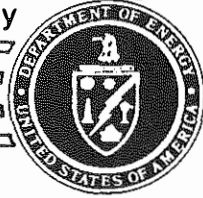


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United States Department of Energy



Final
~~Draft~~ Environmental Impact Statement

**REMEDIAL ACTIONS AT THE FORMER
CLIMAX URANIUM COMPANY
URANIUM MILL SITE
GRAND JUNCTION, MESA COUNTY,
COLORADO**

VOLUME II - APPENDICES

MARCH, 1986

Uranium Mill Tailings Remedial Action Project



DOE/EIS-0126-D

Draft Environmental Impact Statement

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URANIUM MILL SITE
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MARCH, 1986

U.S. DEPARTMENT OF ENERGY

**THIS DRAFT EIS SHOULD BE SAVED BECAUSE PORTIONS THAT ARE NOT
SIGNIFICANTLY REVISED WILL NOT BE REPRINTED IN THE FINAL EIS**

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APPENDIX A

EPA STANDARDS

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A.1 GENERAL

Pursuant to the requirements of UMTRCA, EPA promulgated health and environmental standards on January 5, 1983, to govern cleanup, stabilization, and control of residual radioactive materials at inactive uranium mill tailings sites. The promulgated standards establish requirements for long-term stability and radiation protection and provide procedures for ensuring the protection of ground-water quality.

In developing the 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 such as wind, rain and flood waters" and that "a secondary objective should be to reduce radon emissions from tailings piles." A third objective should be "the elimination of significant exposure to gamma radiation from tailings piles." (Ref. preamble to Standards for Remedial Actions at Inactive Uranium Processing Sites, 40 CFR Part 192.) These conclusions were based on a determination that the most significant public health risks associated with inactive tailings were posed by exposure to people living and working in structures contaminated by relocated tailings. EPA further concluded that the potential for contamination of ground water and surface water should be evaluated on a site-specific basis.

On September 3, 1985, the United States Circuit Court of Appeals set aside EPA's water protection standards, 40 CFR Part 192.20(a)(2)-(3), and EPA has not yet reissued these standards. Section A.5 (Water-Quality Protection) identifies how DOE will approach this issue until water protection standards are reissued.

The EPA standards are summarized in Table A.1.1. The discussion of the EPA Standards in the following paragraphs has been summarized from the Plan for Implementing EPA Standards (DOE, 1984).

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 microrentgens 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 A.1.1 EPA STANDARDS

A.2 LONG-TERM STABILITY

Isolation and stabilization of tailings in order to prevent misuse by man and dispersal by natural forces is the primary objective of the EPA standards. Accordingly, long-term stability was emphasized in the development and promulgation of the standards. This is consistent with the guidance provided by the legislative history of UMTRCA which stresses the importance of avoiding remedial actions which would be effective only for a short period of time and which would require future Congressional consideration.

The EPA standard-setting process distinguished "passive controls," such as thick earthen covers, below-ground disposal, rock covers, and massive earth and rock dikes, from "active controls" such as semi-permanent covers, fences, warning signs, and restrictions on land use. Active control covers could be expected to need frequent replacement or other major repairs requiring the appropriation and expenditure of public funds. In setting the standards, EPA called for designs which rely primarily on passive controls.

The Standard is framed as a longevity requirement which recognizes the difficulty in predicting very long-term performance with a very high degree of confidence. In establishing the longevity requirement, EPA concluded that existing knowledge permits the design of control systems that have a good expectation of lasting at least 1000 years. Therefore, a design objective of 1000 years was established to be satisfied whenever reasonably achievable, but in any case with a minimum performance period of 200 years.

The Standard recognizes the need for institutional controls such as custodial maintenance, monitoring, and contingency response measures. In its preamble to the standards, EPA calls for such controls to be provided as an essential backup to the primary passive controls.

A.3 RADON EMISSIONS CONTROL

EPA identified a reduction of radon emissions from tailings piles as the second objective in its standards for the control of tailings. In developing the standards, it considered several alternative approaches and selected an emission limitation as the primary form of the standard. In addition, it established a concentration limit as an alternative form of the standard for use in cases where the DOE determined that the alternative was appropriate.

In establishing the emission limitation for tailings piles, EPA sought to reduce both the maximum risk to individuals living very near to the sites and the risk to the population as a whole. With regard to individuals very near to disposal sites, EPA estimates that exposure to radon emissions will be reduced by more than 96 percent. The radon standard of 20 pCi/m²s on the disposal site or 0.5 pCi/l outside the disposal site will limit the increase in radon concentration attributable to a pile to a small increase above the background radon level near the disposal site. Both standards are design standards with compliance to be determined on the basis of predicted rather than measured emission rates and concentrations. EPA states that "post-remediation monitoring will not be required to show compliance, but may serve a useful role in determining whether the anticipated performance of the control system is achieved."

In establishing the radon standard, EPA determined that the emission limitation could be achieved by well-designed thick earthen covers and that such control techniques would be compatible with the requirements of the EPA longevity standard.

A.4 CLEANUP OF LANDS AND BUILDINGS

The EPA evaluated the risk associated with the dispersal of tailings off the site and concluded that the principal risk to man was the exposure to radon daughter products inside buildings. EPA therefore stated that the objective of the cleanup of tailings from around existing structures was to achieve an indoor radon daughter concentration (RDC) of less than 0.02 WL (working level). For open lands, the purpose of removing the contamination is to remove the potential for excessive indoor radon daughter concentrations that might arise from new construction on contaminated land. The 5 pCi/g and 15 pCi/g Ra-226 concentration limits for 15-cm surface and subsurface layers were considered adequate to limit indoor RDCs to below 0.02 WL. A secondary concern was to limit exposure to people from gamma radiation.

The Standard requires that residual radioactive materials be removed from buildings exceeding 0.03 WL. In cases where levels are between 0.02 and 0.03 WL, the Federal government will have the flexibility to decide if any measures should be taken. Measures such as sealants, filtration devices, or ventilation devices may be used to provide reasonable assurance of reductions to below 0.02 WL.

A.5 WATER-QUALITY PROTECTION

Prior to the September 3, 1985, decision by the United States Tenth Circuit Court of Appeals, EPA reviewed available water-quality data at inactive tailings sites and determined that there was little evidence of recent movement of contaminants into ground water. They also determined that any degradation of ground-water quality should be evaluated in the context of potential beneficial uses of the ground water as determined by background water quality and the available quantity of ground water.

Rather than establish specific numerical limitations for contaminant discharges or ground-water quality, 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.

Specific site assessments must include monitoring programs sufficient to establish background ground-water quality through one or more upgradient wells and to identify the present movement and extent of contaminant plumes associated with the tailings piles. They further call for judgements of the need for restoration or prevention, or both, to be guided by EPA's hazardous waste management system and relevant state and Federal water-quality criteria. Decisions on specific actions to protect or restore water quality are to be guided by such factors as the technical feasibility of improving the aquifer, the cost of applicable restorative or protective programs, the present and future value of the aquifer as a water source, the availability of alternative water supplies, and the degree to which human exposure is likely to occur.

UMTRCA requires that the standards promulgated by EPA ". . .to the maximum extent practicable, be consistent with the requirements of the Solid Waste Disposal Act, as amended." In setting the standard, EPA determined that the statutory requirement for NRC to concur with the selection and performance of remedial actions and to issue licenses encompassing "monitoring, maintenance, or emergency measures necessary to protect public health and safety" was consistent with the EPA regulations implementing the Solid Waste Disposal Act (47 FR 32274, July 26, 1982). Accordingly, EPA established the implementation procedures requiring case-by-case evaluations of potential contamination at sites. Decisions regarding monitoring or remedial actions will be guided by relevant considerations in the hazardous waste management systems.

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 the legislation. EPA has not identified a date for reissuance of 40 CFR Part 192.2(a)(2)-(3), and it is anticipated that such reissuance will not occur until after remedial action has been initiated at the Grand Junction site. Therefore, DOE and the State will implement the remedial action, with the concurrence of NRC and after consultation with EPA. As implementing agencies with regard to the EPA Standards, DOE, the State and NRC, by executing the remedial action will make every reasonable effort to ensure that water resources are adequately protected.

Whether EPA, in reissuing the water standard, sets forth a technical approach similar to either the current active site water standard or that proposed prior to promulgation of 40 CFR Part 192.20(a)(2)-(3) for the inactive sites, DOE has thoroughly characterized conditions at the Grand Junction mill site and does not anticipate that any substantive changes to the remedial action will be required.

REFERENCES FOR APPENDIX A

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

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B.1 INTRODUCTION

B.1.1 PURPOSE

This appendix provides the information needed to understand the conceptual designs for the remedial action alternatives addressed in this draft Environmental Impact Statement (DEIS). It is intended to provide sufficient detail for the reader to evaluate the feasibility and assess the impacts of each remedial action alternative. It is not intended to provide the detailed engineering necessary to implement the alternatives. Details of the proposed remedial action will be presented in the Draft Remedial Action Plan.

B.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 EPA standards (40 CFR Part 192, Appendix A). Consistent with this purpose and the EPA standards, the following major design objectives have been established:

- o Reduce the average radon flux from the site to levels consistent with EPA standards.
- o Design controls to be effective for up to 1000 years to the extent reasonably achievable, and, in any case, for at least 200 years.
- o Ensure that existing or anticipated beneficial uses of ground and surface waters are not adversely affected.
- o Reduce contaminant levels (radium-226) in areas released for unrestricted use to levels consistent with EPA standards.
- o Minimize the land area to be occupied by the stabilized tailings.
- o Provide flood protection, runoff and sediment control, and treatment of waste water as required.
- o Prevent inadvertent human intrusion into the stabilized tailings.
- o Minimize animal burrowing and root penetration into the stabilized tailings.
- o Protect against releases of contaminants from the site during construction.
- o Minimize areas disturbed during construction and minimize human exposure to contaminated materials.

Figure B.1.1 shows the locations of the Grand Junction processing site, Cheney Reservoir alternate disposal site, Two Road alternate disposal site, and all borrow sites.

