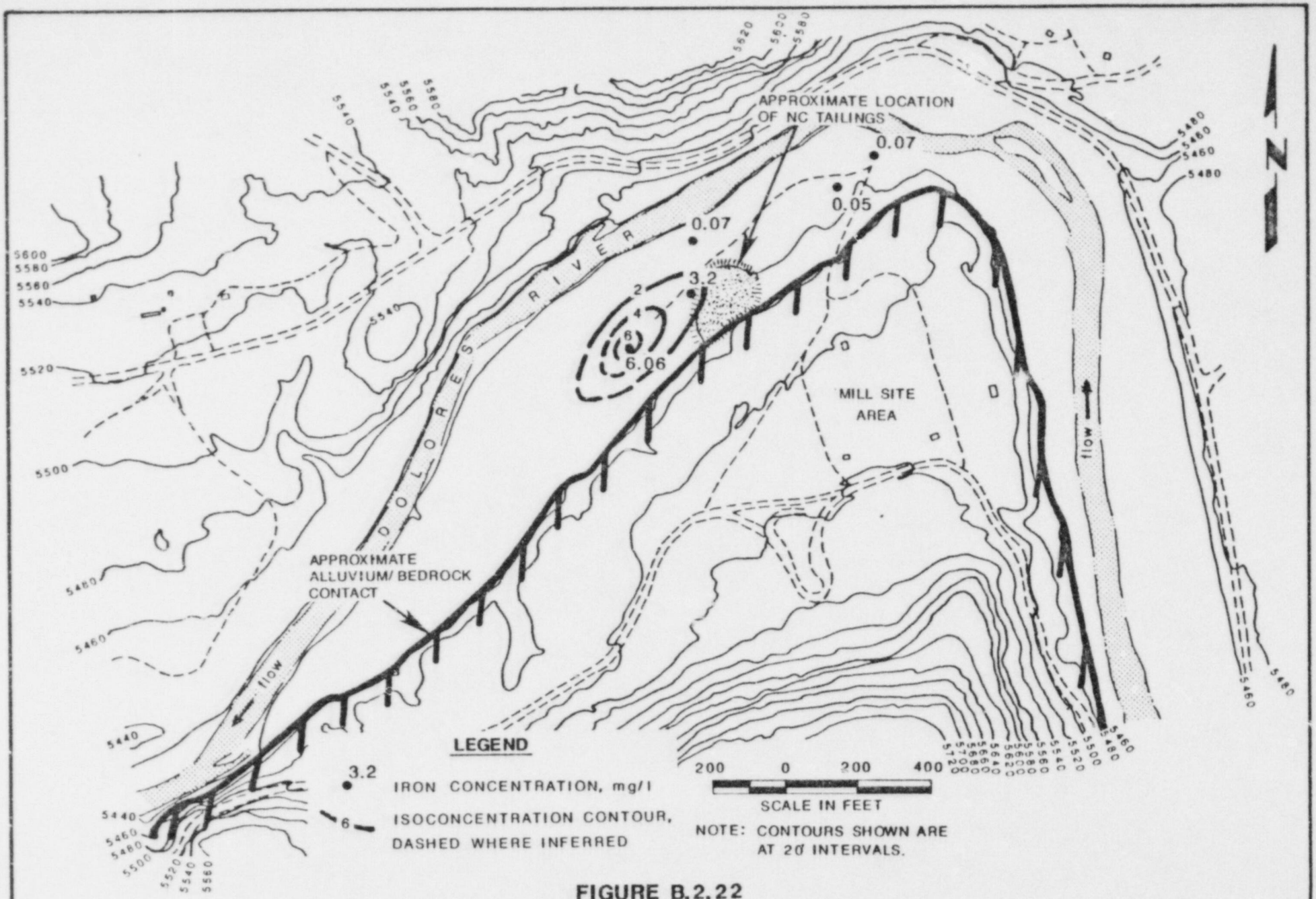

FIGURE B.2.22

IRON PLUME DURING JUNE – JULY, 1986 AT THE NC SITE
SLICK ROCK, COLORADO

Figure B.2.23 Uranium plume in the alluvial aquifer during June-July, 1986 at the NC site, Slick Rock, Colorado

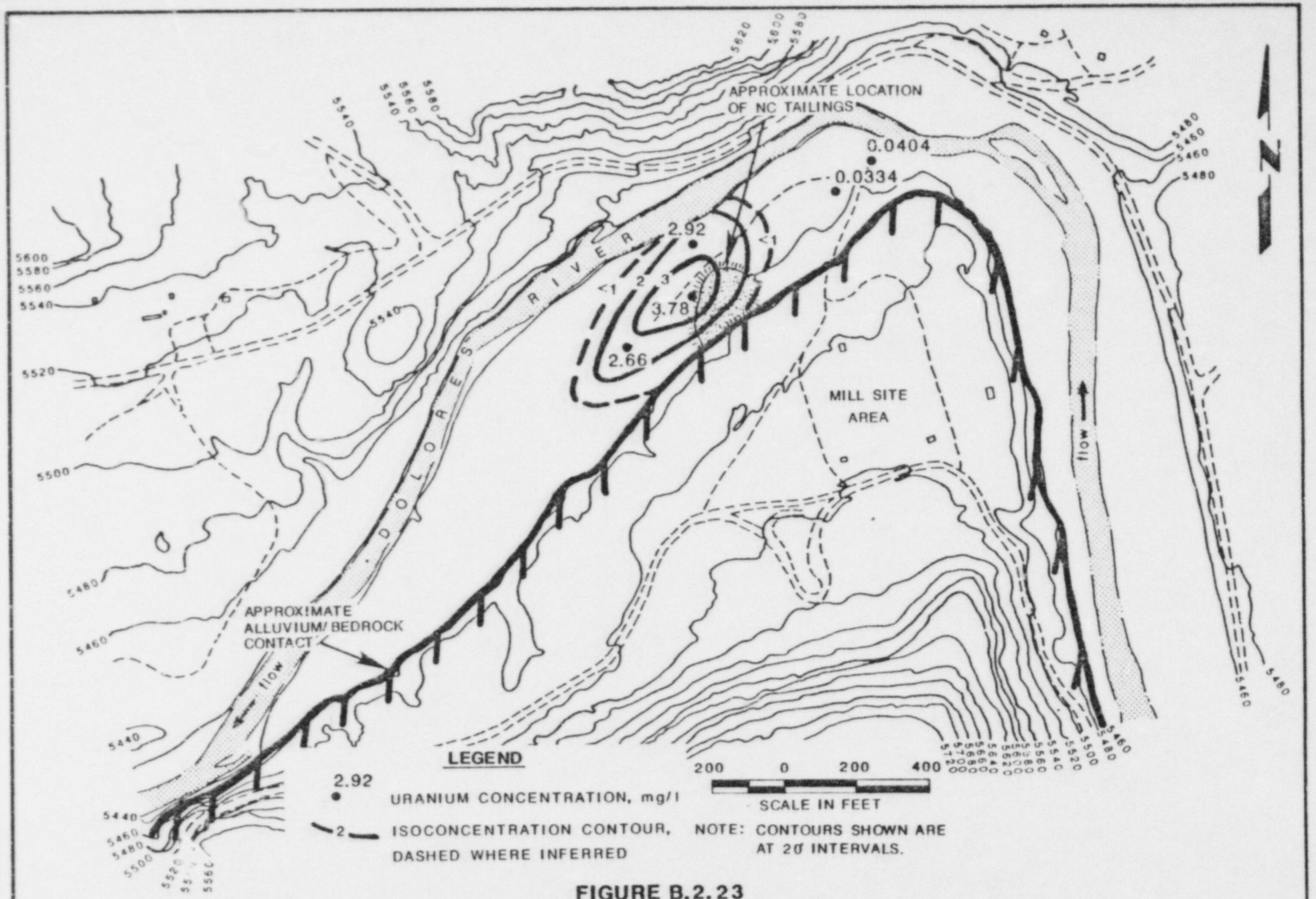

FIGURE B.2.23

URANIUM PLUME DURING JUNE - JULY, 1986 AT THE NC SITE, SLICK ROCK, COLORADO

each of the tailings piles. The calculated effects of these discharges of contaminated alluvial ground water into the Dolores River are discussed in this section.

The ground-water flux within the alluvium downgradient of each tailings pile was calculated using Darcy's Law (Todd, 1980) as follows:

$$Q = WDKi$$

where

Q = flow rate (ft^3/year)
W = saturated width of aquifer (ft)
D = saturated thickness of aquifer (ft)
K = saturated hydraulic conductivity (ft/year)
i = hydraulic gradient (ft/ft)

The minimum, maximum, and mean ground-water flux of alluvial ground water into the Dolores River downstream of the UC and NC piles appears in Tables B.2.14 and B.2.15. The flow in the Dolores River is regulated by McPhee Dam approximately 55 miles upstream of the Slick Rock sites. Flow averages 4000 cfs for the period of May to June, and 80 cfs for the remainder of the year (USBR, 1987). Dilution factors for contaminated alluvial ground water entering the Dolores River downstream of each tailings pile were calculated assuming the

Table B.2.14 Calculated ground-water flux within the alluvial aquifer at the UC site, Slick Rock, Colorado

Component	Maximum flux	Minimum flux	Average flux
W[a] (feet)	1330	1330	1330
D[b] (feet)	25	25	25
K[c] (feet per year)	12785	124	2780
i[c]	0.008	0.008	0.008
Q (cubic feet per year)	3.4×10^6	3.3×10^4	7.4×10^5
Q (gallons per minute)	48.4	0.5	10.5

[a]Width of aquifer measured from tailings pile to farthest downstream extent of alluvial aquifer.
[b]Average alluvial aquifer thickness from borehole logs of alluvial monitor wells.
[c]From Table B.2.5.

Table B.2.15 Calculated ground-water flux within the alluvial aquifer at the NC site, Slick Rock, Colorado

Component	Maximum flux	Minimum flux	Average flux
W[a] (feet)	1600	1600	1600
D[b] (feet)	25	25	25
K[c] (feet per year)	12785	124	2780
i[c]	0.008	0.008	0.008
Q (cubic feet per year)	4.1×10^6	4.0×10^4	8.9×10^5
Q (gallons per minute)	58.4	0.6	12.7

[a]Width of aquifer measured from tailings pile to farthest downstream extent of alluvial aquifer.
[b]Average alluvial aquifer thickness from borehole logs of alluvial monitor wells.
[c]From Table B.2.5.

contaminated ground water enters the river along a reach from the tailings pile to the farthest downstream extent of the individual alluvial aquifer (Table B.2.16). These calculations show that any contaminants discharging from the alluvial aquifers into the Dolores River will be diluted by a factor of 10^{-3} to 10^{-7} in proportion to the difference in flux between the contaminated alluvial ground water and the river.

Table B.2.16 Calculated dilution factors for contaminated alluvial ground water entering the Dolores River from the Slick Rock, Colorado, tailings sites

	Maximum dilution	Minimum dilution
UC site		
Ground-water flux (ft^3/yr)[a]	3.3×10^4	3.4×10^6
Dolores River flow (cfs)[b]	4.0×10^3	8.0×10^1
Dilution factor[c]	2.6×10^{-7}	1.4×10^{-3}
NC site		
Ground-water flux (ft^3/yr)[a]	4.0×10^4	4.1×10^6
Dolores River flow (cfs)[b]	4.0×10^3	8.0×10^1
Dilution factor[c]	3.2×10^{-7}	1.6×10^{-3}

[a]From Tables B.2.14 and B.2.15.
[b]Ref. USBR, 1987.
[c]Dilution factor = Ground-water flux / Dolores River flow.

8.2.4.3 Contaminant sources other than mill tailings

The tailings piles are the likely source of the contaminants found in the alluvial ground water. This is because all of the identified contaminants are known to exist within the piles, are known to have been used in the milling processes, or are commonly associated with uranium mill tailings. In addition, the contaminants are found only below and downgradient of the tailings piles.

8.2.4.4 Geochemical effects on contaminant migration

Dissolved contaminants in the ground water may not move at the same rate as the ground water or maintain their concentration level because of chemical attenuation processes that involve the ground water and the sediment it contacts. In order to make realistic estimates of the rate of migration of a contaminant plume from a mill tailings site, the constituents from the pile that contaminate the aquifer must be identified and the mechanisms that affect solution concentration of the contaminants must be understood in at least a qualitative manner. At the Slick Rock tailings sites the following contaminants from the tailings have been identified: sulfate, iron, manganese, uranium, molybdenum, ammonium, nitrate, chloride, and total dissolved solids (TDS) level. Soil chemical data such as cation exchange capacity

and organic matter content are not available for these sites, therefore, this discussion will be limited to generalizations based on chemical principles and the observed mobility of these contaminants at the Slick Rock sites and other UMTRA Project sites.

Although sulfate concentrations greater than the drinking water standard of 250 mg/l are typical of the background water in the alluvial aquifer it is likely that additional sulfate is added to the ground water by seepage from the tailings piles. Sulfate concentration in the ground water is typically limited by the precipitation of gypsum ($CaSO_4 \cdot 2H_2O$), which becomes oversaturated as the acidic seepage dissolves calcium carbonate minerals in the soil beneath the piles. Gypsum is fairly soluble and its precipitation would not lower sulfate concentration below the drinking water standard under normal conditions. Sulfate may be adsorbed onto sediment minerals, but, in general, its concentration level will not be significantly reduced by this process. Elevated sulfate concentrations can be expected to exist downgradient from the piles to the point where the plumes enter the river.

Neutralization of the acidic seepage from the tailings by carbonate minerals in the subsoil raises the pH of the solution and decreases the solubility of iron and manganese minerals, causing these elements to precipitate as oxide and oxyhydroxides. The solution concentration of these two metals

in equilibrium with their normal soil and aquifer minerals is less than the drinking water standards for the two metals. The fact that they do occur as contaminants at Slick Rock may be a result of incomplete neutralization or insufficient time for precipitation of the concentration-limiting solid phases. Alternatively, complexing agents may be present in the water that elevate the solubility of the minerals under the particular site conditions. The mobility of these contaminants will be affected by the chemical equilibrium established between the solution and solid phases, and local contamination may persist until the source term is decreased or eliminated.

The presence of metal oxides of iron, manganese, and aluminum, which are present in most shallow, oxidizing aquifer systems, affects the mobility of uranium. As tailings seepage moves out of the neutralization zone and into the ground water, uranium is specifically adsorbed onto metal mineral surfaces. However, there is competition for the uranium between the solution and solid phases. The dominant dissolved uranium specie in oxidized water with dissolved carbonate present is a uranyl carbonate specie. It has been shown that under these solution conditions the adsorption of uranium on solid surfaces is not as effective in removing uranium from solution than if carbonate was not present in the ground water. For this reason, along with observed uranium concentrations at other UMTRA Project sites, it is expected

that uranium may not be removed from solution to below the EPA proposed health advisory level (0.015 mg/l) (Cothern et al., 1983). It should be noted that most of the background water in the alluvial aquifer also contains dissolved uranium above this value.