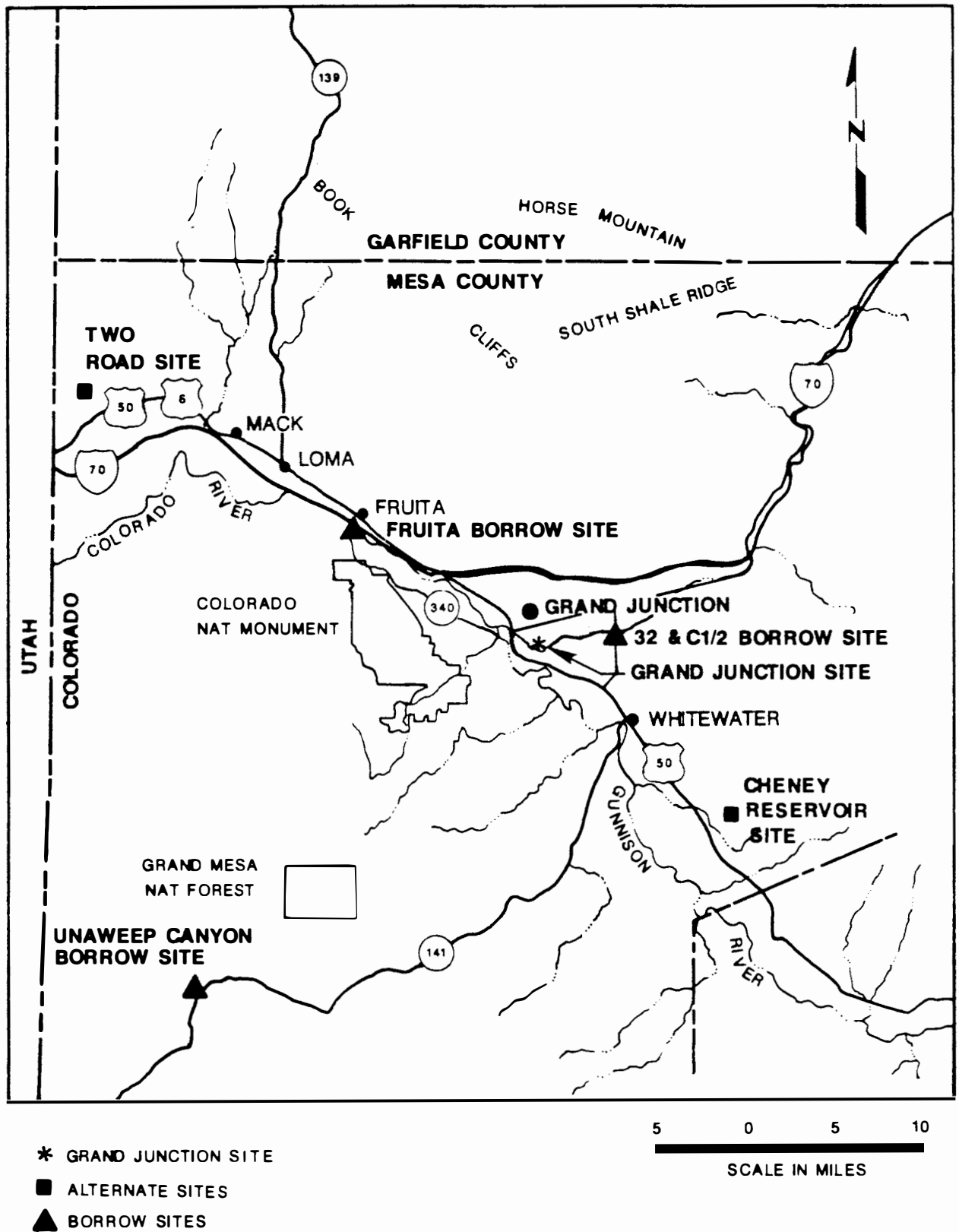


FIGURE B.1.1
GRAND JUNCTION REMEDIAL ACTION - LOCATION MAP

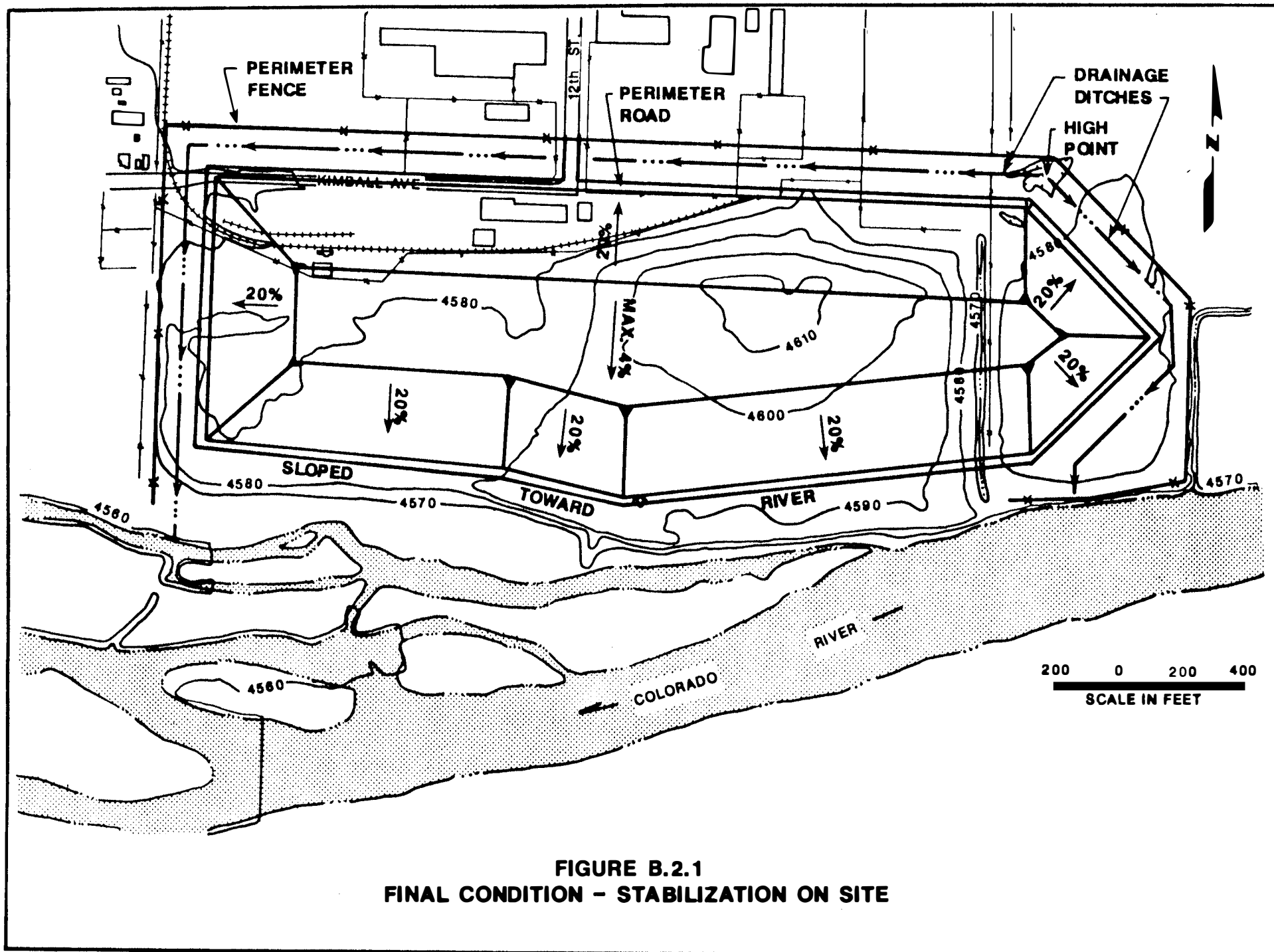
B.2 STABILIZATION ON SITE

B.2.1 DESIGN FEATURES

Under the stabilization on site alternative, the uranium mill tailings and contaminated material would be stabilized at the former Climax Uranium Mill at Grand Junction in a manner which complies with the EPA standards. The principal feature of this design concept is the consolidation of the tailings and other contaminated material into an embankment on the former processing site (Figure B.2.1). Major construction activities for this design are discussed in detail in Section B.2.3. The design would require the following activities at the site and associated borrow areas:

At the Grand Junction site

- o Construction of waste-water retention basins to protect against release of contaminants from the site during remedial action.
- o Installation of temporary security fencing.
- o Construction of drainage control measures to direct all generated waste-water and storm-water runoff to the retention basins during construction activities.
- o Implementation of measures to control erosion and sedimentation from disturbed areas during construction.
- o Installation and operation of a waste-water treatment facility (as necessary) to protect against inadvertent release of contaminants during construction.
- o Protection (or relocation) of surface or subsurface utilities at the Grand Junction site during construction.
- o Installation of sheet piling (as necessary) along the south and portions of the southwest and southeast perimeters of the existing pile to retard surface flows from the Colorado River and ground-water intrusion during excavation.
- o Installation of soldier piling along the northern site perimeter to facilitate excavation of contaminated material adjacent to the site boundary.
- o Excavation and stockpiling of tailings and contaminated alluvial material.
- o Excavation of low strength foundation material and replacement with compacted coarse-grained fill.
- o Construction of the tailings subbase, including fill layer, capillary break layer, low-permeability layer, and below grade rock armor layer (see Section B.2.2).



- o Replacement of tailings and contaminated alluvium over the low-permeability layer.
- o Relocation to the tailings embankment area of off-site tailings and other contaminated materials (including State Repository and vicinity property material).
- o Disposal of evaporation pond and temporary drainage ditch sediments in the embankment.
- o Construction of the final cover system over the tailings and contaminated material to inhibit water infiltration, radon exhalation, and wind and water erosion.
- o Placement of rock to inhibit intrusion by burrowing animals and to provide erosion protection of the embankment, with final grading to provide suitable drainage control.
- o Placement of rock armor layer over the embankment to protect the pile from the effects of a Probable Maximum Flood of the Colorado River.
- o Restoration of excavated areas with backfill.
- o Revegetation of disturbed areas not included in the stabilized pile.
- o Installation of a security fence and warning signs to inhibit human intrusion.

At the 32 and C $\frac{1}{2}$ Road borrow site

- o Excavation of erosion protection and cover material and loading onto trucks.
- o Relocation of borrow material to the Grand Junction processing site.

At the Unaweep Canyon borrow site

- o Excavation of rock armor material by traditional drill and blast methods and loading onto trucks.
- o Relocation of borrow material to the Grand Junction processing site.
- o Reclamation of the site to control erosion according to applicable requirements.

B.2.2 PERMANENT DESIGN FEATURES

Description of final condition

The completed Grand Junction site would cover approximately 93 acres, including 18 acres north of the existing site boundary, and would contain an embankment surrounded by an access road, permanent drainage ditches, and permanent fencing.

The tailings pile would be roughly rectangular in shape with a pointed end to the east (see Figure B.2.1). The pile would cover approximately 72 acres and would be located approximately 200 to 300 feet from the Colorado River. The contaminated material would be covered with an approximately five-foot-thick earth cover. The stabilized pile would have maximum sideslopes of 20 percent (5 horizontal to 1 vertical) and the top would be gently sloped (a maximum of four percent) toward the river. The entire embankment would be covered with a two-foot layer (including filter layers) of graded rock for erosion protection. The erosion protection barrier would tie into a six-foot-thick rock armor wall around the base of the tailings. The final stabilized pile would be a maximum of approximately 55 feet above the northern site boundary.