The mobility of molybdenum in ground water is not as well understood as that of uranium, however, several analogies exist between the two elements. As with uranium, the dominant specie of molybdenum in normal oxidizing ground water is an anion, molybdate ($MoO_4 2-$). This anion also adsorbs onto metal oxide surfaces thereby retarding its movement through an aquifer compared to the ground-water flow rate. This situation has been observed at the Riverton, Wyoming, and Ambrosia Lake, New Mexico, tailings sites where the molybdenum plume is currently near the base of the tailings whereas the head of the sulfate plume is hundreds of feet downgradient. It is expected that a similar situation will exist at the Slick Rock sites in that it will take a much greater amount of time to naturally flush molybdenum from the aquifer than the more mobile contaminants such as sulfate and nitrate.

Nitrate and ammonium contamination in the aquifers at the Slick Rock sites is most likely a result of chemical processing of the ore because natural sources of these constituents are rare and agricultural application of these chemicals as fertilizers at these sites is not considered

important. Nitrate is not strongly attenuated in its movement through ground water and should move at approximately the ground-water flow rate. Ammonium, on the other hand, is strongly adsorbed by common clay minerals because of its chemical similarity to potassium which is a constituent of illitic clays. The movement of ammonium through the aquifer will be much slower than that of the ground water, and ammonium may be oxidized by natural processes to nitrate thereby adding to the nitrate contamination level.

Chloride will act like sulfate in the aquifer and will not be strongly attenuated in its movement through the sediments. The fact that chloride, sulfate, nitrate, and their compensating major cations (sodium, calcium, and magnesium) are elevated in the ground water affected by seepage from the tailings produces a total dissolved solids level several times above the drinking water standard of 500 mg/l. Most of the major anions and cations will move at the ground-water flow rate and will be naturally flushed from the system into the river at a relatively rapid rate compared to those elements which are affected by solution/mineral interactions. The total dissolved solids level is also expected to be lowered along with removal of the more mobile contaminants in the aquifer.

B.2.5 USE AND VALUE OF WATER RESOURCES

B.2.5.1 Existing use and value of water resources

There are 11 registered wells within the general vicinity of the Slick Rock tailings sites (Figure B.2.24). Nine of these wells (2133F, 2135F, 2163F through 2168F, and 15806F) are no longer in use and are in various states of disrepair. Wells which are completed in the Navajo Sandstone include 2134F which is the water supply for the Slick Rock trailer park, well 15805F which supplies the water for the Slick Rock post office and cafe and an unregistered well (numbered 672 for inventory purposes) which supplies water for a local resident. There are no known users of potentially affected ground water in the area of the Slick Rock tailings sites.

It is difficult to assign an absolute value to water resources. Qualitatively, it can be stated that the alluvial ground water affected by the Slick Rock tailings has a very low value due to the limited volume, lack of use, and the availability of alternate water resources (i.e., the Navajo Sandstone aquifer).

B.2.5.2 Future use and value of water resources

Future use and value of the alluvial ground water is expected to remain very low due to the marginal quality of the

Figure 8.2.24 Registered wells in the vicinity of the Slick Rock, Colorado, tailings sites

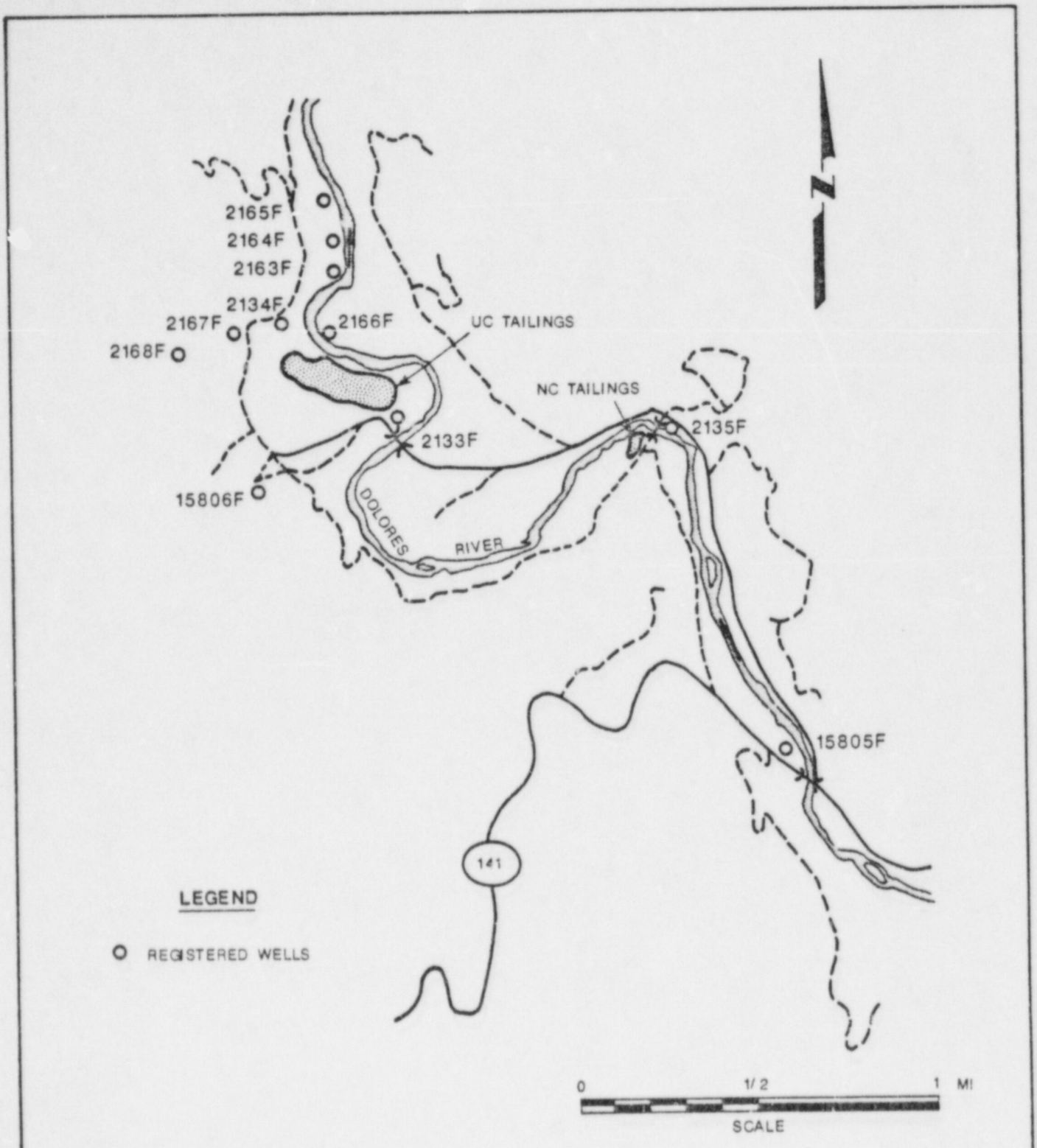

FIGURE B.2.24

REGISTERED WELLS IN THE VICINITY OF THE SLICK ROCK, COLORADO TAILINGS SITES

water for domestic use, the continued lack of use, and the availability of alternate water supplies.

B.2.5.3 Alternate water supplies

The tailings have not affected any ground water that is currently being used. The alternate water supply (Navajo Sandstone aquifer) is currently, and will likely continue, to supply the total water needs of the area.

B.2.6 GROUND-WATER IMPACTS

B.2.6.1 Water-quality impacts

Ground-water contamination beneath the Slick Rock tailings sites depends upon the following:

- The quantity and quality of seepage released from the tailings pile.
- The rate at which contaminants will enter the ground-water system.
- The physical and chemical nature of the ground-water flow system.

The Slick Rock tailings sites' characteristics give a general indication of the present, potential contaminant pathways from the tailings pile to the shallow ground-water system. However, the existing ground-water contamination attributable to the Slick Rock tailings piles was largely produced during the milling operation.

Stabilization on site

Prediction of the effects of the proposed action upon ground water are difficult to quantify due to the complex flow patterns and the limited amount of existing data. However, general trends in the quantities and rates of seepage can be projected.

The principal features of the proposed action that would affect seepage release from the pile are: (1) contouring of the pile to promote surface runoff from the pile with the addition of a low-permeability cover to minimize infiltration; (2) the compaction and consolidation of all the tailings and contaminated materials on the pile; and (3) the relocation of the UC and NC tailings to a position removed from the alluvial aquifers.

The first feature would reduce the infiltration rate through the pile a ' therefore reduce the long-term quantity and rate of seepage from the tailings pile. The compaction of

the tailings involves the addition of water during compaction and the redistribution of existing pore water in the tailings during consolidation, contouring, and settling of the tailings. The volume of water added during remedial action is minimal when compared to the volume of effluent added to the tailings during active milling conditions which produced most of the existing contamination beneath the present tailings piles. However, a small quantity of free water in the voids would gradually drain by gravity from the tailings into the underlying, low-permeability Entrada Sandstone bedrock.

The Entrada Sandstone is unsaturated and would separate the stabilized pile from the underlying, confined Navajo Sandstone aquifer. Depth to water beneath the disposal site would be greater than 60 feet. This unsaturated sandstone, conglomerate, mudstone, and shale beneath the site would act as a physical and chemical buffer to any potential tailings seepage.

No action

Under existing conditions, the volume of recharge to the tailings pile has dropped to only that produced during natural precipitation and infiltration. Both the quality and rate of seepage from the tailings pile have decreased significantly from the period of active milling.

As a result of the no action alternative, it may be expected that continued leaching of contaminants from the tailings piles would be minimal, and the discharge of ground water contaminated by tailings leachate would ultimately cease.

8.2.6.2 Human health risks

Stabilization on site

At present, there are no users of alluvial ground water in the vicinity of the Slick Rock sites and the probability of future use is low. Should ingestion of ground water occur in the future, the concentrations of contaminants produced from the tailings would be less than or equal to existing concentrations.

On-site wells in the alluvium where samples exceeded EPA standards were listed in Table 8.2.13. Consumption of water which exceeds the primary standards can pose a threat to health. However, since there are no existing alluvial ground-water users, no detailed health risk assessment has been completed at this time.

Under the proposed action, health impacts can be minimized by using institutional controls to inhibit ingestion of contaminated water. The readily available water supply which could be obtained from the Navajo Sandstone aquifer would also minimize the need for using contaminated alluvial water in the future.

No action

Health impacts for no action would be the same as for the proposed action.

B.2.6.3 Damage to crops, vegetation, and wildlife

Stabilization on site

The proposed action would not affect agricultural production and there is very sparse vegetation that could possibly be affected in the immediate vicinity of the tailings site.

No action

Under the no action alternative there would be no impacts to crops or vegetation unless irrigation wells were completed in the contaminant plume.

B.2.7 AQUIFER RESTORATION

Aquifer restoration could be used to eliminate potential hazards due to ingestion of contaminated ground water. The need to conduct aquifer restoration at the Slick Rock sites was evaluated based on the following factors: the extent of contamination, the impact of contamination on existing and future ground-water users, the availability of alternative water supplies, and the cost of aquifer restoration.

The extent of ground-water contamination, the availability of alternate water supplies, and the impact to present and future water users were discussed in Sections B.2.4.2, B.2.5.3, and B.2.6.1, respectively. The contaminated ground water has not affected any current users nor is it likely to affect any current users in the future. Future demands for additional water can be met by developing alternate water supplies.

Legal prohibition of ground-water withdrawals from the contaminated or potentially contaminated area would be far less expensive than aquifer restoration. Not performing aquifer restoration would have little effect on available water supplies in the area because alternate surface water supplies are available and are currently being utilized. If legal prohibitions, rather than aquifer restoration, are imposed to protect the health of future water users located near the site, the extra cost would primarily result from transporting water from outside the contaminated area to the point of use.

As an alternative to outright legal prohibition of ground-water use in the potentially contaminated area, those wishing to use the contaminated water in the future could be required to treat it. The most efficient treatment method would probably be individual well-head reverse osmosis units. This would be more expensive than simply implementing use restrictions and would require disposal of the concentrated contaminants, but would still be far less expensive than aquifer restoration.

In conclusion, aquifer restoration is not recommended at the Slick Rock tailings sites based on the following factors:

- Ground-water contamination has not affected any existing water supplies.

- Ground-water contamination will not affect existing water supplies in the future.

- Future ground-water requirements can be met by developing alternate water supplies.
- Aquifer restoration would be technically difficult and very expensive in relation to potential benefits.

- Consumption of contaminated ground water can be prohibited through institutional controls.

When the EPA issues revisions to the water protection standards (40 CFR Part 192.20 (a) (2)-(3)) that were remanded by the U.S. Tenth Circuit Court of Appeals, the ground-water issues at the Slick Rock sites will be re-evaluated to assure that the revised standards are met. Performing remedial actions to stabilize the tailings prior to the EPA issuing new standards will not affect the measures that are ultimately required to meet the revised EPA water protection standards. Conditions have been characterized at the Slick Rock sites and it is not anticipate that any substantial changes to the remedial actions will be required. However, after the EPA re-issues the water protection standards, the need for institutional controls, aquifer restoration, or other controls will be determined and appropriate action will be taken so as to comply with the re-issued standards.

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APPENDIX C

FLORA AND FAUNA

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C.1 FLORA AND FAUNA: AFFECTED ENVIRONMENT

The Slick Rock sites are located in the Great Basin sagebrush habitat of the Colorado Plateau (Kuchler, 1975). The sites are located in the Dolores River Valley which is surrounded by sandstone cliffs and steep, juniper covered hillsides. Flat land is confined to the riparian zone along the river.

Information regarding the flora and fauna at the Slick Rock sites was derived from field reconnaissance surveys (TAC, 1986, 1985; DOE, 1983), consultation with natural resource personnel from state and Federal agencies, and a review of the pertinent literature. Lists of the flora and fauna observed or expected to occur at the sites plus scientific names of species referred to in the text appear in Tables C.1.1 through C.1.5. These tables do not represent a complete listing of species from this area. Rather, they are species observed at the sites during the reconnaissance surveys or species recorded in the area from other sources. The plant species list (Table C.1.1) was derived from site-specific surveys while the fish species list (Table C.1.2) represents species captured in the Dolores River in recent years near the Slick Rock sites. The reptile/amphibian and mammal tables (Tables C.1.3 and C.1.5) were generated from limited site surveys plus other information as referenced in the tables. The bird species table (Table C.1.4) lists nesting birds and a few migratory and wintering species that have been observed at or near the sites.

Table C.1.1 Plant species observed in the area of the Slick Rock sites, Slick Rock, Colorado

Species		Habitat	
Scientific name	Common name	Riparian	Upland
	TREES AND SHRUBS		
Acer negundo	box elder	X	
Artemisia arbuscula	black sagebrush		X
Artemisia tridentata	big sagebrush	X	X
Atriplex canescens	fourwing saltbush	X	X
Atriplex sp.	saltbush	X	X
Brickellia scabra	brickellia	X	
Cercocarpus montanus	mountain-mahogany		X
Chrysothamnus nauseosus	golden rabbitbrush	X	X
Chrysothamnus viscidiflorus	rabbitbrush	X	
Elaeagnus angustifolia	Russian olive	X	
Ephedra sp.	mormon tea		X
Gutierrezia sarothrae	broom snakeweed		X
Haplopappus scopurlorum	goldenweed	X	
Juniperus sp.	juniper	X	
Opuntia polyacantha	plains prickly pear		X
Pinus edulis	pinyon pine		X
Populus angustifolia	narrowleaf cottonwood	X	
Populus fremontii	Fremont cottonwood	X	
Rhus trilobata	squawbush	X	
Rosa fendleri	fendler rose	X	X
Salix sp.	willow	X	
Sarcobatus vermiculatus	greasewood	X	
Tamarix pentandra	saltcedar	X	
Yucca baccata	banana yucca		X
Yucca sp.	yucca		X
	FORBS AND HERBS		
Amaranthus sp.	pigweed	X	
Ambrosia confertifolia	slimleaf bursage		X
Arctium minus	burdock	X	
Astragalus amphioxys	milkvetch	X	X
Astragalus sp.	milkvetch	X	X
Centaurea repens	Russian knapweed	X	X
Chenopodium watsoni	Watson goose foot	X	
Chrysopsis hispida	gold aster	X	X
Clematis liqusticifolia	virgin's bower	X	
Cleome lutea	yellow bee plant	X	
Cleome serrulata	Rocky Mountain bee plant	X	
Descurainia obtusa	tansy mustard	X	
Eriogonum wrightii	Wright buckwheat		X
Glycyrrhiza lepidota	licorice	X	
Grindelia squarrosa	curlycup gumweed	X	

Table C.1.1 Plant species observed in the area of the Slick Rock sites, Slick Rock, Colorado (Concluded)

Species		Habitat	
Scientific name	Common name	Riparian	Upland
	FORBS AND HERBS (Concluded)		
Halogeton glomeratus	halogeton	X	
Helianthus annuus	common sunflower	X	X
Hymenopappus pauciflora	white ragweed	X	
Ipomoea sp.	morning glory	X	
Ipomopsis aggregata	desert trumpet	X	
Lesquerella rectipes	bladder pod	X	
Leucelene ericoides	babywhite aster		X
Melilotus officinalis	yellow sweet clover	X	
Mirabilis multiflora	Colorado four o'clock	X	
Salsola iberica	Russian thistle		X
Senecio multicapitatus	groundsel	X	X
Sphaeralcea coccinea	scarlet globe mallow	X	X
Stanleya pinnata	prince's plume	X	X
	GRASSES		
Agropyron desertorum	creasted wheatgrass		X
Andropogon gerardii	big bluestem	X	
Bouteloua gracilis	blue grama		X
Bouteloua sp.	grama sp.		X
Bromus rubens	red brome	X	X
Bromus tectorum	cheatgrass	X	X
Cynodon dactylon	Bermuda grass	X	
Hilaria jamesii	galleta		X
Oryzopsis hymenoides	Indian ricegrass		X
Phragmites communis	reed	X	
Sitanion hystrix	squirrel tail	X	X
Sporobolus cryptandrus	sand dropseed		X
Stipa comata	needle and thread	X	X

Ref. TAC, 1986; DOE, 1983.

Table C.1.2 Fish species recorded from the Dolores River near Slick Rock, Colorado

Scientific name	Common name
Catostomus discobolus	bluehead sucker
Catostomus latipinnis	flannelmouth sucker
Lepomis cyanellus	green sunfish
Cottus bairdi	mottled sculpin
Cyprinus carpio	common carp
Gila robusta	roundtail chub
Notropis lutrensis	red shiner
Pimephales promelas	fathead minnow
Rhinichthys osculus	speckled dace

Ref. Kehmeier, 1986; Valdez et al., 1982; Holden and Stalnaker, 1975.

Table C.1.3 Amphibians and reptiles observed or expected to occur at or near the Slick Rock sites, Slick Rock, Colorado

Species		Habitat	
Scientific name	Common name	Riparian	Upland
Ambystoma tigrinum	tiger salamander	X	X
Scaphiopus intermontanus	great basin spadefoot	X	X
Bufo punctatus	red-spotted toad	X	
Bufo woodhousii	Woodhouse's toad	X	
Rana pipiens	leopard frog	X	
Crotaphytus collaris[a]	collared lizard		X
Gambelia wislizenii	leopard lizard		X
Phrynosoma douglassii	short-horned lizard		X
Sceloporus undulatus[a]	eastern fence lizard	X	X
Sceloporus graciosus[a]	sagebrush lizard		X
Uta stansburiana[a]	side-blotched lizard		X
Urosaurus ornatus	tree lizard	X	X
Eumeces multivirgatus	many-lined skink	X	X
Chemidophorus tigris[a]	northern whiptail		X
Chemidophorus velox[a]	plateau whiptail		X
Coluber constrictor	racer	X	X
Pituophis melanoleucus	gopher snake	X	X
Lampropeltis triangulum	milk snake	X	X
Thamnophis elegans	western terrestrial garter snake	X	
Crotalus viridis	western rattlesnake	X	X

[a]Species observed on the site.

Ref. Hammerson, 1986; TAC, 1986, 1985; DOE, 1983; Pioneer, 1979; Bernard and Brown, 1978.

Table C.1.4 Bird species observed at or in the area of the Slick Rock sites, Slick Rock, Colorado

Species		Nesting habitat	
Scientific name	Common name	Riparian	Upland
Circus cyaneus[a]	northern harrier	X	
Falco sparverius	American kestrel	X	X
Actitis macularia	spotted sandpiper	X	X
Columba livia[b]	rock dove	X	X
Zenaida macroura	mourning dove	X	
Archilochus alexandri	black-chinned hummingbird	X	X
Colaptes auratus	northern flicker	X	
Picoides villosus	hairy woodpecker	X	
Tyrannus verticalis	western kingbird	X	X
Myiarchus cinerascens	ash-throated flycatcher	X	X
Sayornis saya	Say's phoebe	X	
Eremophila alpestris	horned lark		X
Hirundo rustica	barn swallow	X	
Gymnorhinus cyanocephalus	pinyon jay	X	X
Pica pica	black-billed magpie	X	
Corvus corax[b]	raven		X
Sitta pygmaea	pygmy nuthatch		X
Catherpes mexicanus	canyon wren		X
Salpinctes obsoletus	rock wren		X
Polioptila caerulea	blue-gray gnatcatcher	X	X
Sialia currucoides	mountain bluebird		X
Toxostoma bendirei	Bendire's thrasher		X
Turdus migratorius	American robin	X	
Lanius ludovicianus	loggerhead snake	X	
Vireo vicinior	gray vireo		X
Dendroica petechia	yellow warbler	X	
Icteria virens	yellow-breasted chat	X	
Pheucticus melanocephalus	black-headed grosbeak	X	X
Guiraca caerulea	blue grosbeak	X	
Passerina amoena	lazuli bunting	X	
Pipilo erythrophthalmus	rufous-sided towhee	X	
Pooecetes gramineus	vesper sparrow	X	X
Passerculus sandwichensis	savannah sparrow	X	X
Chondestes grammacus	lark sparrow	X	X
Amphispiza bilineata	black-throated sparrow		X
Sturnella neglecta	western meadowlark	X	X
Euphagus cyanocephalus	brewer's blackbird	X	
Molothrus ater	brown-headed cowbird	X	X
Carpodacus mexicanus	house finch	X	X

[a]Species observed only in Disappointment Valley borrow site area.
[b]Species which nest on cliffs.

Ref. TAC, 1986, 1985; DOE, 1983; Pioneer, 1979.

Table C.1.5 Mammals observed or expected to occur at or in the area of the Slick Rock sites, Slick Rock, Colorado

Species		Habitat	
Scientific name	Common name	Riparian	Upland
Sylvilagus nuttallii	mountain cottontail	X	
Sylvilagus audubonii[a]	desert cottontail		X
Lepus californicus	black-tailed jackrabbit		X
Eutamias minimus[a]	least chipmunk		X
Ammospermophilus leucurus[a]	white-tailed antelope ground squirrel		X
Spermophilus richardsonii[a]	Richardson's ground squirrel	X	X
Spermophilus variegatus	rock squirrel		X
Thomomys talpoides	northern pocket gopher	X	X
Perognathus flavus	silky pocket mouse		X
Dipodomys ordii[a]	Ord's kangaroo rat	X	X
Castor canadensis[a]	beaver	X	
Peromyscus crinitus	canyon mouse		X
Peromyscus maniculatus[a]	deer mouse	X	X
Peromyscus truei[a]	pinon mouse		X
Onychomys leucogaster[a]	northern grasshopper mouse		X
Neotoma lepida[a]	desert woodrat		X
Ondatra zibethicus	muskrat	X	
Zapus princeps	western jumping mouse	X	
Erethizon dorsatum[a]	porcupine	X	X
Canis latrans[a]	coyote	X	X
Urocyon cinereoargenteus	gray fox	X	X
Procyon lotor	racoon	X	X
Mustela frenata	long-tailed weasel	X	X
Mustela vison	mink	X	
Taxidea taxus	badger	X	X
Spilogale gracilis	western spotted skunk	X	X
Mephitis mephitis	striped skunk	X	X
Felis rufus	bobcat	X	X
Odocoileus hemionus[a]	mule deer	X	X
Antilocapra americana[a,b]	pronghorn antelope		X

[a]Species observed at or near the sites.
[b]Species observed only in Disappointment Valley borrow site area.

Ref. TAC, 1986; DOE, 1983; Pioneer, 1979; Bernard and Brown, 1978.

Slick Rock tailings sites

The areas included in this section are the two tailings piles and their associated windblown and waterborne contaminated areas. Most of the contaminated area occurs within the Dolores River floodplain or in upland desert shrub habitat.

Three plant community types were observed; grass/herb, desert shrub, and riparian. The grass/herb dominated type occurs on the tailings piles and other nearby disturbed areas. The UC tailings site was planted with crested wheatgrass; Indian ricegrass and red brome were other grass species that occur sporadically. Widely scattered shrubs including fourwing saltbush, squaw-bush, and rabbitbrush also occur on this pile. Vegetative growth on the pile was sparse and much bare ground is in evidence (DOE, 1983). The NC tailings pile has a better developed plant cover than the UC pile. Commonly observed grass species include cheatgrass, red brome, and Indian ricegrass. Major shrub species observed include saltbush, rabbitbrush, and broom snakeweed. Herbs such as licorice, desert trumpet, scarlet globemallow, and prince's plume were also observed on the NC pile (DOE, 1983).

The second plant community observed was the desert shrub habitat. Widely scattered shrubs (sagebrush, rabbitbrush, and broom snakeweed) were the dominant species in these areas. Ground cover was sparse with various grass and herb species being observed.

The third habitat type was the riparian vegetation. Four plant community subtypes were observed in the riparian zone. The dense riparian shrub subtype

occurred closest to the river and typically grew in thin strips along the riverbank or on islands (Figures C.1.1 and C.1.2). Shrubs such as willow and saltcedar formed a very dense growth in this habitat. Other shrubs observed included fourwing saltbush, squawbush, fendler rose, and big sagebrush. Small narrowleaf cottonwood and Russian olive were occasionally observed. There was little ground cover in the dense growth of willow and saltcedar; more open areas in this subtype had a dense growth of grass and herbaceous species such as yellow sweet clover and milkvetch.

The remaining riparian plant community subtypes occurred next to the dense riparian shrub zone at a somewhat higher elevation above the river. The upper riparian grass type had a dense ground cover of grass and herbs with widely scattered shrubs including big sagebrush, greasewood, saltbush, squawbush, fendler rose, saltcedar, and Russian olive. The upper riparian shrub subtype was similiar except that shrubs were much more common; sagebrush and greasewood were most abundant. This type also had a dense ground cover of grass and herbs.

The final riparian plant community subtype was dominated by cottonwood. Three small stands of cottonwoods occurred in the tailings area (Figure C.1.1). Fremont cottonwood was the dominant species; some narrowleaf cottonwood was also observed. These stands were fairly open and most of the cottonwoods were fairly large. The average height for 14 trees in one of the stands was 45 feet (range of 35 to 60 feet) while the average diameter at breast height (dbh) was about 20 inches (range of 10 to 32 inches). No cottonwood reproduction was observed and in one stand an estimated 34 percent