An unpaved access road would be constructed around the base of the pile on top of the rock armoring, and a drainage ditch would be constructed around the outside edge up the rock armoring on the east, west, and north sides of the pile. The ditch would divert surface-water runoff around and away from the pile. A security fence with locked gates and warning signs would enclose the site.

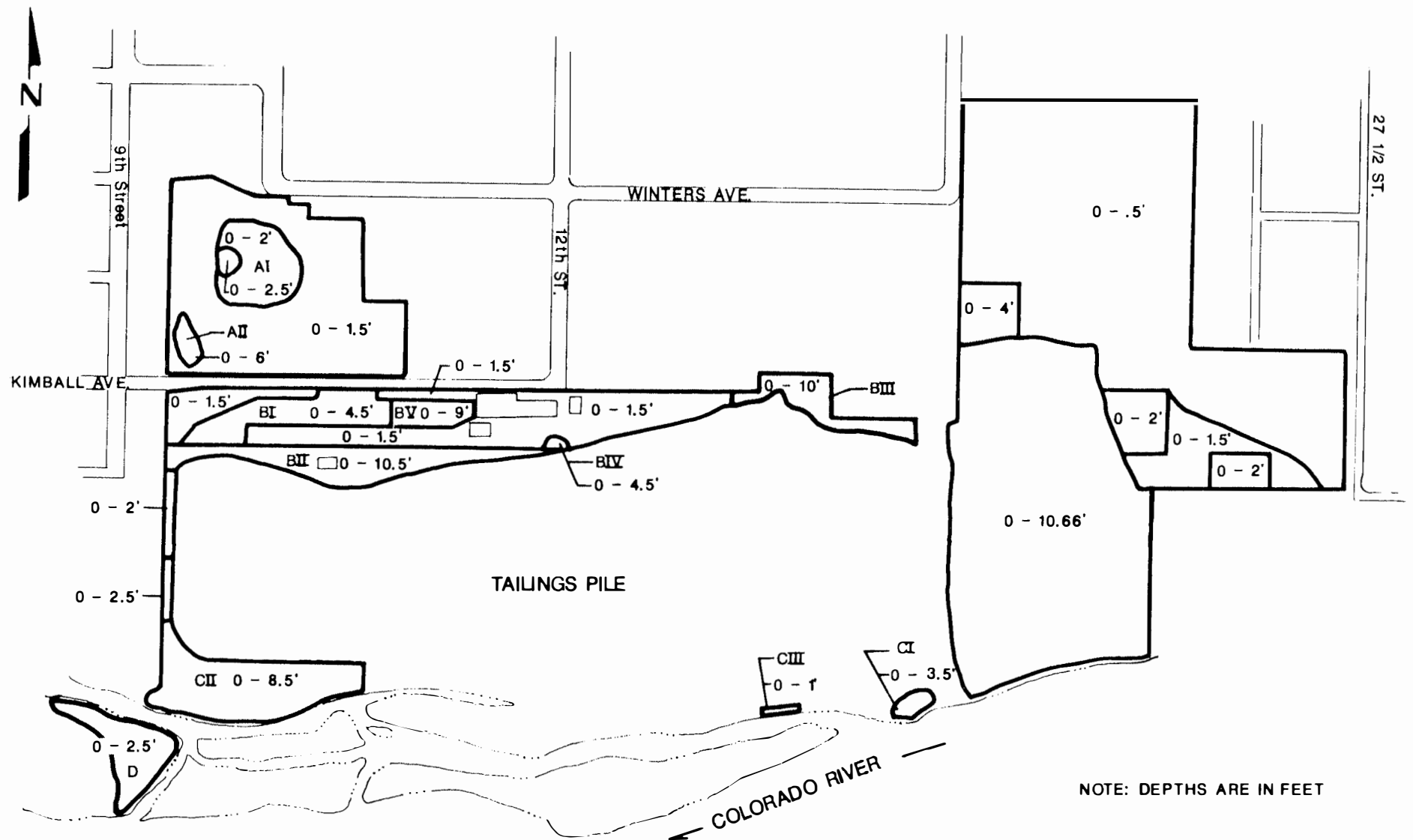
The remaining areas at the Grand Junction site would be restored with uncontaminated fill to conform with the surrounding terrain, graded to promote drainage as required, and revegetated as necessary.

Decontamination and restoration

Material excavated from the Grand Junction site, ore pad, evaporation ponds, mill area, windblown areas, the State Repository, and vicinity properties would be combined in the embankment at the former processing site. Contaminated rubble resulting from demolition of existing structures would also be contained in the embankment.

Subpile contamination averages 4.5 feet below the tailings-alluvium interface. The evaporation pond areas contain an average of one foot of contaminated soil. Approximately five feet of contaminated soil exist in the former mill yard. The former ore pad area contains an average of 1.6 feet of contaminated soil. Contaminated material in the State Repository averages 10.5 feet in thickness. Off-pile limits of contamination are shown in Figure B.2.2.

Areas of excavation on and around the Grand Junction site would be restored with uncontaminated fill to a level compatible with the surrounding terrain and revegetated as necessary.



NOTE: DEPTHS ARE IN FEET

0 200 400 600 800
SCALE IN FEET

FIGURE B.2.2
OFF-PILE, ON SITE DEPTH OF CONTAMINATION
GRAND JUNCTION SITE

Tailings pile construction

The stabilized tailings pile would contain approximately 3.1 million cubic yards of tailings, rubble, and contaminated material and would be designed to provide long-term stability and minimize radon emanation and ground-water contamination.

Because of the proximity of the pile to the Colorado River and the high ground-water levels associated with the river, stabilization on site would require that several features be incorporated into the design of the tailings subpile. A low-permeability earth layer, a capillary break layer, and a layer of uncontaminated backfill would be placed directly beneath the tailings. This would require that all the tailings and the contaminated alluvium be removed and replaced. In addition to the removal of contaminated soil, any soft or disturbed foundation soils would be removed and replaced with suitable compacted backfill material. The backfill material required to raise the capillary break above expected high ground-water levels would be placed once previous activities have been completed. The capillary break layer would be placed directly above the backfill material. This layer of graded coarse-grained material would prevent capillary rise of ground water from saturating the low-permeability earth layer and, consequently, the tailings. If the backfill (or the natural alluvium where no fill is required) is sufficiently pervious, no capillary break would be required. If not, the capillary break would be a graded extension of the backfill layer. The low-permeability earth layer would be constructed over the capillary break. This layer would reduce the amount and the rate of possible contaminant migration.

The replaced tailings and contaminated material would be placed over the low-permeability layer, compacted with suitable compaction equipment, and any unstable materials would be excavated and recompacted to ensure that the embankment would be dense throughout. Because the tailings would be mixed during excavation, replacement, spreading, and compacting, it is not expected that any extensive pockets of slimes would exist in the compacted tailings pile. Consequently, differential and total settlement would not affect the integrity or longevity of the embankment.

In order to minimize the risk of undercutting by scour during peak flows of the Colorado River, a rock armor layer around the entire perimeter of the pile would be carried to the maximum depth of scour that would occur during a PMF.

Organic material such as wood demolition debris and grubbed vegetation would be evenly distributed throughout the embankment so that no more than five percent organics by volume would be contained in any area of the pile. Rubble pieces would be placed in the lower portions of the pile and surrounded with compacted tailings. The procedures for this activity would be specified to ensure that the material is placed to avoid concentration in any area and to ensure good compaction of material around the rubble.

Limiting the pile topslopes to a three to four percent grade and the sideslopes to a 20 percent grade would provide the necessary factor

of safety against embankment slope failure and would reduce the potential effects of erosion.

Cover construction

The tailings radon exhalation rate would be reduced to EPA standards by an approximately five-foot-thick compacted silty clay layer which would serve as a radon barrier. The compaction of the earthen barrier would produce a cover that retains moisture and retards radon gas diffusion.

This cover or earthen barrier would be protected by a two-foot-thick layer of rock designed to protect the soil cover and consequently prevent exposure of contaminated material for 1000 years. The rock cover would reduce the potential for drying of the compacted earthen cover by trapping soil moisture. The bottom one foot of the rock cover would be comprised of graded filter material. The rock layer would resist erosion and gully formation thereby protecting the earthen barrier and preventing it from being eroded away during any rainstorms that can be expected to occur. The rock layer has been designed to withstand the occurrence of the Probable Maximum Precipitation (PMP).

Finally, a rock armor wall would be constructed around the entire perimeter of the pile to further protect the contaminated material from erosion. This rock armor wall would be designed to withstand the effects of channel migration and scour caused by a Probable Maximum Flood (PMF) occurring on the Colorado River. The combined rock layers would also protect the pile from wind erosion and would discourage plant root intrusion and burrowing animals.

Figure B.2.3 shows a typical cross-section for the stabilization on site disposal alternative.

Site drainage

The drainage pattern of the Grand Junction pile area and the surrounding general site grading have been designed to ensure long-term pile stability. The top of the pile would be gently sloped toward the Colorado River. Since the entire site would be inundated during a PMF, it would be impractical to design permanent ditches to contain the PMF flows. Therefore, the stabilized pile would be surrounded to the west, north, and east by a ditch designed to carry the runoff resulting from the 100-year one-hour rainfall event to ensure proper drainage of the pile and site area. The site grading would have a sufficiently shallow gradient so that flow velocities would be non-erosive as flow is directed south toward the Colorado River.

Details on flood protection and flood analysis are provided in Section B.2.6 and in Appendix F, Hydrology Report, Section F.1. The design of the site drainage features is summarized in Section B.6.