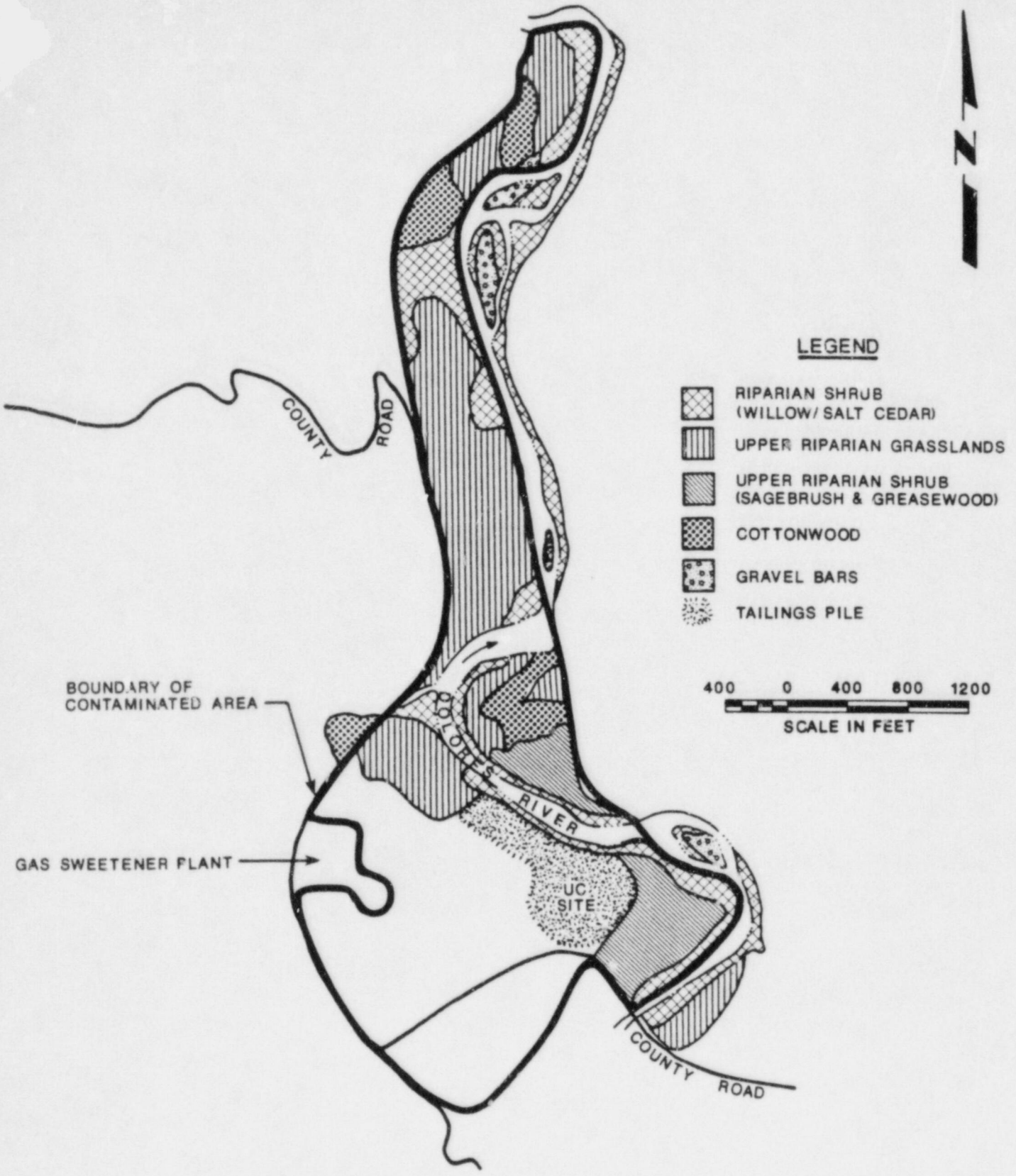

FIGURE C.1.1
PLANT COMMUNITY TYPES IN THE RIPARIAN ZONE ALONG THE DOLORES RIVER AT THE UC SITE SLICK ROCK, COLORADO

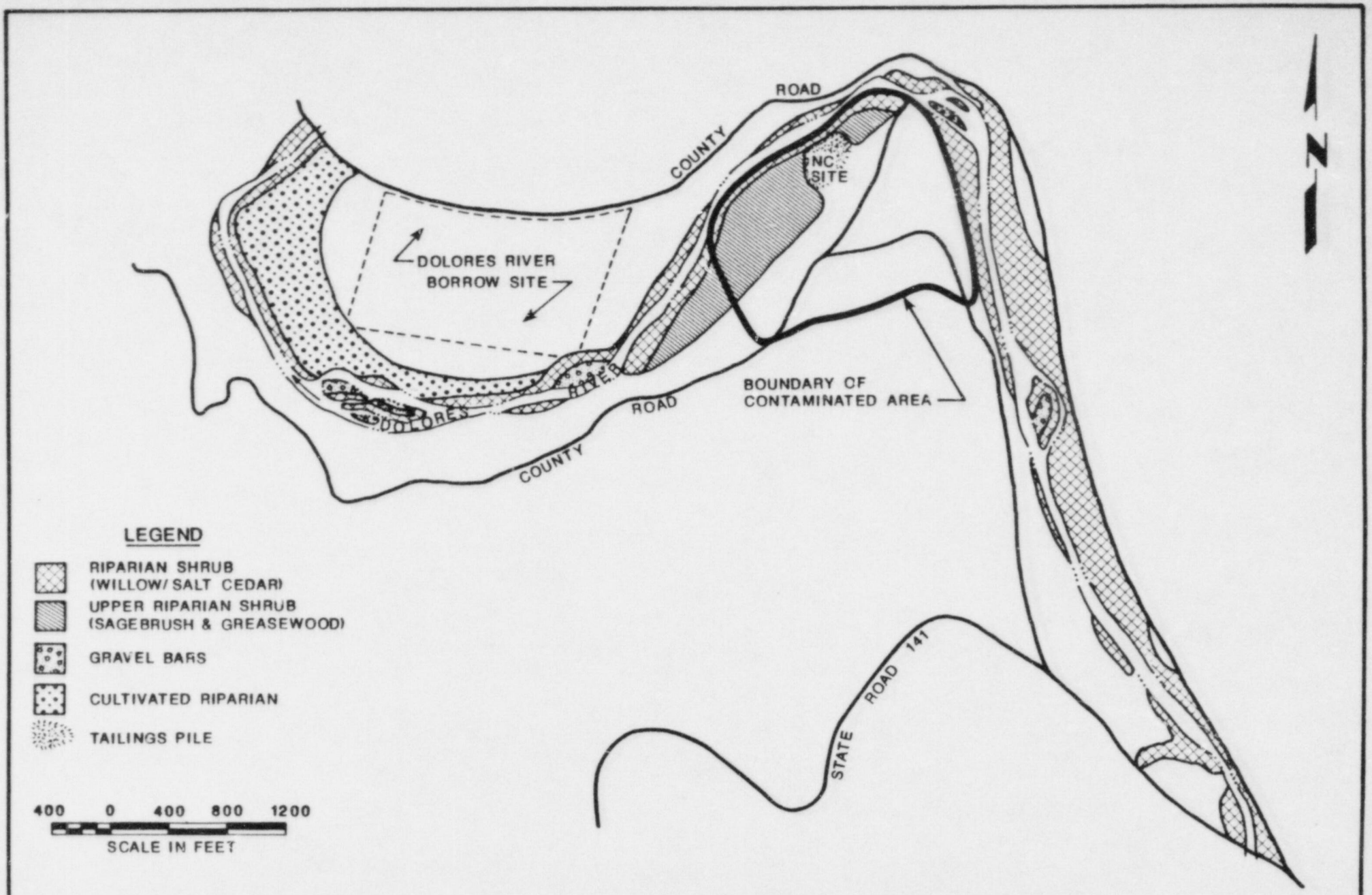

FIGURE C.1.2
PLANT COMMUNITY TYPES IN THE RIPARIAN ZONE ALONG THE DOLORES RIVER AT THE NC SITE, SLICK ROCK, COLORADO

of the trees were either dead or dying. There was a dense grass ground cover in these stands and scattered shrubs including squawbush, sagebrush, greasewood, rabbitbrush, and box elder were observed.

The Dolores River flow patterns have been altered in recent years due to the diverting of water for irrigation by the Montezuma Valley Irrigation Company. Little or no flow occurs in the river near Slick Rock during the summer and fall due to these diversions (Valdez et al., 1982). In addition, spills from mining operations have resulted in fish kills in recent years (Sigler et al., 1966; Nolting, 1957). As a result, only nine species of fish have been collected from the Dolores River in the Slick Rock area in recent years (Table C.1.2). Valdez et al. (1982) stated that many fish (especially native species) migrated out of the Dolores River during periods of low flow and that the remaining pools harboured mostly non-native species.

Detailed studies regarding the terrestrial wildlife at and near the Slick Rock sites have not been conducted. Reconnaissance surveys at and near the sites (TAC, 1986; 1985) and studies in nearby Disappointment Valley (Pioneer, 1979) resulted in the observation of the red-spotted toad and six species of lizards in the area (Table C.1.3). An additional 14 species of amphibians and reptiles may occur at or near the sites.

A total of 39 species of birds were observed at or near the Slick Rock sites (Table C.1.4). This list represents common nesting species along with a few species that are migrants or nest some distance from the sites. The yellow-breasted chat and yellow warbler were commonly observed in the dense brushy riparian habitat along the river. The lazuli bunting, mourning dove,

blue grosbeak, and robin were frequently observed in the cottonwood stands and nearby open shrub riparian habitat.

Very few waterbird species (i.e., waterfowl, wading birds, shorebirds) were observed near the Dolores River. The river does not provide nesting waterfowl habitat because there is a lack of brood rearing habitat especially with the summer drawdown of the river. Waterfowl winter along the river in very small numbers (BLM, 1980). The only water bird species recorded was the spotted sandpiper which may nest along the river.

The only species of raptor observed near the tailings sites was the kestrel. This species probably nests in the cottonwood stands along the river. An aerial (helicopter) survey for nesting raptors was conducted on April 10, 1986, by the U.S. Fish and Wildlife Service (USFWS) at the Slick Rock sites. Potential nesting habitats (primarily cliffs and cottonwoods along the river) were examined for breeding pairs of golden eagles, bald eagles, and larger falcons while the pinyon-juniper habitat surrounding the sites was searched for other nesting raptors such as Swainson's and ferruginous hawks. No nesting raptors were located during this survey (USFWS, 1987).

A total of 30 species of mammals have been observed or may occur at the Slick Rock sites (Table C.1.5). Fourteen of these species were observed on the sites or in nearby Disappointment Valley (Table C.1.5) (TAC, 1986, 1985; Pioneer, 1979). Fresh beaver sign (cuttings) were observed along the river in 1985 and 1986 within the dense riparian shrub habitat. The only large ungulate species observed near the UC and NC sites was the mule deer. The

Slick Rock sites are summer range for this species and its droppings were common in the Dolores River floodplain.

Borrow sites

Two borrow sites have been identified for possible use at the Slick Rock sites. The Dolores River borrow site is located on a terrace above the Dolores River. Part of the area is cleared pasture with a vegetative cover dominated by grass and herbs. The remainder of the borrow site is desert-shrub habitat similiar to that described above for the Slick Rock tailings sites. Wildlife that would occur at this borrow site are similiar to those described for the tailings sites, except that open ground nesting birds such as the meadowlark and horned lark would be more common.

The Disappointment Valley borrow site is located on relatively flat terrain about 4.5 miles east of the tailings sites. This site is located in desert shrub habitat where relatively low growing black greasewood (one to three feet high) was the dominant shrub species observed. Widely scattered fourwing saltbush, rabbitbrush, and big sagebrush were also noted. Grass was the dominant ground cover (mostly blue grama) along with scattered herbs. Wildlife indicative of upland shrub habitat occur at this borrow site. The horned lark, western meadowlark, vesper sparrow, and black-throated sparrow were the most common nesting bird species in the grassland and shrub habitats near the site (Pioneer, 1979).

Threatened and endangered species

The determination of threatened and endangered (T&E) species and other species of concern that may occur at the Slick Rock sites was accomplished through consultation with the USFWS, the Colorado Natural Areas Program, the Colorado Division of Wildlife, and the BLM. This process resulted in the identification of 13 species that may occur at the sites (Table C.1.6); six were Federally listed species, while seven were Federal candidate species. Seven of these 13 species are on the State of Colorado T&E species list.

Four of the 13 species listed on Table C.1.6 are fish species. Fish sampling in 1971 and more recently in 1981 failed to result in the capture of bonytail chub, humpback chub, Colorado squawfish, or razorback sucker in the Dolores River. Valdez et al. (1982) not only failed to capture any bonytail chub, humpback chub, or razorback sucker, they also found no records of these species being observed or captured in the Dolores River. The Colorado squawfish occurred historically in the Dolores River but was probably absent from the river by 1960 (Sigler et al., 1966). Valdez et al. (1982) indicated that Dolores River flow reductions due to irrigation, dominance of non-native fish species, and point-source pollution are the principal factors that have resulted in the elimination of T&E species from the Dolores River. Further, suitable habitat for these species does not occur near the Slick Rock sites due to the change in flow patterns.

The bald eagle is not known to nest along the Dolores River but does occur along the river during the winter. Winter use is very dispersed (BLM, 1980) and consists principally of diurnal feeding activities (Button, 1986). There are no known nocturnal roost sites along the river. The nearest

Table C.1.6 Threatened or endangered species and other species of concern that may occur at the Slick Rock sites, Slick Rock, Colorado

Species		Federal	Federal	State
Scientific name	Common name	listed	candidate	species
Gila elegans	bonytail chub	X		X
Gila cypha	humpback chub	X		X
Ptychocheilus lucius	Colorado squawfish	X		X
Haliaeetus leucocephalus	bald eagle	X		X
Falco peregrinus	peregrine falcon	X		X
Mustela nigripes	black-footed ferret	X		X
Xyrauchen texanus	razorback sucker		X	
Buteo regalis	ferruginous hawk		X	
Buteo swainsoni	Swainson's hawk		X	
Plegadis chihi	white-faced ibis		X	
Numenius americanus	long billed curlew		X	
Astragalus linifolius	Grand Junction milkvetch		X	X
Lupinus crassus	Paradox lupine		X	

Ref. Smith, 1986; CDOW, 1978; USFWS, 1978.

nocturnal roost to the Slick Rock sites is located approximately seven miles to the southeast along Disappointment Creek in Disappointment Valley. The roost site is located in a stand of large, old cottonwoods. The number of bald eagles which roost at this site is directly proportional to the severity of the winter with approximately 20 bald eagles recorded at one time during the mild winter of 1985-86 and over 70 during the more severe winter of 1984-85 (Button, 1986). One of the Disappointment Valley nocturnal roost sites is located approximately 1.5 miles south-southeast of the proposed Disappointment Valley borrow site.

Historically, the peregrine falcon nested in at least 27 locations in Colorado. By 1972, there were eight known nesting locations none of which produced any young. This drastic reduction was due to the widespread use of Dichloro Diphenyl Trichloroethane (DDT) (Scott, 1985). The peregrine falcon recovery program began in 1975; as of 1984, the total number of breeding territories had increased to 14 with 13 pairs successfully fledging young (CDOW, 1985).

One of the state's successful peregrine falcon breeding territories is located approximately eight air miles from the Slick Rock sites. In 1984, an adult male and immature female engaged in nesting behavior but did not lay eggs. Young were successfully fledged at this site in 1985 and 1986 (Button, 1986; Craig, 1986). Peregrine falcons have also been observed engaged in nesting behavior at another site which is also approximately eight air miles from the Slick Rock site. A pair occupied a territory in 1984 and produced infertile eggs. Nesting behavior was not observed in 1985 and 1986 although adult birds were in the area both years (Button, 1986; Craig, 1986).

The Slick Rock sites are within the historic range of the black-footed ferret (CDOW, 1978). Presently, the only known ferret population is in Wyoming (Clark et al., 1984). This species is closely associated with prairie dogs in that the prairie dog is the ferret's main food source and it uses prairie dog burrows for shelter and to raise its young (Hillman and Clark, 1980). For this reason, all prairie dog colonies are considered potential black-footed ferret habitat.

Prairie dog colonies do not occur at the tailings piles, the windblown and waterborne contaminated areas, or at the Dolores River borrow site. No prairie dog colonies were observed during a brief survey in the area of the Disappointment Valley borrow site. However, surveys near the proposed site indicate that the Gunnison prairie dog (Cynomys gunnisoni) is a common inhabitant of the grassland areas in Disappointment Valley (Pioneer, 1979). More detailed surveys for the prairie dog will be conducted in Disappointment Valley once the exact location of the borrow site is known.

The remaining six species on Table C.1.6 are Federal candidate species. The ferruginous and Swainson's hawks are two birds of prey that occur in semi-arid plains and intermountain areas of Colorado and other western states. These two species are frequently found in close association. Schmutz et al. (1980) found no evidence of ecological segregation between the species, while Thurow and White (1983) postulated that this association may be related to mutual nest defense behavior. Both species typically nest in junipers though the ferruginous hawk will nest on the ground or rock outcrops if tree nesting sites are not available (Schmutz, 1984; Perkins and Lindsey, 1983; Thurow and White, 1983; Smith and Murphy, 1982).

Natural resource personnel familiar with the Slick Rock sites have no records of either the ferruginous or Swainson's hawk nesting at or near the sites (Button, 1986). Further, ground surveys in the area failed to document the occurrence of either of these species (TAC, 1986, 1985; DOE, 1983; Pioneer, 1979). In addition, the USFWS conducted an aerial survey during the 1986 nesting season. Neither species nor nests indicative of these species were observed (USFWS, 1987). This analysis indicates that these two species of raptors did not nest at or near the sites in 1986. Further, it is doubtful that these species have occurred at the sites during recent years except for an occasional migrant.

The white-faced ibis is a medium-sized wading bird that nests in colonies scattered throughout the Great Basin and Rocky Mountain region (Armbruster, 1983). The colonies range in size from a few to several thousand and they are always associated with shallow water marshes. These marshes are typically dominated by tule (Scirpus sp.), and tule, cattail (Typha sp.), and reed are used as nesting substrate. Surveys along the Dolores River failed to locate this species. In addition, shallow water wetland habitat necessary for nesting does not occur at the Slick Rock sites. For these reasons, it is assumed that the white-faced ibis does not occur at or near the Slick Rock sites.

The long-billed curlew nests ". . . in arid grasslands and open brushy habitats in the western Great Plains and Great Basin" including much of Colorado (Armbruster, 1983). It nests in the shortgrass prairie regions of Colorado with the major concentrations occurring in eastern Colorado (McCallum and Graul, 1977). An estimated 15 hectares of short vegetation are required for each nesting pair (Armbruster, 1983). This information indicates that the

riparian habitat and the juniper-shrub habitat on the surrounding slopes in the Dolores River valley are not appropriate nesting habitat for this species. Appropriate habitat for this species may occur in the area of the Disappointment Valley borrow site. Surveys for this species may be necessary once the boundary of the borrow site is determined.