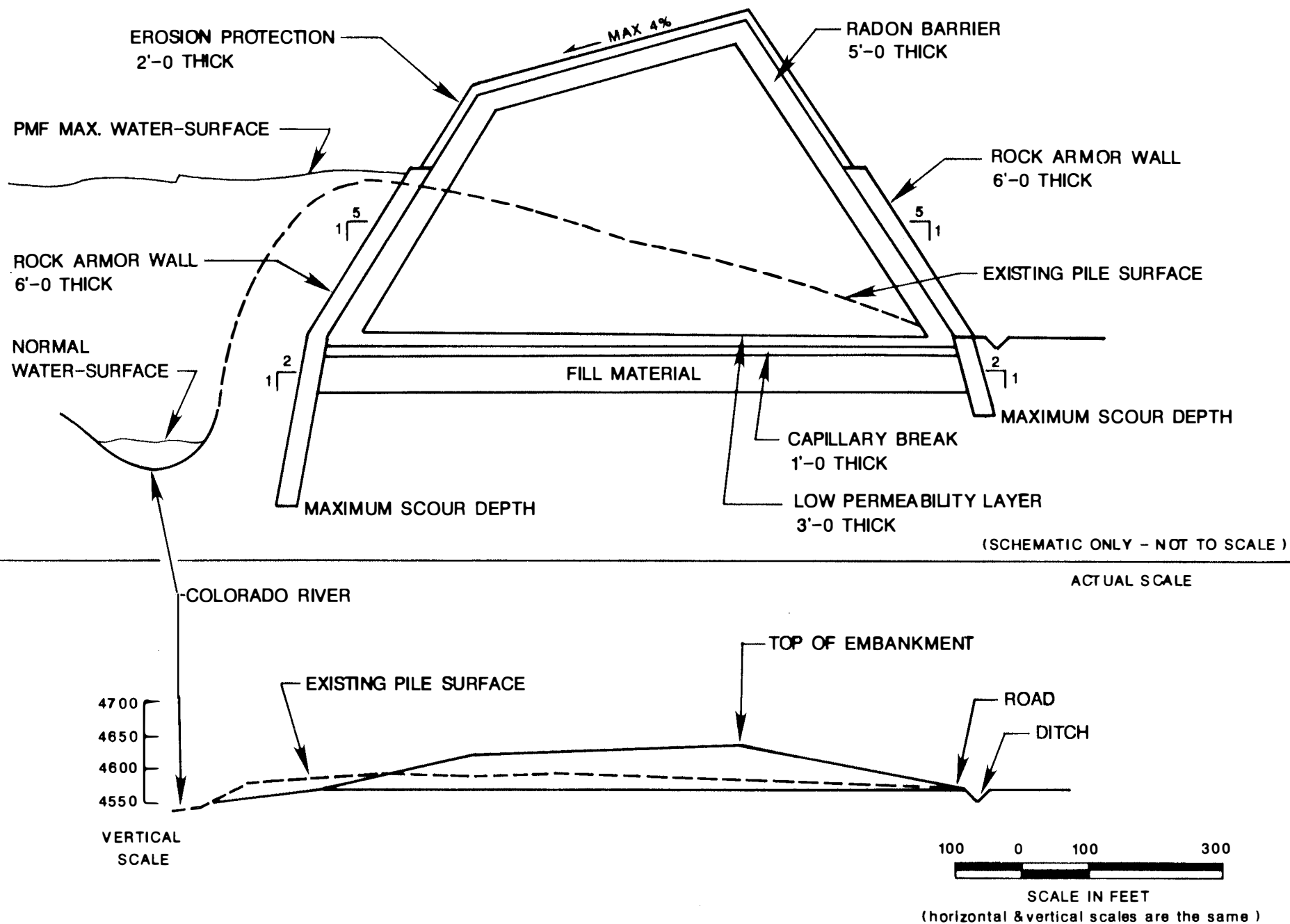


FIGURE B.2.3
TYPICAL CROSS-SECTION - STABILIZATION ON SITE

Ground-water protection

The stabilized tailings pile would be designed to minimize ground-water contamination. The preparation of the subbase, placement of the tailings, and placement of the earth cover would serve to prevent migration of contaminants to the ground-water system by restricting downward contaminant migration and preventing capillary rise of ground water into the tailings. Details are provided in Section B.2.7.

Site access

After remedial action is complete, roads would be constructed along the perimeter of the embankment allowing access for custodial and inspection purposes. The reclaimed site would also be surrounded by a security fence with locked gates and warning signs to prevent inadvertent human intrusion.

B.2.3 MAJOR CONSTRUCTION ACTIVITIES

B.2.3.1 Layout

Construction activities would be primarily confined within the tailings pile area except for adjacent contaminated areas.

The exact locations and sizes of all construction features such as the staging areas, decontamination facilities, drainage ditches, and waste-water retention basins would be determined during final design. The following paragraphs present one possible layout and are provided to allow a better understanding of all aspects of the remedial action.

The staging area would be in the former mill area north of the pile. An equipment decontamination facility would be located adjacent to the staging area. Ditches and berms surrounding the site would direct uncontaminated flows away from the site. Contaminated water would be directed to waste-water retention basins and a treatment facility constructed on the site. A construction fence would surround the area.

B.2.3.2 Site access

The construction fences would provide control of traffic entering and leaving the site and prevent unauthorized traffic from entering the area. Equipment would be decontaminated prior to leaving the Grand Junction site.

B.2.3.3 Staging area facilities

During construction operations, temporary facilities would be required for construction workers along with supervi-

sory, engineering, administrative, security, and radiation monitoring personnel. The facilities would consist of office space, laundering facilities, showers, and change facilities for all personnel working on the site. Portable construction toilets would be provided for on-site workers. On-site equipment would be stored in the staging areas. Parking areas would also be constructed at the site.

B.2.3.4 Utilities

All known existing utilities at the Grand Junction site as shown in Figure B.2.4 would be protected during construction or would be relocated as necessary prior to construction.

Water for dust suppression on contaminated areas at the Grand Junction mill site would be obtained from the tailings and subsoil dewatering or would be recycled water from the waste-water retention basins. Potable water, construction water, electricity, gas, and phone service would be obtained from local suppliers.

B.2.3.5 Drainage, erosion control, and waste-water retention basins

During remedial action, all drainage from the Grand Junction site would be blocked from reaching any waterways. Areas of the site disturbed by construction activities would be graded so that runoff would drain to the waste-water retention basins. Drainage ditches would be lined with erosion-resistant materials if sediment build-up in the waste-water retention basins becomes a problem. In addition, the ditches would be designed and maintained to carry the 10-year one-hour storm event for the area tributary to the channel. Runoff from land outside of affected areas would be diverted away from the site by diversion ditches designed and maintained to retain the runoff from the 10-year one-hour storm event.

The waste-water retention basins would receive waters resulting from:

- o Decontamination activities including equipment washing and truck washdown.
- o Runoff from contaminated materials.
- o Laundry waste from washing protective clothing.
- o Shower and wash basin waste water.
- o Site dewatering (if contaminated).

The retention basins at the site would be designed to retain the runoff from a 10-year 24-hour storm as well as the waste water from the decontamination operations and site

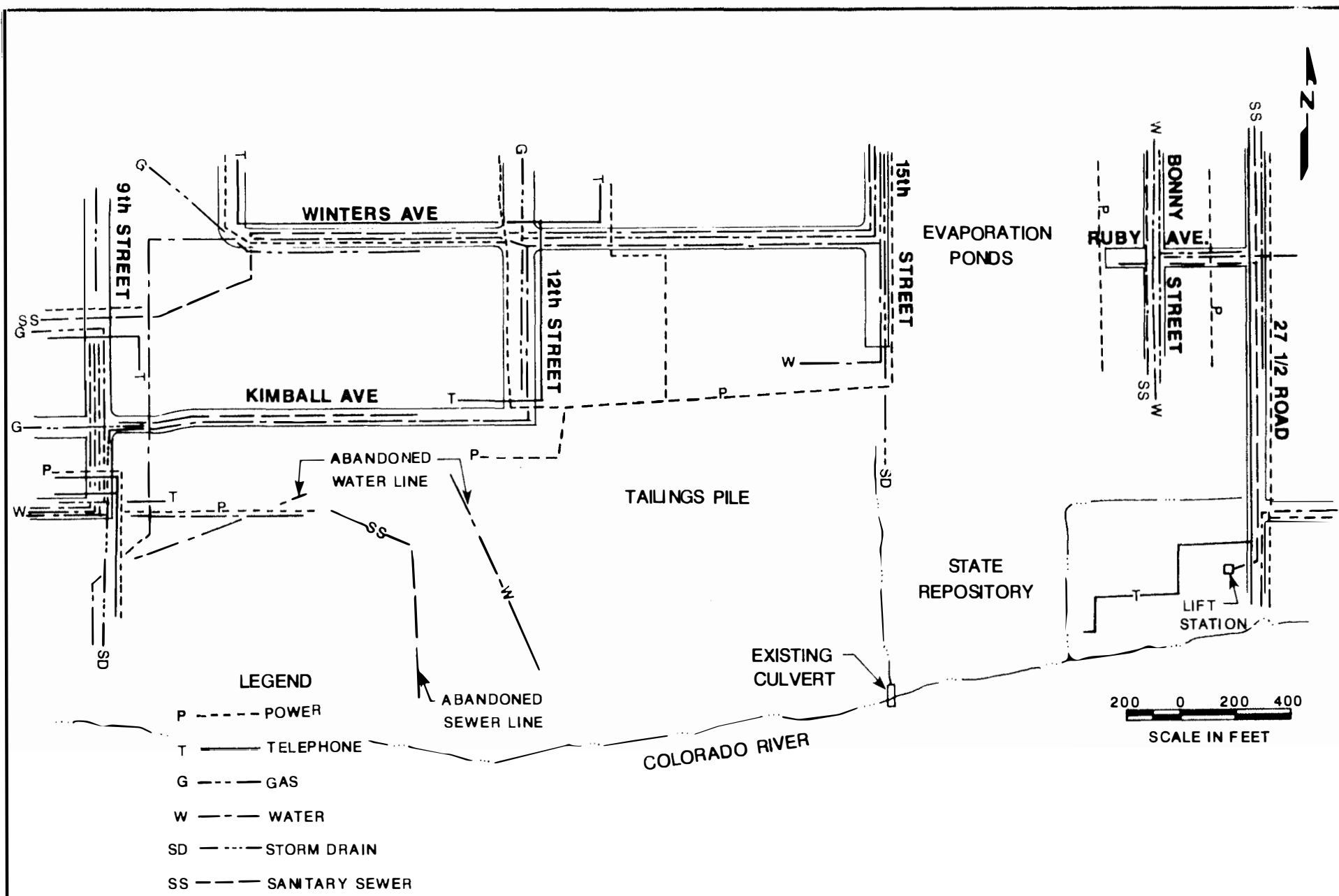


FIGURE B.2.4
GRAND JUNCTION EXISTING UTILITY LOCATION MAP

dewatering. The retention basins shall have sufficient capacity to hold all sediment inflow over the entire life of the project without any need for removal. The emergency outlets from the basins would be designed to safely discharge the 25-year storm peak runoff while maintaining a minimum of one foot of freeboard. Final location and design of the retention basins would be determined during final design.