The Grand Junction milkvetch was originally described in 1928 and the type locality may have been in the Colorado National Monument area (USFWS, 1978). The species was rediscovered in the 1970s, 20 to 30 miles south of Grand Junction; another population was discovered in the early 1980s near Grand Junction (Anderson, 1985). All populations occurred on soil derived from the Morrison Formation. This formation outcrops on the steep slopes of the Dolores River canyon. The site features near the Dolores River are on alluvium (tailings pile and riparian zone windblown and waterborne contaminated areas), Quaternary terrace gravel (NC site upland contaminated areas and Dolores River borrow site), and pre-Summerville rocks (upland contamination near the UC site) (Foley et al., 1985). The Disappointment Valley borrow site occurs on Mancos Shale (Tweto, 1979).

The Paradox lupine was first described in 1915; the original collection was from Naturita (Payson, 1915). This species is known in six locations, all in Montrose County, Colorado (Peterson, 1983). The closest location to the Slick Rock sites was near East Paradox Creek about 15 miles to the north. This species occurs in draws and washes with sparse vegetation between 5000 and 5800 above mean sea level (MSL). In the Paradox Valley area, this species is " . . . found on Quaternary alluvium derived from the Chinle Formation" while in the Naturita area it occurs " . . . on clayey soils derived from the Mancos Shale Formation" (Peterson, 1983). Neither the Chinle nor Mancos Shale

Formations outcrop in the Dolores River Valley in the area of the tailings piles, windblown/waterborne contaminated areas, or the Dolores River borrow site. Therefore, the Paradox lupine would not be expected to grow at or near these areas. Mancos Shale derived soil covers the Disappointment Valley borrow site. Surveys for this species should be conducted at the Disappointment Valley borrow site, especially along the wash that traverses this area, once the exact location of the borrow site is known.

C.2 FLORA AND FAUNA: IMPACTS

C.2.1 INTRODUCTION

Remedial action would result in direct and indirect impacts to flora and fauna. Direct impacts would be the loss of wildlife habitat due to surface disturbances (e.g., cleanup of contaminated soils, haul road construction, and borrow activities), the destruction of less mobile wildlife such as small mammals and reptiles, and the displacement of larger mammals and birds from affected areas. In addition, displaced wildlife could be forced to compete with resident wildlife for habitat or to inhabit marginal habitat resulting in a reduced survivorship for the displaced wildlife. The severity and duration of these direct impacts would depend on the quality of the habitat to be affected and the type of reclamation. On a per-unit-area basis, direct impacts would be less severe in areas of low productivity such as the tailings piles and more severe in more productive areas such as the riparian habitat along the Dolores River. Another direct impact would be wildlife mortality along the haul roads between the borrow sites and disposal site and between the NC pile and disposal site.

Indirect impacts would result from the dust and noise created by the remedial action activities. The impacts of fugitive dust include reduced palatability of vegetation for wildlife and physiological stress on plants. In a site near Durango, Colorado, it was estimated

that fugitive dust emissions from dirt roads would preclude wildlife consumption of vegetation within 200 feet of the emission source and that this impact would cease at a distance of 1200 feet from the emission source (Hoover and Associates, 1984). The impacts of noise on wildlife vary from direct effects on hearing to indirect effects such as masking (the inability to hear important environmental cues) and loss of usable habitat. These effects can be compounded by the presence of humans, and the effects are often hard to separate. The impact of noise on wildlife is poorly understood, but many species seem to be capable of adjusting to relatively constant noise levels of up to 70 decibels (dBA) (DuFour, 1980); therefore, it was assumed that wildlife in areas of 70 dBA or greater would be adversely affected by remedial action.

C.2.2 PROPOSED ACTION

Stabilization of the tailings and other contaminated materials at the proposed disposal site would result in the clearing and disturbance of approximately 236 acres of land. Approximately 98 acres of upland habitat would be cleared in the tailings pile/mill/ore storage areas, while 96 acres of windblown/waterborne contaminated land within the Dolores River floodplain would be cleared. The remaining disturbed land would be in upland habitat and includes 11 acres at each of the borrow sites and 20 acres of off-site storage and use areas.

Of the three plant community types, the desert shrub habitat would be the largest type cleared (Table C.2.1). This habitat type occurs in

Table C.2.1 Number of acres in three plant community types to be cleared during remedial action at the Slick Rock sites, Slick Rock, Colorado

Site feature	Plant community type (in acres)							
	Disturbed areas (grass dominated)	Desert shrub	Riparian					
			Riparian shrub	Upper riparian grass	Upper riparian shrub	Cottonwood	Total riparian	Total
UC site[a]	24	42	19	50	4	9	82	148
NC site[a]	--	32	4	--	10	--	14	46
Dolores River borrow site	--	11	--	--	--	--	--	11
Disappointment Valley borrow site	--	11	--	--	--	--	--	11
Off-site use areas	--	20	--	--	--	--	--	20
Total	24	116	23	50	14	9	96	236
Percent	10%	49%	10%	21%	6%	4%	41%	100%

[a]Includes tailings piles.

small parcels at the various site locations with the largest segments occurring near the UC and NC sites. Both borrow sites are located in desert shrub habitat; the Dolores River borrow site is in sagebrush/rabbitbrush shrubland while the Disappointment Valley borrow site is in greasewood dominated shrublands.

The off-site use areas would be located directly adjacent to the UC (15 acres) and NC (five acres) sites. The exact location of these sites has not been determined, but they will most likely be in desert shrub habitat adjacent to these sites.

The remaining upland plant community type that would be impacted is the grass dominated disturbed sites such as the UC tailings pile and nearby disturbed land. This type comprises 10 percent of the land to be cleared.

The riparian plant community would be the second largest type to be cleared; 96 acres (41 percent) of the land is this type. The riparian zone of the Dolores River became contaminated by windblown or waterborne contamination from the tailings piles. In addition, a small section of riparian vegetation (approximately one acre) near the UC site became contaminated near the turn of the century from the operation of a radium mill.

The riparian plant communities are the most productive and diverse habitats in the arid southwest for vegetation and wildlife. The riparian vegetation along the Dolores River is a mosaic of habitat

types (see Figures C.1.1 and C.1.2) that differ from each other primarily due to different species and/or vertical configuration of the vegetation. At present, the major factors affecting the pattern of this mosaic appear to be elevation relative to the Dolores River and grazing. The upper riparian grassland type is the most abundant habitat within the contaminated area (50 acres). Part of this area had been irrigated for alfalfa; presently it is grazed. This type probably has the least diverse wildlife community due to its lack of vertical stratification of vegetation. The next most abundant type is the dense riparian shrub plant community. This type covers approximately 23 acres and occurs in the lowest lying areas next to the river. In terms of wildlife use, this area is quite productive and attracts species found only in riparian areas. The upper riparian shrub type covers approximately 14 acres in the contaminated areas. This type is dominated by shrubs from more upland areas (i.e., sagebrush and rabbitbrush), but riparian species such as willow occur in this area. Wildlife use of the type is probably less than the dense shrub and cottonwood riparian types but more than the upper riparian grassland habitat. Cottonwood dominated areas covering approximately nine acres in the contaminated zone represent the final riparian habitat type to be impacted. Three small stands of cottonwood ranging from 1.9 to 3.7 acres would be impacted. These stands are fairly old and reproduction was not observed. The lack of reproduction could be the result of grazing or lowered water table due to irrigation withdrawals upstream of Slick Rock. This cottonwood habitat is productive in terms of wildlife use.

The impacts on vegetation and wildlife due to clearing 236 acres of land would constitute an unavoidable impact. In terms of habitat quality, the least impact would occur in the disturbed areas due to the sparse vegetation. Wildlife use of these areas would be relatively light. Wildlife use of the desert shrub habitat would be greater than at the disturbed areas. In addition, this habitat type would be the largest type impacted. The loss of the riparian habitat would have a greater impact on wildlife than the other two habitat types. This type is much more productive than the surrounding upland types. For example, quantitative studies of breeding birds indicate that densities are three to 10 times higher in the riparian zone than the desert shrub habitat (Szaro and Jakle, 1985; Johnson and Carothers, 1978). Comparative studies of reptile use of riparian versus upland habitat are few. In one study, lizard density was highest along the shore of the Colorado River in the immature riparian zone, next highest in the mature riparian, and lowest in the desert-shrub habitat (Warren and Schwalbe, 1985). Observations at the Slick Rocks sites also indicate that mule deer use of the riparian zone was higher than the surrounding upland habitat (DOE, 1983).

The clearing of vegetation from the riparian zone and other habitats would reduce wildlife use to essentially zero. The duration of this impact would depend on the level of restoration efforts undertaken. Remedial action not only removes the vegetation but it also removes most, if not all, of the topsoil. This topsoil cannot be stockpiled (except at the two borrow sites) because it is contaminated and must be incorporated into the stabilized pile. Research has shown

that the rate of vegetation recovery on mine spoil varies widely depending on the restoration methods employed (Aldon, 1981; Wagner et al., 1978). The hypothetical maximum impact would involve no restoration (except recontouring) which would result in the recovery of the biotic community on land devoid of topsoil. In this case, primary succession (i.e., a sequence of plant communities developing in a newly exposed habitat devoid of life (Ricklefs, 1979)) would take place and recovery would take years. Studies of unreclaimed mine lands in Arizona determined that plant growth was very sparse in these areas 15 to 25 years after abandonment and consisted mostly of early successional species (Evans et al., 1978).

Recent revegetation work on mine spoil areas indicates that sagebrush/rabbitbrush habitats can be restored provided the ground is fertilized and the proper seed mixture is used. Protection from grazing is also helpful especially for the successful growth of rabbitbrush (Richardson et al., 1986).

Recent work in revegetating riparian habitats with pole plantings has proven successful (Swenson and Mullins, 1985; SCS, 1983). Dormant cuttings of species such as cottonwood and willow have been successfully established provided the cuttings extend into the ground water and beaver and livestock activities are controlled.

Prior to initiation of surface disturbance, the plan for restoration of excavated areas would be determined by the Remedial Action Contractor (RAC) and DOE in consultation with the appropriate

regulatory agency or other authority. In general, this plan would involve backfilling, recontouring, and revegetating. Impacts would be mitigated by scheduling restoration as soon as possible after completion of surface disturbing activities.

The impacts on game species at the Slick Rock sites are expected to be minimal. The mule deer is the major game species observed at the Slick Rock sites. Habitat features such as critical winter range do not occur on the sites. As indicated above, use of the riparian zone by mule deer tended to be higher than the surrounding upland habitats.

The analysis of T&E species indicated that wintering bald eagles occur sporadically along the Dolores River. However, remedial action activities would not have a direct impact on wintering bald eagles since the project would be shut down during the bald eagle wintering period. In addition, bald eagle use of the nocturnal roost site in Disappointment Valley would not be affected due to the same shut down. Winter bald eagle use of the Dolores River may be indirectly affected if cleanup of the contaminated riparian zone results in clearing all the large cottonwoods. These trees provide potential diurnal roost sites for eagles hunting in the area. This impact is expected to be minimal.

The peregrine falcon nests within eight to nine air miles of the Slick Rock sites. Remedial action activities would not have a direct impact on nesting peregrines; however, peregrine falcons may travel long distances from the eyrie to secure food. The Slick Rock sites are

located within the feeding range of nesting peregrine falcons, which has been estimated to be up to 10 miles (CDOW, 1978). In addition, preferred feeding areas are riparian habitat such as occur along the Dolores River at the Slick Rock sites (USFWS, 1984). Remedial action activities would probably preclude the use of the Dolores River riparian zone in the area of the tailings piles by peregrine falcons. These activities would take place for two nesting seasons and would constitute a short-term limited impact. Following remedial action, peregrine falcon use of the riparian zone near the piles would be reduced since there would be a reduced prey base as a result of clearing the vegetation. This impact would be relatively long term and its duration would depend on how long it takes for the riparian habitat to recover. Overall, the impacts on the peregrine falcon would be fairly minor. Remedial action would take place on the periphery of the hunting territory; presumably, numerous feeding areas for the nesting peregrine falcons are located elsewhere within the range of the eyrie.

Prairie dog towns and, thus, potential black-footed ferret habitat were not observed at the Slick Rock sites along the Dolores River. Prairie dogs are known to occur in Disappointment Valley. A survey for this species will be conducted when the Disappointment Valley borrow site is delineated.

An analysis of Federal candidate species indicates that none are likely to occur in the areas that would be impacted along the Dolores River. This analysis did indicate that two species (long-billed curlew and Paradox lupine) may occur in Disappointment Valley. Surveys for

these two species will be conducted if this area is used as a borrow site.

Another source of direct wildlife mortality could occur along the haul roads between the NC pile and between the borrow sites and the disposal site. Wildlife mortality is greatly reduced along roads that do not promote high-speed traffic such as haul roads (Lyon, 1984). The haul roads from the NC pile and Dolores River borrow site to the stabilized pile are relatively short and would not promote high speed traffic. Haul truck speeds from the Disappointment Valley borrow site to the stabilized pile would tend to be faster. The potential exists for game species (i.e., mule deer) and other wildlife mortality to occur along these haul roads.

The major indirect impact on wildlife would result from noise and human activity. The focus of this activity would be at the disposal site. Noise levels of 70 decibels or greater would occur in a zone extending approximately 1320 feet out from this site. The impact on wildlife northwest, north, and northeast of the pile would be minimal since the tailings piles and other contaminated areas occur in these directions. Desert shrub habitat occurs south of the stabilized pile and wildlife use in this area would be impacted. This impact would be relatively short term (for the life of the project) and would not occur during the winter shutdown. Clearing windblown/waterborne contaminated land would involve working near undisturbed habitat which would have an indirect impact on wildlife. However, this impact is expected to be relatively minor since the noise source is constantly moving as areas

are cleaned up. Work at the two borrow sites and NC pile would occur over five- and 10-month periods, respectively, and indirect impacts would be more substantial than in the windblown area. The NC and Dolores River borrow sites are located near the river and noise impacts have the potential of affecting additional riparian habitat. The 70-decibel noise levels would extend 1320 and 750 feet out from the NC and Dolores River borrow sites, respectively. This would have the potential of reducing wildlife use in a small amount of riparian habitat near the NC and the Dolores River borrow sites. These impacts would be short term, lasting only as long as remedial action activities continue in these two areas.

Noise impacts would occur at the Disappointment Valley borrow site for five months. The 70-decibel level would extend approximately 1000 feet out from the source. Wildlife habitat affected by noise impacts would be desert-shrub habitat similar to that which would be cleared at the borrow site.

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APPENDIX D

RADIATION

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D.1 RADIATION

This appendix addresses the increased radiation doses and health impacts to the general public and remedial action workers that might occur because of exposure to low levels of radiation from the tailings and the proposed remedial action at the Slick Rock tailings sites. The slightly increased doses can, in a statistical sense, increase the potential for individual and general public health effects (i.e., excess fatal cancers) above those naturally expected. Assumptions made during the calculations of excess health effects for the general public and remedial action workers are considered to be conservative.