B.2.3.6 Waste-water treatment

Waste water generated from sources mentioned in Section B.2.3.5 would be directed to waste-water retention basins (if necessary) which would provide primary settling, along with flow and contaminant equalization. Some of this water would be utilized for dust control on contaminated areas. The remainder of the water would be treated to meet applicable Federal and Colorado Department of Health water-quality standards (as necessary) before discharge.

Performance specifications for the treatment unit would be determined in the final design. After completion of remedial action, the treatment system would be either decontaminated and salvaged or buried.

B.2.3.7 Dewatering (sheet piling)

Ground water at the Grand Junction site rises into the tailings. To facilitate handling, some of the tailings would require dewatering.

Dewatering would be accomplished by installing either well points or drainage ditches with sump pumps in the excavations, lowering the ground-water level until it is at an elevation below the excavation depth. The dewatered material would then be excavated. Contaminated water would be used as dust suppression water on contaminated areas or would be pumped to a sedimentation basin and treated prior to discharge.

Due to the presence of the Colorado River adjacent to the tailings pile, additional measures would be taken during site preparation in order to reduce the dewatering effort. Sheet piles would be driven (if necessary) to competent bedrock to form a cutoff wall along the base of the pile adjacent to the river and along the southwest and southeast sides of the pile. Also, soldier piles would be driven along the northern site perimeter. These braced excavations would inhibit surface-water recharge and ground-water flow into the excavation and, along with dewatering, would ensure stable excavation slopes during placement of the rock armor wall and excavation of the contaminated alluvium.

B.2.3.8 Dust control

Dust generated by excavation, earth movement, vehicle use, temporary materials stockpiling, and similar activities would be controlled and minimized by the use of water and water-based surfactants sprayed from hoses or trucks. Special care would be taken to control dust created by building decontamination or demolition and the temporary stockpiling or mixing of contaminated materials.

The sources for dust suppression water on contaminated areas would include recycled water from the waste-water retention basins, or water from tailings and subsoil dewatering. Uncontaminated water would be used for the decontaminated areas.

The schedules for spraying the roads, the pile, and other contaminated areas would vary daily and would be determined on an hour-by-hour basis in accordance with applicable state permits. The frequency of spraying would increase when combinations of low soil moisture and high wind speed are encountered.

B.2.3.9 Borrow areas

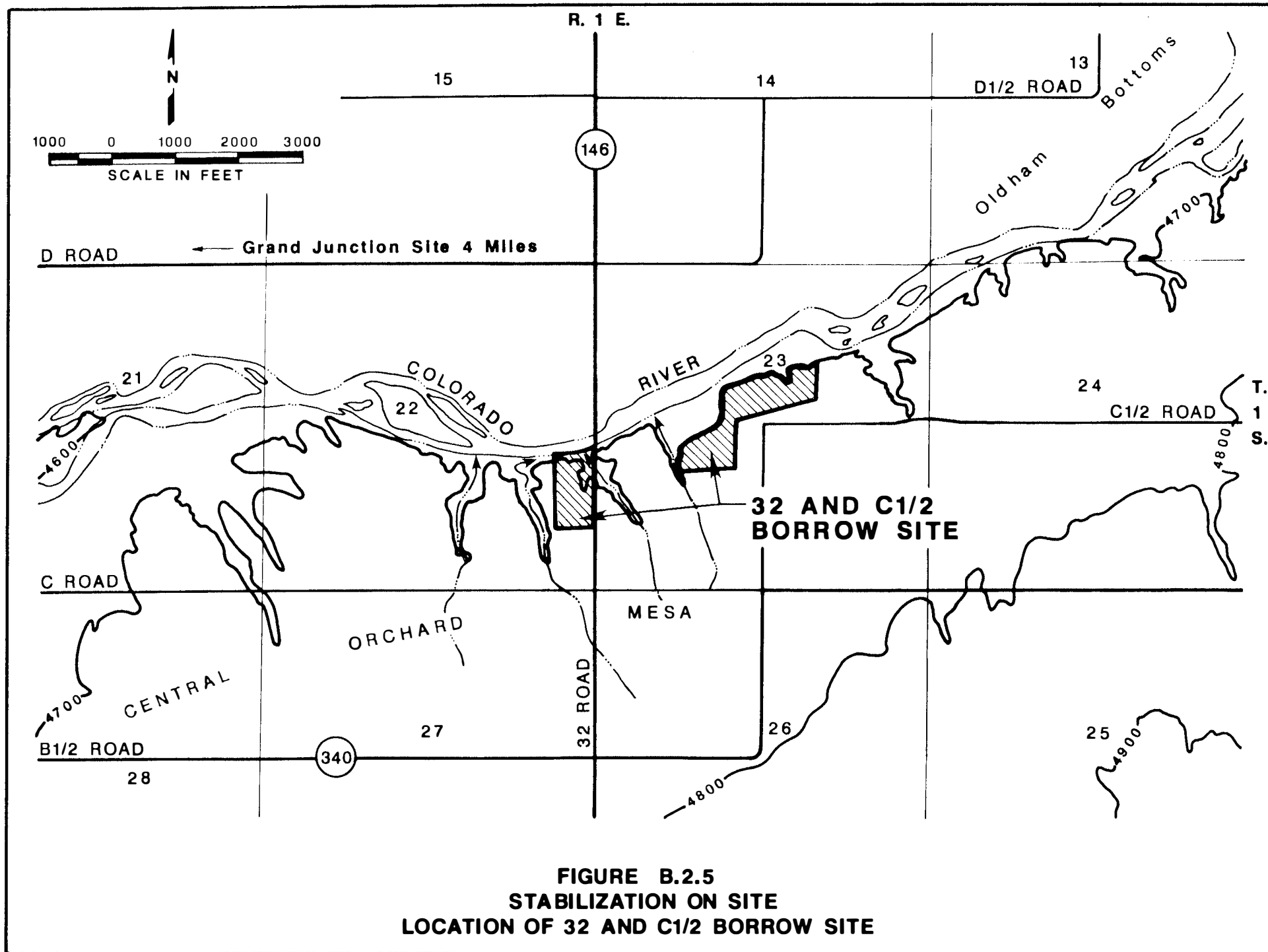
Two separate borrow areas have been identified for the stabilization on site alternative. The first is located approximately seven road miles east of the former processing site and will be referred to as the 32 and C½ borrow site (Figure B.2.5). Material for the erosion protection layer, backfill, and earth cover would be purchased at these privately owned pits and hauled to the site.

The only material not locally available would be the large rock required for the armoring. A source for this material has been identified near Gateway, Colorado, in Unaweep Canyon approximately 47 miles from the site (see Figure B.1.1). This material would be mined by traditional drill and blast techniques and hauled to the site. This borrow site will be referred to as the Unaweep Canyon borrow site.

B.2.3.10 Construction sequence

The following construction sequence is proposed as a possible sequence for the remedial action. As with the layout (Section B.2.3.1), the final design would contain greater detail and the construction subcontractor would be allowed the flexibility of executing his work as he desires, given certain constraints. Therefore, the actual construction sequence and methods of construction may differ from the following.

Each of the alternatives, except no action, was developed using a three-year construction schedule for remedial action.



The construction schedule could be extended to four years, or longer, which would decrease the intensity and increase the duration of many of the environmental impacts associated with the project.

Initially, a site security system would be established at each site and coordinated with staging and vehicle decontamination areas. This would provide control of traffic entering and leaving each site and prevent unauthorized traffic from entering either site.

The sheet piling to inhibit ground-water flow and reduce the dewatering effort would then be driven (if necessary) along the base of the pile adjacent to the river and on the southeast and southwest sides of the pile.

At the same time as the sheet piling is driven, soldier piling would be driven along the northern site boundary in order to facilitate excavation of contaminated material.

A waste-water treatment facility would be installed (if necessary) to treat contaminated water and to protect against inadvertent contaminant release during construction. Demolition or decontamination of existing structures would also be performed during site preparation.

The next major item of site preparation would consist of constructing retention ponds at the site. Materials excavated from each pond would be stockpiled for later use as fill. Site preparation would also include construction of drainage and erosion control measures.

Upon completion of the site preparation, removal of the tailings and contaminated material would begin. Excavated tailings and contaminated material would be stockpiled, as fill material from the 32 and C $\frac{1}{2}$ borrow sites would be placed and compacted. At this time, soft zones of foundation soils exposed during the excavation process would also be removed and stockpiled. Concurrently, the below-grade portion of the rock armor wall would be placed around the perimeter of the pile and backfill placed against the wall as necessary.

The capillary break layer, a graded extension of the backfill material, would then be placed. The low-permeability layer would be placed and compacted on top of the capillary break layer. As preparation of the low-permeability layer is completed, the tailings and contaminated alluvium would be replaced and compacted.

Uncontaminated cover material, from the 32 and C $\frac{1}{2}$ borrow sites, would be added to the pile after all contaminated materials and vicinity property materials are in place. Drainage ditches would be excavated around the stabilized tailings pile. The final stages would involve reestablishing overall site drainage, grading, monitoring for settlement, placement of rock erosion material and the rock apron over the stabi-

lized tailings, revegetation of disturbed areas, and the construction of an access road and security fencing around the tailings.

Demobilization would consist of the removal of the remaining waste-water retention basins and temporary drainage ditches. The water would be treated and discharged while the bottom sludges and dikes would be disposed in the embankment. All decontamination areas would be removed and the equipment cleaned for salvage. The staging areas would be dismantled with the contaminated items either cleaned and salvaged or buried. All contractor equipment would be decontaminated and inspected prior to release from the contaminated areas.

Figure B.2.6 shows a construction schedule for stabilization on site.

B.2.4 RADON CONTROL

Control of radon emissions from the stabilized embankment would be accomplished by placing a compacted soil cover over the tailings and other contaminated materials.

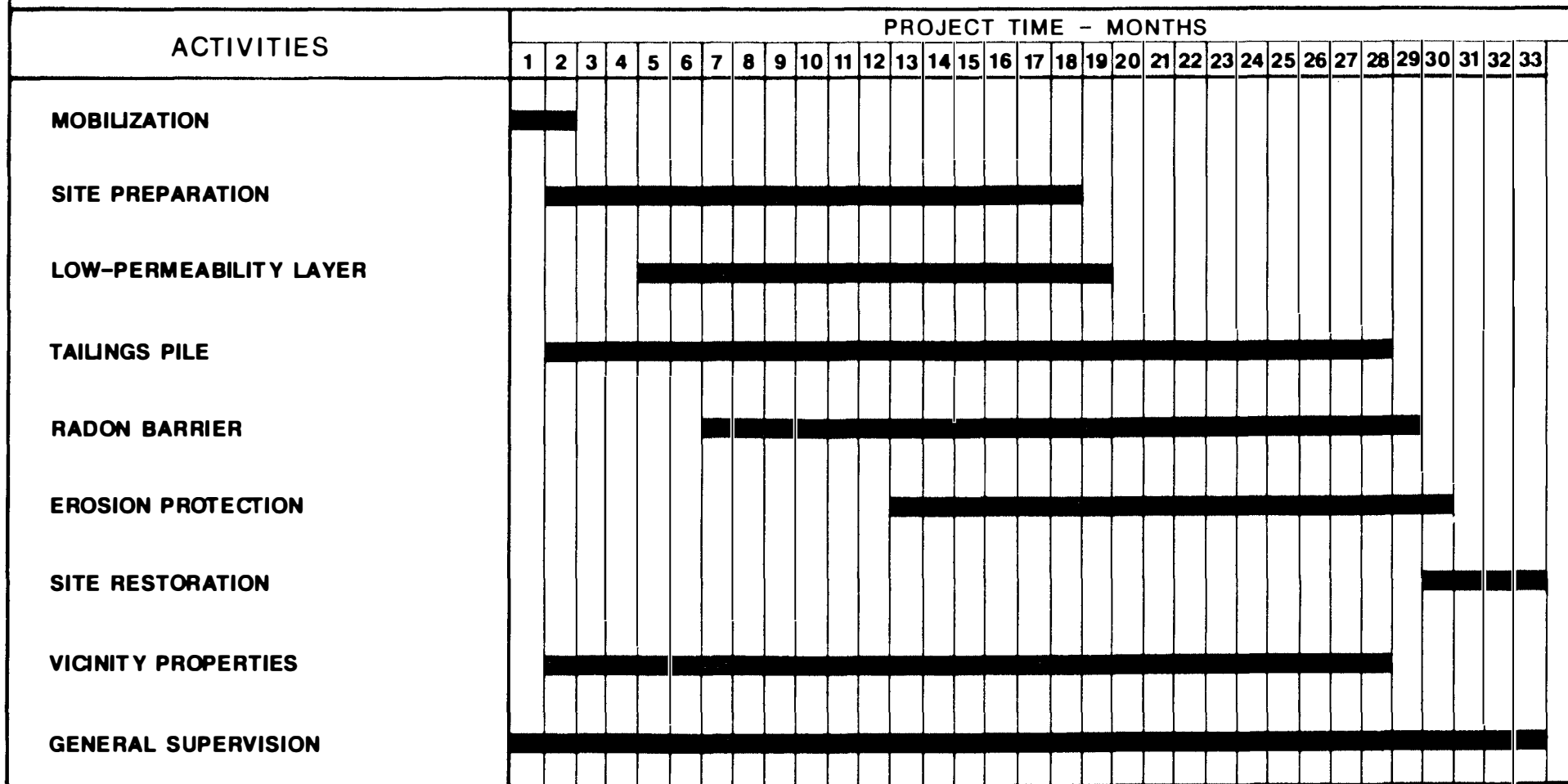
Data on the distribution of radium in the tailings, on the properties of the borrow material, and on the anticipated depth of excavation in areas to be restored were analyzed in order to develop an estimate of cover thickness.

The thickness of cover material required to limit radon flux to 20 pCi/m²s was calculated using the computer code RAECOM (NRC, 1984). The mathematical model implemented in RAECOM describes one-dimensional steady-state radon diffusion through a two-phase multi-layer system of porous media, representing the tailings pile and its cover. Multiple layers of tailings and cover are allowed in the model, with differences in physical, radiological, and diffusional properties represented by seven layer-specific input parameters. The seven values required for each layer of the tailings pile system modeled by RAECOM are:

- o Thickness of layer₃(cm).
- o Bulk density (g/cm³).
- o Porosity (fractional).
- o Long-term moisture content (percent dry weight basis).
- o Emanating fraction of radon (fractional).
- o Radon diffusion coefficient (cm²/sec).
- o Radium concentration (pCi/g).

In addition to these parameters describing the layers of the stabilized pile, RAECOM requires input of the total number of layers in the pile and the layer to be optimized in meeting the specific flux limit (20 pCi/m²s) at the surface. Also, the radon boundary conditions at the top and bottom of the pile must be specified. The bottom condition is always an incoming flux equal to zero pCi/m²s for tailings piles. The top condition is the observed ambient radon concentration (pCi/l) in air near the site.

FIGURE B.2.6 REMEDIAL ACTION SCHEDULE: STABILIZATION ON SITE



The actual thickness of the radon barrier may vary depending on additional borrow source evaluation and analyses to be performed during final design. Plant root intrusion, intrusion by burrowing animals, and constructibility are also considerations in determining radon barrier thickness. For purposes of this EIS, the radon barrier required to meet the EPA standard would be constructed of approximately five feet of material available at the 32 and C½ borrow site. Using this thickness and including the additional erosion barrier, radon emissions after remedial action are calculated to be less than 20 pCi/m²s. The data and analyses are available in the DOE UMTRA Project Office, Albuquerque, New Mexico.

B.2.5 DESIGN CONSIDERATIONS

A number of alternative designs were investigated in order to ensure long-term stability of the tailings pile. Major concerns related to disposal at the Grand Junction site include: proximity to the Colorado River, vulnerability to channel shifts of the river, high ground-water table, large quantity of contaminated material involved, and constraints imposed by the limited areal extent of the site. Since the pile would be located adjacent to the city of Grand Junction, efforts were also made to reduce visual impacts from the stabilized tailings.

Initially a stabilization in place design was investigated. Under this option, the tailings pile would be surrounded by a slurry wall designed to contain and demobilize contaminated ground water. Very little rehandling of the tailings would be required. As in the proposed design, an earth cover and erosion protection would be placed over the compacted tailings. It was determined, however, that the Colorado River is susceptible to channel shifts in the vicinity of the site and the slurry wall would not withstand the effects of major flood flows impinging directly on the pile. In addition, it was determined that the slurry wall technique is an unproven technology and would not reasonably assure pile integrity. In order to ensure long-term protection against release of contaminants, the pile would have to be elevated above expected ground-water levels. The proposed subpile design was investigated and found to contain the characteristics required to provide long-term stability and ground-water protection.

The need to remove the unstable material and raise the pile above ground-water levels requires that the tailings and contaminated alluvium be excavated and replaced after placement of the subbase. Under the proposed configuration, the pile would be constructed with a minimum of rehandling. The sideslopes of the pile were analyzed in order to determine a slope that would provide the necessary factor of safety against slope instability, reduce the potential effects of erosion, and maximize the volume contained within the limited area. Limiting the pile sideslopes to a 20 percent grade would ensure pile stability as well as provide sufficient volume within the embankment, despite the limited width of the site.

The upstream (eastern) side of the pile would be pointed in order to divert flow around rather than directly toward the pile. This would

result in lower flow velocities, thereby reducing the size of the rock armoring material.

Grouted riprap or other cementitious materials were eliminated from consideration as flood protection because excessive maintenance would be required during the design life, which does not meet the intent of the standards.

Although detailed analysis would be performed during final design, it is recognized that road improvements may be required on D Road and State Highway 141 and some city streets prior to transport of borrow material from the 32 and C $\frac{1}{2}$ borrow site.

B.2.6 LONG-TERM STABILITY

Water erosion

Severe rainfall events have the potential to develop rills and gullies on the steeper (20 percent) sideslopes of the stabilized tailings pile and erode some or all of the radon cover in small, undefinable areas. One such potential rainfall event is commonly referred to as the Probable Maximum Precipitation (PMP). The PMP is defined as the maximum precipitation that could occur from the most severe combination of meteorological conditions that are reasonably possible in a region. For the Grand Junction site, the local one-hour PMP storm was calculated to be 8.1 inches. Based on this one-hour intensity, a maximum five-minute intensity was calculated based on the time of concentration for flow off the pile. This intensity was then converted to an equivalent one-hour rainfall intensity of 43.7 inches per hour. This PMP would generate sheet flow rates ranging from 0.40 to 0.70 cubic foot per second per foot of slope width (cfs/ft) on the pile.

To protect the site from the impact of a PMP, the stabilized tailings pile would have a two-foot layer of rock as part of the cover system. Rock sizes required to withstand sheet erosion on the pile top and sideslopes during a PMP event are shown in Table B.2.1. Discussions on the methodologies used to determine the PMP and the erosion protection requirements are contained in Section B.6.

To further reduce the potential for water erosion by surface runoff, additional control features were incorporated into the design to reduce surface runoff velocities. The slopes of the stabilized tailings pile would be limited to 5 horizontal to 1 vertical (20 percent). The top of the pile would be gently sloped (a maximum of four percent) to promote drainage.

It is anticipated that a filter layer would be required on the top and sideslopes. The gradations of the filter layer would be determined during final design when the grain size distribution of the radon barrier and rock erosion protection are finalized. The following criteria would be used in the final design:

Table B.2.1 Erosion protection requirements - stabilization on site

Location	Rock size ^a requirements (inches)	Thickness ^b	Design flow
Topslopes (4%)	$D_{50} \geq 1.5$ inches	24 inches	0.40 cfs/ft
	$D_{100} \leq 3.0$ inches		
Side- slopes (20%)	$D_{50} \geq 4.0$ inches	24 inches	0.70 cfs/ft
	$D_{100} \leq 8.0$ inches		

^a"D" corresponds to required rock diameter.

^bIncluding filter layers.

$$\frac{D_{15} \text{ filter}}{D_{85} \text{ base}} < 5$$

The acceptability of the rock source would be determined well in advance of the time when the rock would be required for placement. The selected rock must meet specific testing criteria for long-term durability.

Wind erosion

High wind velocities could damage the radon cover of the stabilized tailings pile if left exposed. The same rock layers used to protect the pile from water erosion would provide sufficient protection of the pile from the effects of potentially erosive wind velocities.

Flood protection

The Grand Junction processing site is located along the north bank of the Colorado River about 0.75 mile upstream from the Gunnison River confluence. The tailings lie within a gentle meander of the Colorado River, which exhibits an island-braided pattern as it flows along the southern boundary of the tailings pile. The opposite bank is a 60-foot-high bluff with the lower segment composed of Mancos Shale. The watershed upstream of the site is 8150 square miles of steeply sloped terrain. Elevations in the basin range from 4560 feet at Grand Junction to more than 14,000 feet in the highest headwater areas.

Because of the location of the tailings pile with respect to the Colorado River, flooding presents a significant risk to the long-term stability of the stabilized tailings pile. Flood flows surrounding the

pile with high flow velocities could damage the rock erosion protection barrier and subsequently the compacted earthen radon barrier. Furthermore, flooding could cause rapid shifts of the river channel or localized scour that could undercut and erode the pile.