D.1.1 BASIC FACTS ABOUT RADIATION AND ITS MEASUREMENT

Atoms that spontaneously transform, or decay, into new atoms are termed radioactive. The decaying atom is called the parent, and the atom produced by the transformation is called the daughter. The rate at which atoms decay is the radioactivity, measured by the unit curie (Ci). A more convenient unit for measuring the radioactivity of tailings piles is the picocurie (pCi), which is one-millionth of one-millionth (1×10^{-12}) of a curie. The half-life of a radioactive substance (i.e., radionuclide) is the time required for it to lose 50 percent of its radioactivity by decay. Each radionuclide has a unique half-life.

When atoms undergo radioactive decay, they emit radiation. The most common types of radiation are alpha particles, beta particles, and gamma rays. Alpha and beta radiation are tiny particles with excess energy, and gamma radiation is pure energy without mass. Radiation transmits energy to matter as it travels through matter. Alpha radiation penetrates only a few micrometers into matter, beta radiation penetrates a few centimeters, and gamma radiation, like X-rays, penetrates deeper into matter. Alpha radiation will not penetrate through a layer of dead skin, whereas gamma radiation can easily penetrate tissue and hence deliver a dose to any internal organ. However, alpha radiation, if inside the body, will deliver a larger dose to the immediate tissues since all of its energy will be deposited within a small volume.

The amount of radiation to which an individual is exposed may be expressed in terms of the amount of energy imparted to cells and tissues by the radiation and the degree of biological damage associated with the energy as it is absorbed. This absorbed energy is termed the absorbed dose and is given in units of rads, where one rad equals 100 ergs of energy absorbed per gram of material irradiated. When the irradiated material is living tissue, the damage per rad varies depending on the type of radiation. By mathematically applying a "quality factor" to each specific type of radiation, the degree of biological damage can be expressed independently of the type of radiation causing it. The biologically relevant absorbed energy is termed the dose equivalent, and the unit is the rem. One rad is equal to one rem for less damaging radiations where the quality factor is equal to one (e.g., gamma rays). For comparison, one rad of internal

alpha-deposited energy is equal to 20 rem because alpha particles are more damaging to tissue and the quality factor for alpha radiation is 20. The millirem equals one-thousandth (1×10^{-3}) of a rem and is in more common usage when expressing doses from environmental levels of radiation. When the radiation dose in rads is corrected by the quality factor to reflect the differences in tissue damage from the different types of radiation, then the value obtained in rems is called a dose equivalent. In addition, when the dose being calculated is from radioactive material deposited permanently in the body, total dose committed to the person's body over a lifetime is usually calculated. This is termed the dose equivalent commitment.

When a succession of radioactive parent atoms decay to radioactive daughter atoms, a radioactive decay series is formed. Uranium-238 (U-238) is such a radioactive parent atom and the U-238 decay series is shown in Figure D.1.1 (BRH, 1970; Lederer et al., 1967). The U-238 decay series includes thorium-230 (Th-230), radium-226 (Ra-226), radon-222 (radon or Rn-222), short-lived radon daughters, lead-210 (Pb-210) and polonium-210 (Po-210). The U-238 decay series ends with lead-206 (Pb-206), an atom that is stable and not radioactive. When the daughter products in a radioactive decay chain have shorter half-lives than the parent, the daughter radioactivities will increase, termed ingrowth, until they equal the radioactivity of the parent.

Radon is one of the radionuclides of primary importance to the UMTRA Project because it represents the largest radiation exposure pathway to the general public. The half-life of radon (3.8 days) is

Nuclide	Historical name	Half-life	Major radiation energies (MeV) and intensities†		
			α	β	γ
$^{238}_{92}U$	Uranium I	4.51×10^{9}y	4.15 (25%) 4.20 (75%)	---	---
$^{234}_{90}Th$	Uranium X_1	24.1d	---	0.103 (21%) 0.193 (79%)	0.063c‡ (3.5%) 0.093c (4%)
$^{234}_{91}Pa^{m}$	Uranium X_2	1.17m	---	2.29 (98%)	0.765 (0.30%) 1.001 (0.60%)
99.87% | 0.13%					
$^{234}_{91}Pa$	Uranium Z	6.75h	---	0.53 (66%) 1.13 (13%)	0.100 (50%) 0.70 (24%) 0.90 (70%)
$^{234}_{92}U$	Uranium II	2.47×10^{5}y	4.72 (28%) 4.77 (72%)	---	0.053 (0.2%)
$^{230}_{90}Th$	Ionium	8.0×10^{4}y	4.62 (24%) 4.68 (76%)	---	0.068 (0.6%) 0.142 (0.07%)
$^{226}_{88}Ra$	Radium	1602y	4.60 (6%) 4.78 (95%)	---	0.186 (4%)
$^{222}_{86}Rn$	Emanation Radon (Rn)	3.823d	5.49 (100%)	---	0.510 (0.07%)
$^{218}_{84}Po$	Radium A	3.05m	6.00 (~100%)	0.33 (~0.019%)	---
99.98% | 0.02%					
$^{214}_{82}Pb$	Radium B	26.8m	---	0.65 (50%) 0.71 (40%) 0.98 (6%)	0.295 (19%) 0.352 (36%)
$^{218}_{85}At$	Astatine	~2s	6.65 (6%) 6.70 (94%)	? (~0.1%)	---
$^{214}_{83}Bi$	Radium C	19.7m	5.45 (0.012%) 5.51 (0.008%)	1.0 (23%) 1.51 (40%) 3.26 (19%)	0.609 (47%) 1.120 (17%) 1.764 (17%)
99.98% | 0.02%					
$^{214}_{84}Po$	Radium C'	164μs	7.69 (100%)	---	0.799 (0.014%)
$^{210}_{81}Tl$	Radium C''	1.3m	---	1.3 (25%) 1.9 (56%) 2.3 (19%)	0.296 (80%) 0.795 (100%) 1.31 (21%)
$^{210}_{82}Pb$	Radium D	21y	3.72 (.000002%)	0.016 (85%) 0.061 (15%)	0.047 (4%)
$^{210}_{83}Bi$	Radium E	5.01d	4.65 (.00007%) 4.69 (.00005%)	1.161 (~100%)	---
~100% | .00013%					
$^{210}_{84}Po$	Radium F	138.4d	5.305 (100%)	---	0.803 (0.0011%)
$^{206}_{81}Tl$	Radium E''	4.19m	---	1.571 (100%)	---
$^{206}_{82}Pb$	Radium G	Stable	---	---	---

FIGURE D.1.1 URANIUM-238 DECAY SERIES

short relative to the half-life of Ra-226 (1602 years). As Ra-226 decays, the newly produced radon will begin to decay, and the radon radioactivity will become equal to the Ra-226 radioactivity within 30 days. Similarly, the short-lived radon daughter radioactivities will ingrow within four hours to equal the radioactivity of radon and Ra-226. When the radioactivities of the parent and its daughters are equal, the daughters are said to be in 100 percent equilibrium or simply in equilibrium. If the daughters are diluted or carried away in the air as they are formed, they will not reach 100 percent equilibrium.

The only member of the U-238 decay series that is not a solid is radon. Radon is an inert gas and does not react chemically with other elements; it therefore can diffuse out of matter and into the atmosphere. The atmospheric radon concentration is measured in units of picocurie per liter (pCi/l). In the uranium milling process, Ra-226, the parent of radon, is left in the tailings, which then becomes a source from which radon diffuses into the atmosphere. Once in the atmosphere, radon is transported downwind and decays into the short-lived radon daughters which can attach to particulates in the air. Since radon is an inert gas, it is inhaled and exhaled, contributing very little radiation exposure to the lung. The radon daughters are solids, however, and once inhaled can deposit in or attach to the lung and then decay, transmitting alpha energy in the lung. Because of the short half-life, these daughters may decay before being removed from the lung.

Human exposure to radiation originates from both natural and man-made sources. The major natural sources of radiation are from cosmic and terrestrial origins and from naturally occurring radionuclides which are deposited inside the body via the ingestion and inhalation pathways. Since trace amounts of U-238 a found everywhere on the earth, radon and its short-lived daughters contribute to the natural background radiation exposure to the general public. All natural sources of radiation contribute approximately 51 percent of man's total exposure (Shleien and Terpilak, 1984).

Exposure to man-made sources results primarily from medical exposures (e.g., diagnostic X-rays) which contribute approximately 45 percent to man's total radiation exposure. Other man-made contributors, including airline travel, atmospheric weapons tests, the nuclear industry, and consumer and industrial products together account for approximately four percent of man's total exposure.

D.2 METHOD OF ANALYSIS

Radiation and its associated health effects have been studied more thoroughly than health effects from other carcinogenic agents. The evaluation of health effects caused by low-level radiation is, however, a difficult task, and many uncertainties are associated with the estimation of risks from low-level radiation. The traditional approach for estimating risks from low-level radiation exposures is to extrapolate from effects observed at high radiation exposures using the linear dose response and no threshold assumptions.

There are five principal pathways which could potentially result in exposure of man to radiation from the tailings pile. These are: (1) inhalation of radon daughters; (2) direct exposure to gamma radiation emitted from the contaminated area; (3) inhalation and ingestion of airborne radioactive particulates; (4) ingestion of ground and surface waters contaminated with radioactive materials; and (5) ingestion of contaminated foodstuffs produced in areas contaminated by tailings. In addition, exposure is possible after a transportation accident involving spillage of tailings.

For detailed calculations of health effects in this appendix, only the most significant radiation exposure pathways are considered; these are inhalation of radon daughters, and direct exposure to gamma radiation. Analyses of radiation health effects from air particulates at other UMTRA Project sites and at active uranium mill tailings sites in the vicinity of Slick Rock indicate that this pathway would result in excess health effects

orders of magnitude less than those from inhalation of radon daughters (DOE, 1987, 1986; Millard and Baggett, 1984). The water ingestion pathway has also been shown to be a relatively insignificant cause of excess health effects (DOE, 1986, 1985a,b). This is expected to be the case at the Slick Rock sites since the alluvial aquifer contaminated by the tailings is not used as a source of drinking water or for agricultural purposes (see Section B.2 in Appendix B, Hydrology, for more details). Chemical analyses of ground-water samples obtained from wells completed within the Navajo Sandstone indicate milling-related contamination has not affected this usable aquifer. For these reasons, the air particulate inhalation and drinking water ingestion pathways are not considered further in this appendix. Contaminated material may be entering the food ingestion pathway since livestock graze in areas contaminated by windblown tailings, and may also have consumed potentially contaminated water from the Dolores River. Consumption of contaminated livestock as a sole source of meat has been shown to be potentially hazardous (Lapham et al., 1985). However, at the present time no consumption of potentially contaminated livestock as a sole source of food occurs. The magnitude of radiation exposure and subsequent health effects to the general public associated with the spill of tailings during a transportation accident would be minimal (DOE, 1984). The cleanup of the spill would be completed promptly and exposure to the remedial action workers would be small. Therefore, this exposure pathway is not addressed further in this document.

When risk estimates were calculated for the various remedial action alternatives, the following means of rounding significant figures was used to facilitate comparison of the alternatives. Any estimates that were used in further calculations, such as summations of risk, were rounded to two

significant figures. Final estimates, such as total risk estimates, were rounded to one significant figure.

Health risk estimates in this appendix make use of recommendations published in scientific reports and journals (NCRP, 1984; Evans et al., 1981; Evans, 1980; NAS, 1980; ICRP, 1977; UNSCEAR, 1977).

Quantitative risk estimation of somatic effects (e.g., cancer) for various organs of the body can be obtained using available human radiation exposure data. The manifestation of a cancer caused by radiation exposure would occur after a latent period of up to 25 years or more, depending on the type of cancer and the age of the person exposed. The risks from radiation vary with adult age and sex but are presented here as average values assuming that the variation due to adult age and sex is small. No data are available that indicate whether risk estimates for adults are appropriate for radiation exposure during childhood.

D.2.1 HEALTH EFFECTS OF EXPOSURE TO RADON DAUGHTERS

The health effects of radon diffusion from tailings arise from inhalation of the short-lived radon daughters which deposit alpha energy in the lung. For radiation protection purposes, the International Commission on Radiological Protection (ICRP, 1977) proposed an individual lung cancer risk factor of 20×10^{-6} per rem, or 20 excess fatal cancers where one million individuals each receive a one-rem lung dose equivalent commitment.

Health effects from radon daughter inhalation can also be expressed as excess risk of lung cancer based on the collective lung dose equivalent commitment in person-working-level months (person-WLM). The unit of working level (WL) is defined as any combination of short-lived radon daughters in one liter of air which, on complete decay, gives a total emission of 1.3×10^5 million electron volts of alpha radiation. One WL is equivalent to 100 pCi of radon per liter of air with the short-lived radon daughters in 100 percent equilibrium. At equilibrium levels less than 100 percent, the WL corresponding to a given radon concentration is reduced. The working-level month (WLM) is a unit defined as the exposure resulting from the inhalation of air with a concentration of one WL of radon daughters for 170 working hours. The total dose of one or more persons is the product of the number of persons and the average dose they receive; the unit for the measurement of such a population dose is the person-WLM.

Following are estimates of excess lung cancers given in terms of person-WLM. The United Nations Scientific Committee on the Effects of Atomic Radiation utilized a range of 200 to 450×10^{-6} lung cancers per person-WLM (UNSCEAR, 1977), the NRC in its environmental impact statement on uranium milling used 360×10^{-6} fatal cancers per person-WLM (NRC, 1980a), the BEIR-III report (NAS, 1980) indicated 850×10^{-6} lung cancers per person-WLM, and EPA used 760×10^{-6} lung cancers per person-WLM (EPA, 1984). The ICRP (1981) has adopted 150 to 450×10^{-6} as the risk of lung cancer per person-WLM. Evans et al. (1981) reviewed the BEIR-III study, lung cancer risk estimates published by other authors, and epidemiological evidence. They concluded that the most defensible upper bound to the lifetime lung

cancer risk for the general public is 100 x 10^{-6} lung cancers per person-WLM. Table D.2.1 presents these and other risk factors. A risk factor of 300 x 10^{-6} deaths per person-WLM is used in this appendix for calculating health effects due to exposure to radon daughters. This risk factor is close to an average of all risk factors reported in the literature and provides the consistency needed to compare alternatives in terms of health effects.

Table D.2.1 Lifetime risk factors for excess lung cancers reported in the literature

Source	Lung cancer per person-WLM x 10^{-6}
Evans et al. (1981)	100
NCRP (1984)	130
ICRP (1977)	150--450
UNSCEAR (1977)	200--450
NRC (1980a)	360
AECB (1980)	600
EPA (1984)	760
BEIR-III (NAS, 1980)	850

D.2.2 HEALTH EFFECTS OF EXPOSURE TO GAMMA RADIATION

Tailings piles emit gamma radiation that delivers an external exposure to the whole body of a person near the pile. The BEIR-III report contains several models for estimating cancer risk resulting from exposure to gamma radiation. Health effects estimates in this appendix for excess cancers due to gamma radiation use a risk factor of

120×10^{-6} cancers per person-rem (NAS, 1980; Cohen, 1981). This is equivalent to 120 excess cancers in an exposed population for each 1,000,000 person-rems of collective dose equivalent. A person-rem is the product of the radiation dose equivalent multiplied by the number of people receiving that dose.

For gamma radiation, one rem is approximately equal to one roentgen (R) which is the unit for measuring gamma radiation exposure in air. A microroentgen (microR) is 1×10^{-6} R, and typical environmental gamma radiation levels are expressed in microR per hour (microR/hr).