In order to design adequate protection against flooding for the stabilized tailings pile, a flood analysis of the site was performed using the HEC-1 (COE, 1981) and HEC-2 (COE, 1982) computer models. This analysis evaluated the Probable Maximum Flood (PMF) using the PMP estimate for a severe summer storm on the Colorado River watershed above Rifle, Colorado, and extrapolating this PMP to the study area of 8150 square miles by methods developed by McCain and Jarrett (1976). A detailed discussion of the flood analysis and the rationale for this extrapolation are provided in Appendix F, Hydrology Report, Section F.1.2.1.

The flood analysis resulted in calculation of a peak flood flow in the Colorado River of 889,000 cfs. Under PMF conditions, a floodway of 4000 to 8000 feet wide, as shown in Figure B.2.7, would be required to convey the flow. All sides of the site would be exposed to channel flow. The peak water-surface elevation would vary from 4589 feet to 4600 feet along the pile and mean channel velocities would range from approximately 12 to 19 fps. Floodway constrictions at the site would cause unstable flow conditions in the form of near critical flow to occur. The river would attempt to moderate the steep energy gradient and stabilize the flow by scouring alluvium. Using methods outlined for the Bureau of Reclamation by Pemberton and Lara (1984), a depth of zero sediment transport (depth of maximum scour) would be 12.4 feet below the channel bottom. A cross-section at Station 387.86 (Figure B.2.8) shows maximum water-surface and scour elevations for the PMF event.

To protect the stabilized tailings pile from the maximum flood conditions described above, it would be completely surrounded by a six-foot-thick rock armor apron. The rock armoring would extend from the expected maximum water surface to the base of the pile at a slope of 5 horizontal to 1 vertical. Below grade, the rock armor would extend to the maximum scour elevations at a slope of 2 horizontal to 1 vertical. The rock protection requirements for this design are shown in Table B.2.2.

A discussion on the methodology used to design the rock armor wall is provided in Section B.6.

Geomorphology (river meander)

The tailings site is in a meander path of the Colorado River and overlies five to 15 feet of unconsolidated alluvial material. Particle sizes of the alluvium at the site vary from minor amounts of silt sized particles to gravelly sands to cobbly gravels. Given these site conditions, the river could cut through the site if not properly controlled.

The pile would act as a constriction during major flood events causing unstable flow conditions, accelerated velocities, and scouring of alluvium at the site.

The existing islands indicate aggradation normally occurs near the site. Several factors tend to cause sediment aggradation including a de-

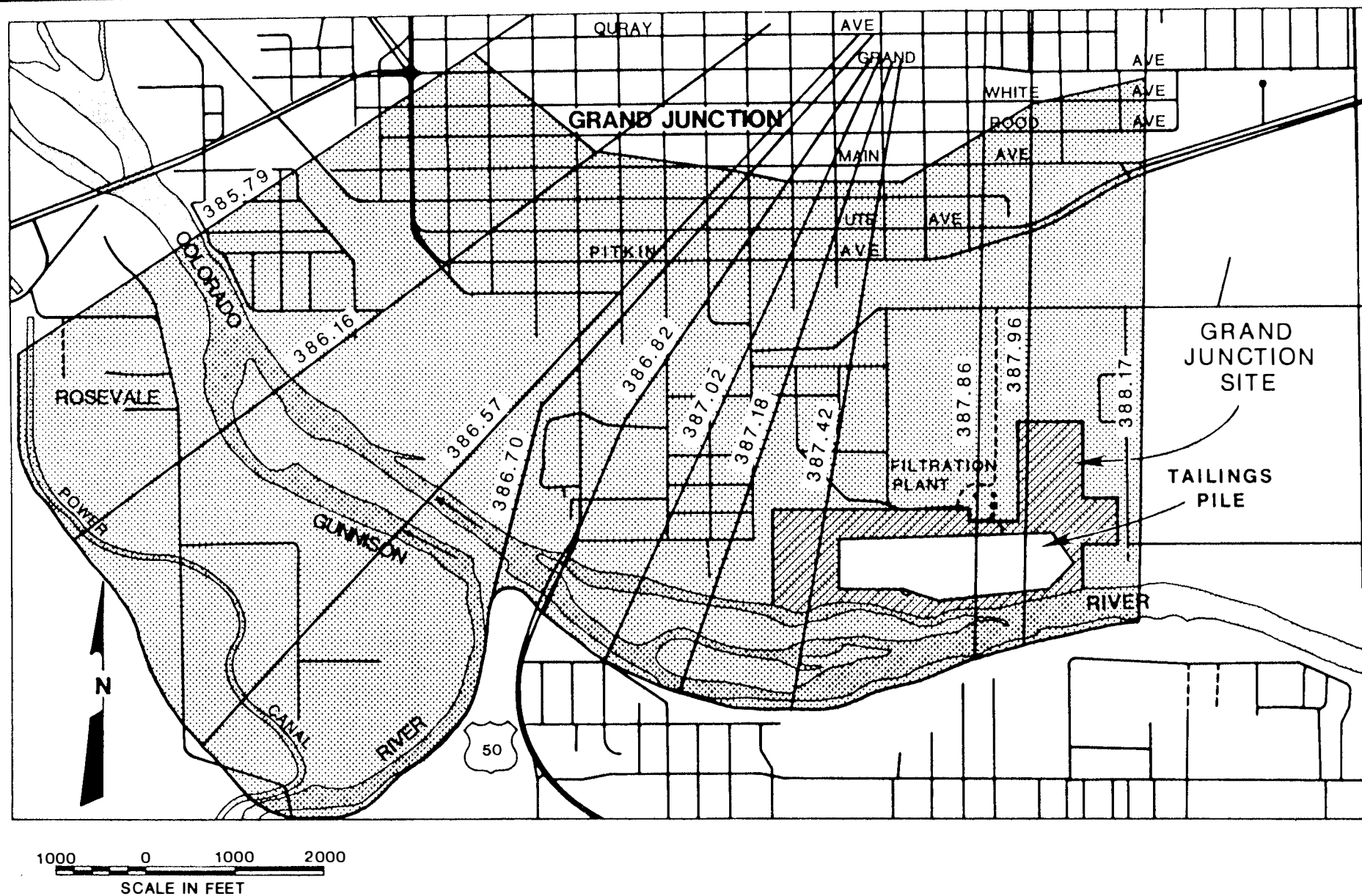


FIGURE B.2.7
LOCATION OF CROSS SECTIONS & FLOODPLAIN BOUNDARIES OF THE PMF EVENT

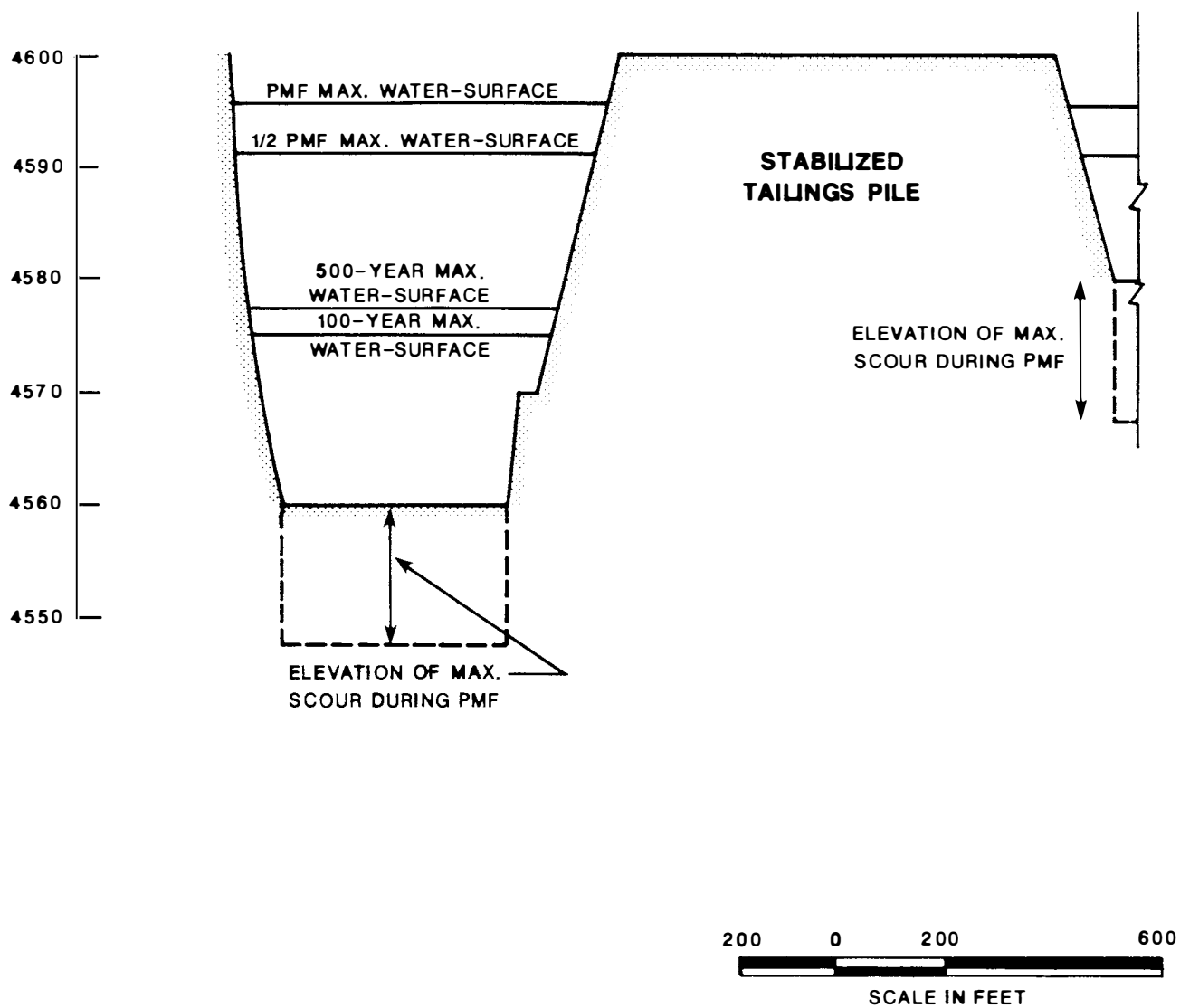


FIGURE B.2.8
CROSS SECTION AT STATION 387.86

Table B.2.2 Flooding - rock protection requirements

Rock size (inches)	Rock thickness (feet)	Design flow
5 to 1 slopes $D_{50} \geq 20$	6	40 feet deep 20 fps
2 to 1 slopes $D_{50} \geq 30$	6	40 feet deep 20 fps

crease of channel gradient, proximity of the confluence with the Gunnison River, and a broad floodplain along the northern bank. Aggradation would likely occur during the receding portion of a large flood and scouring would occur during the peak stages, possibly undermining the tailings pile if not controlled. A detailed description of the geomorphic setting at the Grand Junction site is included in Appendix E, Soils, Geologic, and Seismic Information.