The health effects attributed to a gamma radiation dose are categorized into two general types: somatic and genetic. Somatic effects are manifested in the exposed individual (e.g., cancer) and genetic effects are manifested in the descendants of the exposed individual. The ICRP (1977) reported that the average risk estimated for genetic effects, as expressed in the first two generations and considered genetically significant, is 40×10^{-6} per rem. For all subsequent generations, the risk is estimated to be equal to that expressed in the first two generations. The total genetic risk (all generations) is, therefore, 80×10^{-6} per rem. Measures taken to reduce the somatic effects would also reduce the genetic effects. Calculations in this appendix reflect only the somatic risk, which is expected to be greater than the genetic risk.

D.3 CALCULATIONS OF HEALTH EFFECTS

The computation of excess health effects begins by determining the additional amount of radiation that a tailings site contributes to an area. Only this additional amount is used to estimate excess health effects. At Slick Rock, which has two separate tailings sites, radiation induced health effects from each site were summed and reported as total excess health effects in the following sections. For each radiation type, there is a risk factor that associates a health effect with a specific amount of that radiation (e.g., rem). Multiplying the additional amount of radiation in an area, the time spent in that area, the number of people in that area, and the risk factor for the radiation type of concern gives the estimated number of excess health effects that might occur in the people being exposed to the additional radiation. This estimated number of excess health effects is the number of cancers that might occur due only to the radiation from the tailings.

D.3.1 STABILIZATION ON SITE

General public health effects from radon daughter exposure

The population distribution within a four-mile radius of the Slick Rock sites was used as a basis to calculate the excess health effects to the general public during stabilization on site. There are currently 23 people living within a 1.6-mile radius of the UC and the NC tailings sites (Stockings, 1987). A total of four people work at the

gas sweetener plant. Three of these individuals live at the trailer park near the UC site while the fourth person commutes to the plant. For the purposes of health effects calculations, it was assumed that this fourth person lived full time within 0.3 mile of the UC site. Therefore, the total population used for the health effects calculations was 24 (Table D.3.1).

To develop the radon source term for the existing tailings sites and the disposal site during the proposed action, the radon flux was calculated for each site area using the RAECO model (NRC, 1984) assuming that no cover exists on the tailings and other contaminated materials. Table D.3.2 presents the volumes, Ra-226 concentrations, and radon source terms for the contaminated areas at the UC and NC sites (Figure D.3.1). Total volumes of contaminated materials include excess volumes resulting from the unavoidable excavation of soils with Ra-226 concentrations less than 5 pCi/g. However, excess volumes were not included in determining the average Ra-226 concentrations presented in Table D.3.2 and subsequent radon flux calculations. Since average Ra-226 concentrations are expected to decrease when excess volumes are included, this was considered to be a conservative assumption. The area-weighted average flux across the UC site is 12.9 picocuries per square meter per second (pCi/m^2s) and is 67.8 pCi/m^2s for the NC site.

The principal feature of the proposed action is the removal of all tailings and associated contaminated material out of the Dolores River floodplain. The material would be placed on the escarpment immediately

Table D.3.1 Population distribution at the UC and NC sites, Slick Rock, Colorado

Site	Direction	Distance from tailings site center (miles) 0–0.3	0.3–0.5	0.5–1.0	1.0–1.6
UC	SW	18			
	SSE		1		
	ESE		3		
	SE				2
NC	W		3		18
	WSW			1	
	SSE			2	

Table D.3.2 Volumes and radium–226 concentrations of contaminated materials at the Slick Rock sites, Slick Rock, Colorado

Source of material	Contaminated area (acres)	Average depth (feet)	Total[c] contaminated volume (cy)	Average[d] Ra–226 concentration (pCi/g)	Radon source term (Ci/y)
Union Carbide site					243
tailings pile/ subpile[a]	17.0	13.8	380,000	126	
mill yard/ore storage	30.7	1.2	54,300	50	
Curie's area[b]	1.5	2.2	5,900	222	
ponds	10.6	1.0	17,800	15	
windblown/waterborne	88.2	0.8	107,100	30	
Subtotal	148.0		565,100		
North Continent site					402
entire site	46.4	1.3	97,000	261	
Total	194.4		662,100		645

[a]Includes 344,000 cy of tailings and 36,000 cy of contaminated subpile materials.

[b]This area is the site of a former radium processing mill operated by Madame Curie at the turn of the century.

[c]Total contaminated volumes include excess volumes resulting from the excavation of soils with Ra–226 concentrations less than 5 pCi/g.

[d]Average Ra–226 concentrations do not include excess soils at 5 pCi/g. Actual Ra–226 concentrations are expected to be lower due to dilution of contaminated materials with excess soils.

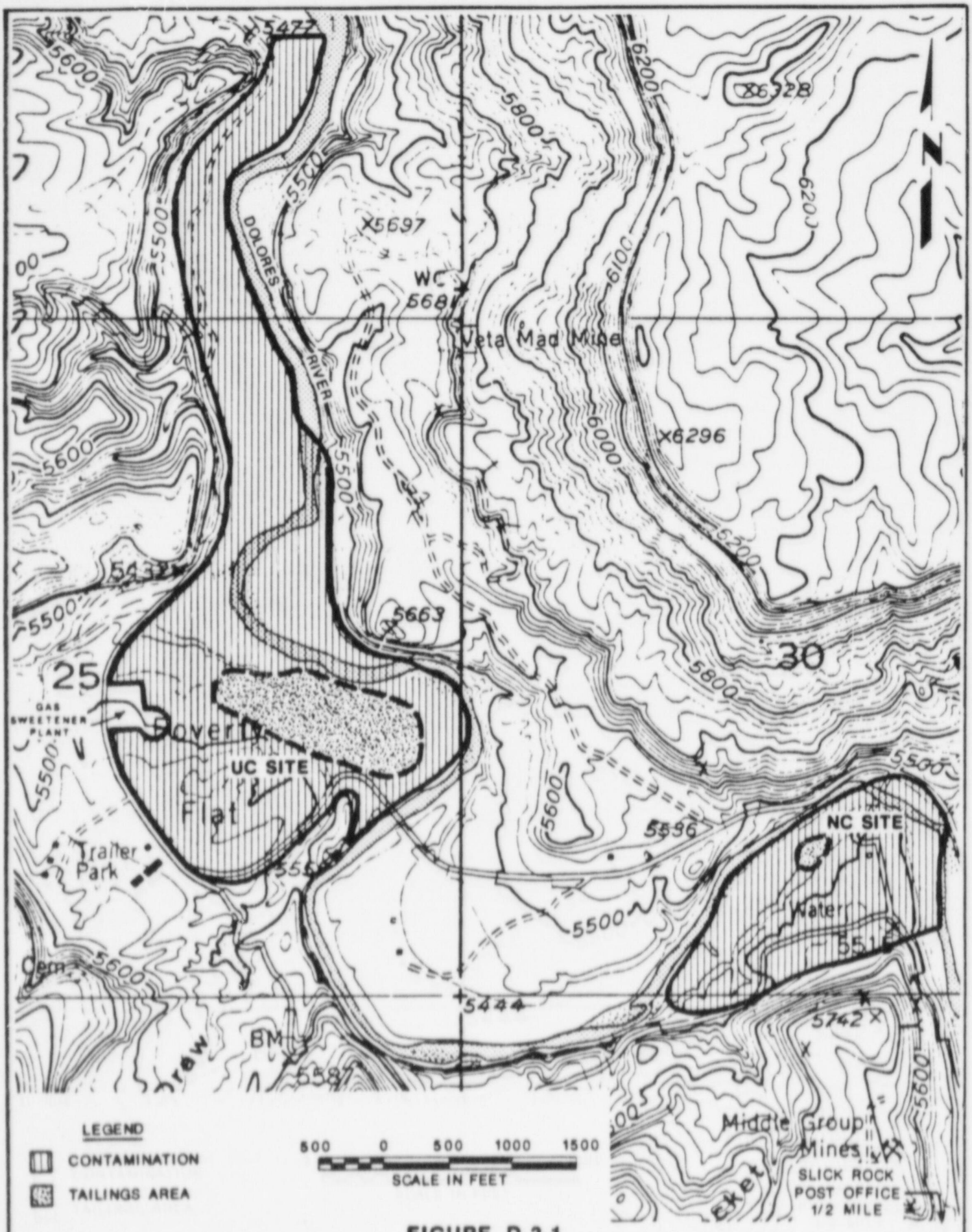

FIGURE D.3.1

AREAL EXTENT OF Ra-226 SOIL CONCENTRATIONS EXCEEDING 5 pCi/g AT SLICK ROCK TAILINGS SITES, SLICK ROCK, COLORADO

south of the UC pile's present location and would be out of the Probable Maximum Flood (PMF) floodplain. The final stabilized pile would be layered from bottom to top as follows: all contaminated material from the NC site, tailings from the UC pile, all other contaminated material, radon barrier, and erosion protection. The final stabilized pile would cover an area of 13 acres.

Remedial action at the Slick Rock sites is expected to take 17 months, and exposure and disturbance of the tailings would occur for approximately 11 months. Radon flux would increase during disturbance of the tailings and other contaminated materials due to the release of radon that was trapped in soil interstitial pore spaces. It was assumed that the tailings and contaminated off-pile material at each site would be handled and moved one time during remedial action and that all the radon in the pore spaces would be released to the atmosphere when the materials were moved. At each site this release was calculated as a total instantaneous release. This release was then added to the "as is" flux calculated by RAECOM. The site radon source term was calculated by summing the separate source terms.

Using the UC tailings pile Ra-226 concentration of 126 picocuries per gram (pCi/g) (Table D.3.2), an emanation fraction of 0.19, a tailings and subpile contaminated materials volume of 380,000 cy, a tailings density of 1.5 grams per cubic centimeter (g/cm^3), and a conversion factor of 7.64×10^5 cubic centimeters per cubic yard (cm^3/cy), the total number of curies of radon to be released from the UC tailings pile pore spaces during remedial action was calculated as follows:

$(380{,}000\ cy)(126\ pCi/g)(1.5\ g/cm^3)(0.19)(7.64 \times 10^5\ cm^3/cy)$
$(10^{-12}\ pCi/Ci) = 10.4\ Ci.$

The off-pile materials at the UC site include the mill yard/ore storage area, the former pond area in the northeast corner of the site, and all windblown and waterborne contamination (BFEC, 1986). The off-pile contamination also includes a small area (1.5 acres) that was a site of one of Madame Curie's radium mills that was operated around the turn of the century. This site is within the UC designated site boundary and approximately 0.5 mile southeast of the UC tailings pile. To calculate the radon released from the UC off-pile contamination, it was assumed that 100 percent of the off-pile contamination would be handled and moved and that all radon would be released from the tailings pore spaces. Using an off-pile, volume-weighted Ra-226 concentration of 40 pCi/g, an emanation fraction of 0.45, an off-pile tailings volume of 185,100 cy, and a soil density of 1.6 g/cm^3, the total number of curies of radon released from UC off-pile material was calculated as follows:

$(185{,}100\ cy)(40\ pCi/g)(1.6\ g/cm^3)(0.45)(7.64 \times 10^5\ cm^3/cy)$
$(10^{-12}\ pCi/Ci) = 4.1\ Ci.$

A similar calculation was performed for the NC site (includes pile and off-pile materials) and yielded the following:

$(97{,}000\ cy)(261\ pCi/g)(1.5\ g/cm^3)(0.42)(7.64 \times 10^5\ cm^3/cy)$
$(10^{-12}\ pCi/Ci) = 12.2\ Ci.$

The radon concentration at the disposal site is contributed to by the flux from the contaminated materials presently at the UC site, by the flux from materials from the NC site being moved to the UC site, and by the flux from the NC materials at the NC site. It was assumed in the following calculations that the radon flux from the NC materials at the NC site is negligible compared to the other radon sources.

The radon flux from the UC materials can be estimated from the RAECOM determined site flux plus the pore-space flux:

$$(243 \text{ Ci}/12 \text{ mos} \times 11 \text{ mos}) + 10.4 \text{ Ci} + 4.1 \text{ Ci} = 237 \text{ Ci}$$

It was assumed that the NC site material would be excavated at a uniform rate, and therefore the area of contamination would decrease linearly from 46.4 acres (188,000 m^2) to zero during the 11-month disturbance period. Since the NC material has a radon flux of 67.8 pCi/m^2s, this contribution to the total source term can be estimated by integrating over time (t) as follows:

$$67.8 \text{ pCi}/\text{m}^2\text{s} \left[\left(\int_0^{2.891 \times 10^7} \frac{188{,}000 \text{ m}^2}{} - \frac{188{,}000 \text{ m}^2}{2.891 \times 10^7 \text{ s}} \, t \, dt \right) \right] \left(\frac{\text{Ci}}{10^{12} \text{ pCi}} \right) = 185 \text{ Ci}$$

It will be assumed that one-half of the pore space release estimated for the NC material (6.1 Ci) will contribute to the UC site source term.

The total radon source term for stabilization on site is the sum of 237 + 185 + 6.1 which equals (428 Ci), or 45 pCi/m^2s. During remedial action, the flux would actually be less than 428 Ci per 11 months as the more highly contaminated material is being continually covered by lesser contaminated material and then cover material. Noting the high conservatism, however, the following health effects are calculated assuming that the radon flux remains at 428 Ci per 11 months over an average exposed area of 80.5 acres. Similar calculations for the NC site resulted in 191 Ci radon released per 11 months over an average exposed area of 23.2 acres or an average NC site flux of 70 pCi/m^2s.

The radon concentration on the disposal site was determined by summing the radon concentrations from the tailings pile, ponds, mill yard/ore storage area, and the NC material at the UC site. An average wind velocity of 3.5 meters per second was used. This value was calculated by weighting each wind speed by its frequency of occurrence. Area radii of 150 meters for the UC tailings pile, 117 meters for the UC ponds, 200 meters for the mill yard/ore storage, 44 meters for Curie's area, 340 meters for the waterborne/windblown area, and 130 meters for the NC material at the UC site were used in each determination of radon concentration.

The area geometries were assumed to be circular. The radon concentration at the center of each circular area was estimated by calculating the concentration for each of the six standard stability classes, weighting each by the frequency of occurrence, and summing the weighted values. The concentration at the area center for each

stability class was calculated by integrating the functional form of sigma Z as a function of distance from the site center back to the site edge, ignoring crosswind dispersion. This is similar to assuming that the center of the area is always at the edge of an infinite strip of area source, with the width equal to the area radius. The average radon concentration at the center of the site was calculated to be 3.4 pCi/l during remedial action.

To estimate the radon concentrations and working levels downwind from the UC tailings site, annual average radon concentrations and working levels as a function of distance from the UC and NC sites were calculated using a sector-average form of the Gaussian diffusion equation (Turner, 1969) and a calculation of the ingrowth of radon daughters as a function of time (Evans, 1980). An area source of 80.5 acres (average exposed area over the 11-month remedial action period at the UC site) was treated as a point source which was assumed to be located at the site center with a source strength of 467 Ci per year (428 Ci per 11 months). The calculated radon concentration is a function of wind speed and stability class for distance downwind in a given direction. A conservative distribution of wind speed and stability class was assumed that would result in maximized radon and radon daughters concentrations downwind from the site for a sector. This bi-variate joint frequency distribution was then used to time-weight the radon concentration calculated at a given downwind distance according to the percent of the time that each wind speed and stability class pair occurs. Similarly, the percent ingrowth of radon daughters at a given downwind distance was calculated based on the transit time of the radon from the area source center. The working

levels at varying distances from the site are dependent on the percent ingrowth of radon daughters. Between a transit time of one and 40 minutes, the working level grown into 100 pCi/l of radon can be represented within plus or minus five percent by the following approximate analytical expression (Evans, 1980):

Equation D.3.1

$$WL = 0.023\ T^{0.85}$$

where:

WL = working level.
T = transit time in minutes.

The use of the sector-average model, with the area source replaced by a point source, tends to overpredict the radon concentrations at distances close to the source. At distances greater than several source diameters from the edge of the source, the model is reasonably accurate; however, overprediction can be up to a factor of two at distances less than several source diameters. To estimate radon concentrations within this overprediction area, interpolation was performed on a log-log basis between the previously calculated on-pile radon concentration (3.4 pCi/l) and the modeled radon concentrations beyond one mile of the site edge. Similarly, the working level exposures within one mile of the site were determined by extrapolating on a semilogarithmic basis from the modeled working levels beyond this distance.

The percent ingrowth formula (Equation D.3.1) used to derive working levels assumes that no daughter products are removed from the air by plate-out. Plate-out occurs when the electrically charged radon daughters attach to surfaces and are removed from the air, thereby reducing the percent equilibrium of radon daughters in the air inhaled. To account for plate-out in health effects calculations for outdoor conditions, the working level was assumed to be one-half of that calculated from the ingrowth formula; that is, 50 percent plate-out was assumed. A 50 percent equilibrium factor for radon daughters was also assumed for indoor working levels. This is applied in Equation D.3.2 to both outdoor and indoor inhalation. It was assumed that people spend 75 percent of their time in the immediate vicinity of their residences (25 percent outdoors and 50 percent indoors) and 25 percent of their time beyond a distance from the site where radon daughter health effects are negligible. Also, health effects were estimated for the four workers at the gas sweetener plant. These workers were modeled as though they were part of the general population 0.3 mile southwest of the UC site even though one of those workers does not reside in the local area. Working levels obtained for each distance were converted to working level-months using the following equation:

Equation D.3.2

$$WLM(r) = \left[\left(\frac{R(r)}{100} \times I\right) + (WL(r) \times O)\right] \left[\frac{H}{(170 \text{ hours/WLM})} \times T\right]$$

where

WLM(r) = working level months at distance r.

R(r) = radon concentration at distance r (pCi/l).

I = fraction of time spent indoors multiplied by the radon daughter equilibrium factor (0.5 x 0.5).

WL(r) = working level at distance r.

O = fraction of time spent outdoors multiplied by the radon daughter plate-out factor (0.25 x 0.5).

H = hours per year (8760 hours).

T = duration of exposure (years).

The results of the above calculations are presented in Table D.3.3. The excess health effects were calculated by multiplying the working level months by the population at each distance in a given sector and by the conversion factor of 300×10^{-6} excess health effects per person-WLM. The excess health effects were then summed over the distances and sectors. Radon and working level contributions from the UC and NC tailings sites were summed to give an estimate of the total excess health effects to the exposed population of 24 persons.

The estimated number of excess radon daughter health effects due to the 11-month tailings disturbance for the general public within 1.6 miles of the UC and NC sites was calculated to be 0.000046 or one chance in 22,000 (Table D.3.3).

Table D.3.3 Radon daughter health effects to the general public during remedial action[a]

Distance from center of UC tailings pile	Population	Modeled outdoor radon concentration (pCi/l)	Modeled outdoor WL x 10^{-5}	Calculated WLM x 10^{-3}	Excess health effects x 10^{-5}
0.3	18	0.038	5.0	4.8	2.6
0.4	1	0.066	8.6	8.3	0.3
0.5	3	0.131	19.5	16.6	1.5
1.6	2	0.025	12.3	3.7	0.2
Total	24				4.6

[a]Table values include contributions from the UC and NC sites.

General public health effects from gamma exposure

The estimated population distribution (Table D.3.1) and an aerial radiological survey report (EG&G, 1982) were used to calculate the excess health effects to the general public from gamma exposure.

An aerial radiological survey was flown in September, 1981, over a 3.5-square mile area surrounding the Slick Rock sites. The highest radiation levels (normalized to three feet above the ground) were 55 microR/hr over the UC tailings pile and 400 microR/hr over the NC site (EG&G, 1982). These radiation levels were higher than background levels due to Ra-226 and Th-232. Average background levels in the area ranged from 10 to 20 microR/hr. For the purposes of health effects calculations, it was assumed that 18 people lived within 0.3 mile of the UC site. The gamma radiation levels within this distance range

from 14 to 35 microR/hr (EG&G, 1982). The excess health effects to the 18 people who live or work near the UC tailings pile were estimated assuming an increased (above background) exposure rate of 15 microR/hr. Input parameters and health effect results due to the 11-month disturbance period are shown in Table D.3.4. Since the individuals are assumed to spend 75 percent of their time at home, the period of exposure is 0.75 x 11 months or 6023 hours. Using the risk factor presented in Section D.2.2, the number of excess health effects due to gamma radiation for 18 members of the general public who live within 0.3 mile of the UC tailings site is estimated to be 0.00020 or one chance in 5000. No excess health effects due to gamma radiation are attributable to the NC pile since no one lives within the area of elevated radiation levels.

Table D.3.4 General public health effects from gamma exposure during remedial action

Distance from center of UC tailings pile (mile)	Population	Individual hours exposed	Excess gamma exposure rate (microR/hr)	Excess health effects
0.3	18	6023	15	0.00020

The total estimated excess health effects to the general public during stabilization on site from radon daughter inhalation and gamma radiation are 0.0003 or one chance in 3300.

Remedial action worker health effects from radon daughters exposure

The radon concentration during remedial action was calculated to be 3.4 pCi/l at the Slick Rock UC designated site. This concentration leads to a conservative estimate of excess health effects from radon daughter exposure since the concentration in any individual area would be less than the sum-total concentration for the Slick Rock UC site.

An average of approximately 58 workers would be required during the 17-month remedial action process. To estimate an upper bound for excess health effects to remedial action workers, it was assumed that each worker would spend eight hours per day, 15 days per month, over 11 months (1320 hours) at the UC designated site (workers would be exposed to radiation for 11 of the 17 months). Each worker would be exposed to a radon concentration of 3.4 pCi/l as calculated previously for the 11-month period of tailings disturbance. (The estimated average radon concentration at the NC site is 1.7 pCi/l.) The radon daughters percent equilibrium on the pile was conservatively assumed to be 20 percent based on percent equilibrium measurements made near the Grand Junction, Colorado, uranium mill tailings pile (Borak and Inkret, 1983). The estimated excess health effects due to radon daughter exposure to workers during the remedial action period (11 months) at the disposal site are 0.00092 (one chance in 1100).

Additional conservatism was applied by assuming that the workers at the NC site are exposed to the same radon concentration as the UC site workers.

Remedial action worker health effects from gamma exposure

The greatest exposure rate from the two tailings piles (400 microR/hr at the NC pile) was used to calculate the excess health effects to remedial action workers from gamma exposure. The exposure rate at the disposal site would be reduced by a factor of 10 for each foot of radon cover material. Also, the majority of workers would be enclosed in cabs of earthmoving equipment which would provide shielding. Thus, the maximum exposure rate of 400 microR/hr would be reduced to approximately 40 microR/hr. Based on 40 microR/hr, the external gamma radiation exposure that a worker could be expected to receive from working 1320 hours over an 11-month period would be 0.05 rem which is within the standard limit of five rem per year for occupational exposure (NRC, 1980b). For 58 remedial action workers, the estimated excess health effects due to gamma radiation are 0.00037 (one chance in 2700).

The total estimated excess health effects to remedial action workers during stabilization on site from radon daughter inhalation and gamma radiation are 0.001 (one chance in 1000).

Structures on the UC and NC sites

The areas occupied by the gas sweetener plant and trailers near the UC site were surveyed and found to be free of Ra-226 and Th-230 contamination. No structures presently exist at or adjacent to the NC site.

D.3.2 NO ACTION

General public health effects from radon daughter exposure

The annual average radon flux was calculated to be 12.9 pCi/m^2s at the UC site and 67.8 pCi/m^2s at the NC site or approximately 243 and 402 Ci/yr, respectively. The total site source terms are different from those for stabilization on site due to movement of contaminated materials from the NC site to the UC site. The downwind radon concentrations at each site were determined using the long-term sector average model described in Section D.3.1. Table D.3.5 provides the predicted radon concentrations and working levels as a function of distance from the UC tailings pile center. These radon concentrations and working levels include contributions from both sites.

Table D.3.5 Radon daughter health effects to the general public per year for the no action alternative[a]

Distance from center of UC tailings pile (miles)	Population	Modeled outdoor radon concentration (pCi/l)	Modeled outdoor working level x 10^{-5}	Calculated annual WLM x 10^{-3}	Excess health effects per year x 10^{-5}
0.3	18	0.028	5.9	4.0	2.2
0.4	1	0.041	6.4	5.7	0.2
0.5	3	0.106	14.8	14.6	1.3
1.6	2	0.022	9.9	3.5	0.2
Total	24				3.9

[a]Table values include contributions from the UC and NC sites

Equations D.3.1 and D.3.2 were applied to determine excess radon daughter health effects to the general public within 1.6 miles of the UC and NC tailings piles and resulted in an estimated 0.000039 (one chance in 26,000) excess health effects per year (Table D.3.5).

General public health effects from gamma exposure

The estimated population distribution (Table D.3.1) and an aerial radiological survey (EG&G, 1982) were used as a basis to calculate the health effects to the general public per year due to gamma exposure for the no action alternative. The same conditions were assumed for the no action alternative as were stated in Section D.3.1 with the exception that one year instead of 11 months was used for the calculation.

The estimated number of excess health effects in the general public living within 0.3 mile of the UC site due to gamma radiation originating from the tailings is 0.00021 or one chance in 4800 per year (Table D.3.6).

D.3.3 EXPOSURES AFTER REMEDIAL ACTION

The only radiation exposure pathway of importance after remedial action would be that due to inhalation of radon daughters from the stabilized tailings pile. Following remedial action, there would be essentially no gamma radiation exposure. Thus, the general public gamma excess health effects would be considered negligible.

Table D.3.6 General public health effects from gamma exposure per year for the no action alternative

Distance from center of UC tailings pile (mile)	Population	Individual hours exposed per year	Excess gamma exposure rate (microR/hr)	Excess health effects per year
0.3	18	6570	15	0.00021

The EPA has established an upper limit for the radon concentration at the site boundary of 0.5 pCi/l above background (40 CFR Part 192). Table D.3.7 gives maximum radon and radon daughter concentrations downwind of the stabilized pile and calculated excess health effects following the proposed action. The values in Table D.3.7 are based upon a radon flux of 20 pCi/m^2s and a stabilized tailings pile surface area of 13 acres. The excess radon daughter health effects to the general public within two miles of the site following stabilization of the tailings were calculated to be 0.0000029 or one chance in 350,000 per year. Since the excess health effects from gamma exposure would be negligible after remedial action, the total excess health effects to the general public would also be 0.0000029 per year. This is a factor of 86 lower than the excess health effects for the no action alternative.

Table D.3.7 Radon daughter health effects to the general public after stabilization on site

Distance from center of UC tailings pile (miles)	Population	Modeled outdoor radon concentration (pCi/l)	Modeled outdoor WL x 10^{-6}	Calculated WLM per year x 10^{-4}	Excess health effects per year x 10^{-6}
0.3	18	0.0023	2.0	3.1	1.7
0.4	1	0.0045	5.7	6.2	0.2
0.5	3	0.0074	12.6	10.3	0.9
1.6	2	0.0012	6.8	2.0	0.1
Totals	24				2.9

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APPENDIX E

PERMITS, LICENSES, AND APPROVALS

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E.1 INTRODUCTION

This appendix contains a summary of the permits, licenses, and approvals that would be required for the proposed remedial action at the Slick Rock, Colorado, uranium mill tailings sites. Regulatory permits, licenses, and approvals would be obtained by the RAC or the DOE, whichever is appropriate.

E.1.1 Permits, licenses, and approvals for remedial action

Permit, license, or approval	Granting or approving agency	Statute or regulation	Activity
NRC License	U.S. Nuclear Regulatory Commission	Public Law 95-604, Section 104(f)	Surveillance and maintenance at the disposal site after completion of the remedial action.
Section 404 Dredge and Fill Permit	U.S. Army Corps of Engineers	Clean Water Act of 1977; 33 United States Code 1344	Dredging and filling of wetlands.
Free Use Permit	Bureau of Land Management	Material Sales Act of 1947; 43 Code of Federal Regulations Part 3611	Extraction of common minerals (sand, rock, and the like) on lands administered by the Bureau of Land Management.
Right-of-Way and Temporary Use Permits	Bureau of Land Management	43 United States Code 1761 through 1771; 43 Code of Federal Regulations Part 2800	Access to and temporary use of (e.g., construction staging areas) lands administered by the Bureau of Land Management.
Threatened or Endangered Species Consultation	U.S. Fish and Wildlife Service	Endangered Species Act of 1973, Section 7; 16 United States Code 1531, et seq.	Any action which might affect threatened or endangered species.

E.1.1 Permits, licenses, and approvals for remedial action (Continued)

Permit, license, or approval	Granting or approving agency	Statute or regulation	Activity
Cultural Resource Clearance	Bureau of Land Management and Colorado Historical Society	Historic Preservation Act of 1966; 16 United States Code 470	Any action which might impact historic or cultural resources.
Colorado Pollutant Discharge System Permit	Colorado Department of Health, Water Quality Control Division	Colorado Water Quality Control Act; Colorado Revised Statutes 1973, 25-8-501 through -508	Controlled surface discharge of waste water.
Air Pollutant Emissions Notice and Permit	Colorado Department of Health, Air Pollution Control Division	Colorado Revised Statutes 1973, 25-7-112; Colorado Air Pollution Control Commission Regulations 1 and 3	Construction or modification of a new source of air pollution.
Water Rights Application	Colorado District Water Court, Water Division No. 4	Colorado Revised Statutes 1973, 37-92-300 as amended	Water use.
Permit to Construct a Well	Colorado Department of Natural Resources, Division of Water Resources	Colorado Revised Statutes 1973, 37-90-137 and 37-92-602	Drilling and construction of water wells and monitor wells.

E.1.1 Permits, licenses, and approvals for remedial action (Concluded)

Permit, license, or approval	Granting or approving agency	Statute or regulation	Activity
Approval of Test Hole or Monitor Well Abandonment	Colorado Department of Natural Resources, Division of Water Resources	Colorado Revised Statutes 1973, 37-91-104(1)(d) and 37-91-110(2) as amended; Rules and Regulations for Water Well and Pump Installation Contractors	Plugging and abandonment of monitor wells.
Mining and Reclamation Permit	Colorado Department of Natural Resources, Mined Land Reclamation Division	Colorado Revised Statutes 1973, 34-32-101; Mined Land Reclamation Board Rules and Regulations	Extraction of common minerals (sand, rock, and the like).
State Highway Access Approach Permit	Colorado Department of Highways	Colorado Revised Statutes 1973, 43-2-147	Temporary and permanent access to state highways.
San Miguel County Road Access Permit	San Miguel County Road Department	San Miguel County Planning Regulations	Access to County roads