The rock armor apron described in the previous section would be designed to protect the pile from the potential impacts related to channel meander and scour as described above. The rock armor would be constructed around the entire perimeter of the pile and would extend to the maximum calculated depth of scour.

Slope stability/seismic risk

Slope failure due to instability under static and seismic loading is another phenomena that could affect the integrity of the stabilized tailings pile.

Stability analyses were performed for each loading condition to estimate factors of safety against slope failure. In particular, the seismic loading conditions were evaluated by applying the horizontal acceleration resulting at the site from a Maximum Credible Earthquake (MCE). The evaluation estimated an MCE which would generate an on-site effective peak horizontal bedrock acceleration of 0.34g. Details on the seismic analysis for the Grand Junction site are provided in Appendix E, Soils, Geologic, and Seismic Information. A discussion of the methodology involved in the slope stability analysis is presented in Section B.6.

The factors of safety against slope failure under both static and seismic loading for the designed slope exceed generally accepted limits of 1.5 and 1.0 (Sowers, 1979; DOA, 1970), respectively. The static and seismic safety factors calculated for stabilization on site are 2.9 and 1.1, respectively. The calculated short-term factor of safety (immediately following construction) is 4.3.

A principal seismic hazard to the stabilized tailings pile is the potential for slope failure or cover disruptions due to seismically induced liquefaction of saturated tailings or underlying soils. The tailings and contaminated material would be prevented from becoming saturated by the low-permeability earthen cover, subbase layer, and the capillary break layer. Also, any extensive pockets of slimes would be eliminated as the tailings are excavated and blended. Therefore, saturation, a prerequisite for liquefaction, would be eliminated. The fill that would be required to raise the base of the tailings above expected high ground-water levels would be composed of coarse-grained, densely compacted material, thereby eliminating the possibility of liquefaction of the foundation soils. The majority of the existing foundation material is composed of alluvium deposited by the Colorado River; however, zones of silts and clays that exhibit extremely low strength do exist within the existing pile foundation. These zones of weak soils would be removed from the foundation immediately beneath and adjacent to the pile and replaced with compacted coarse-grained fill. The dense, coarse nature of the remaining foundation soils preclude liquefaction at the site based on the projected MCE acceleration.

Settlement and cover cracking

Differential settlement of the stabilized tailings pile has the potential hazard of cracking the cover due to horizontal strains and thus could affect the integrity of the pile. Differential settlement could also increase the potential for gully action due to concentrations of surface runoff.

Due to the difficulty in controlling differential settlement of the reshaped tailings pile, settlement monitoring devices would be installed to measure the total settlement of the tailings and underlying soils caused by reshaping of the tailings. Upon the completion of 90 percent of all of the settlement, the earth cover would be placed over the tailings pile, and the settlement would be monitored again. Final grading and compaction of the earth cover would be performed only after sufficient settlement had occurred to prevent cracking of the earth cover and concentration of surface runoff flows. An additional discussion on settlement is provided in Section B.6.

Frost heave/solifluction

Frost heave and solifluction are processes which pose a hazard to the long-term performance of any structure constructed to isolate the tailings at the site. Climatic conditions at the site favor the occurrence of these processes during the winter.

Frost heave and associated frost creep or frost sloughing are processes which can occur under the climatic conditions at the tailings site. The latter two occur in fine-grained sediments on slopes (Linell and Lobacz, 1980), and can be mitigated by using an aggregate (rock) cover.

Frost heave is the expansion toward the surface from the freeze-thaw cycle and generally has the largest movement from the summer-winter cycle of freeze-thaw. The process requires that adequate soil moisture be present to form ice lenses at boundaries in fine-grained soil which acts as a barrier to water penetration. The remedial action design includes the use of sufficiently impermeable earth materials to restrict ice lens formation and a sufficiently porous surface aggregate layer, in conjunction with a continuous slope to allow drainage across the embankment surface, that would restrict water buildup over the earth cover and mitigate the problem.

Solifluction is the action of slow flowage in saturated soils in periglacial regions (Ritter, 1978). Only the surface layer is affected, and very low slopes can flow if saturated. The remedial action design includes the use of a permeable aggregate (rock) layer above the fine-grained earth cover, in conjunction with a continuous slope to allow drainage across the embankment surface, thus removing the saturation prerequisite for this process and mitigating the hazard.

Plant root, burrowing animals, and human intrusion

Under this alternative, the stabilized tailings would be covered with a five-foot-thick layer of compacted, low-permeability earthen material. This layer would then be covered with a two-foot-thick layer of rock erosion protection material (including filter layer).

This seven-foot-thick layer of rock and compacted soil, along with the rock armor apron around the pile, would inhibit plant root intrusion into the contaminated material. The rock covers would also discourage intrusion by burrowing animals and would inhibit inadvertent human intrusion. The final embankment would be surrounded by a security fence with locked gates and warning signs.

B.2.7 GROUND-WATER PROTECTION

The three uppermost hydrogeologic units in the site vicinity are, in decreasing order with depth, alluvium, Mancos Shale, and Dakota Sandstone. The tailings at the Grand Junction site rest within alluvial deposits of the Colorado River. Depending on location and seasonal variations in the level of the river, between five and 15 feet of alluvium comprise the saturated ground-water system. Some portions of the tailings are below the water table. The direction of ground-water flow is generally parallel to or toward the river, and discharge is ultimately to the river.

The hydraulic conductivity of the alluvium is high enough (greater than 10^{-2} cm/sec) that it could be considered a good aquifer (Davis and DeWiest, 1966). The hydraulic conductivities of the Mancos Shale and the Dakota Sandstone are lower (10^{-4} to 10^{-7} cm/sec). The Mancos Shale is not considered water bearing in the Grand Junction area and the Dakota Sandstone is recognized as yielding only small amounts of water (Lohman, 1965). The Mancos Shale does contain small amounts of ground water near the site. Measured vertical hydraulic gradients are small and it is uncertain at this time whether they are upward or downward.

Water quality in the alluvium is predominantly brackish, although seasonally and very near the river it can be classified as fresh. Water quality in the Mancos Shale and Dakota Sandstone can also be classified as brackish. The Dakota Sandstone also contains oil near the tailings site. Ground water in the alluvium and the Mancos Shale has been contaminated by the tailings. There is no apparent contamination of the Dakota Sandstone near the site. There are no known uses of water from these units in the vicinity of the tailings. One shallow well, upgradient of the tailings, is used to drain low-lying land flooded during high stages of the Colorado River. Potential use of the three units is also thought to be minimal due to the low yields of the lower two units, the brackish quality of the ground water, and the availability of a good quality municipal water supply in the area. The ground-water environment is discussed in detail in Appendix F, Hydrology Report.

The Grand Junction tailings have not impacted any existing use of ground water, and the potential use of shallow ground water near the tailings is thought to be minimal. Despite the lack of impacts on existing or potential uses, the design for stabilization of the tailings on the site incorporates several features which would provide ground-water protection.

Several design features would serve to minimize the potential for contaminant migration from the stabilized tailings pile to the ground-water system. First, the base of the stabilized pile would be at an elevation above maximum expected ground-water levels. This would remove the main source of ground-water contamination at the site, the flow of ground water through the tailings.

Two major design features which would also serve to mitigate potential ground-water contamination at the site are the compacted low permeability earth cover above the tailings and the compacted earth layer below the tailings. The compacted earth cover would be less permeable than the earth layer below the tailings to avoid the possibility of a "bathtub" effect. The layer placed underneath the tailings would be composed of natural recompacted silt and clay soils (ML, MH, and CL designations in the unified soils classification system). These types of soils typically have high adsorption and ion exchange potential and thus would provide a high attenuative capacity to restrict downward contaminant migration. The low permeability (hydraulic conductivity) of the soils in the earth cover would reduce infiltration of water through the tailings pile. Analyses of the design for this alternative indicate that the permeability (hydraulic conductivity) of the soils in the compacted earth cover would have to be approximately 10^{-7} cm/sec. The tailings would be compacted to below the optimum moisture content to minimize drainage from the stabilized pile. Thus, infiltration, the driving force for leachate production, and mobilization of contaminants into the ground-water system would be minimal.

After the tailings have been stabilized, the affected system should be flushed out by flux from the river. Restoration of the affected aquifer would not be necessary because of the lack of current or potential use, and because of the flushing expected after remedial action. Limited measures would be required to prevent use of water from the previously mentioned drainage well upgradient of the site.

B.3 DISPOSAL AT THE CHENEY RESERVOIR ALTERNATE DISPOSAL SITE

B.3.1 INTRODUCTION

This section provides the information necessary to understand the proposed conceptual design for the relocation of the tailings from the former Climax Uranium Mill at Grand Junction, Colorado, to a disposal site identified as Cheney Reservoir which is located approximately 18 miles southeast of the processing site (Figure B.3.1). Two methods of transporting the tailings are evaluated in this section; one includes the relocation of the tailings entirely by truck. Under this alternative, the trucks would be loaded at the former processing site and would deliver their loads directly to the disposal site excavation. The second method includes the relocation of the tailings by loading them onto train cars at the former processing site. The tailings would be transported by train to Whitewater, Colorado, where they would be transferred to trucks. The trucks would haul the tailings to the excavation at the Cheney Reservoir alternate disposal site.

B.3.2 DESIGN FEATURES

The remedial action would stabilize the uranium mill tailings and contaminated material at the Cheney Reservoir site in compliance with EPA standards. The principal feature of the design concept is the removal of all contaminated material from the Grand Junction site and consolidation of this material into a contoured embankment at the Cheney Reservoir site. Major construction activities for this relocation alternative, including the method of transporting the tailings, are discussed in detail in Section B.3.4. Construction design features are listed below.

Truck option

- o Construction of waste-water retention basins at both sites to protect against release of contaminants during remedial action.
- o Installation of temporary security fencing at both sites.
- o Construction of drainage control measures to direct generated waste-water and storm-water runoff to the retention basins during construction activities.

At the Grand Junction site

- o Installation of sheet piling (if necessary) along the south and portions of the southwest and southeast perimeters of the existing pile to retard surface flows from the Colorado River and ground-water intrusion during excavation.
- o Implementation of measures to control erosion and sedimentation from disturbed areas during construction.

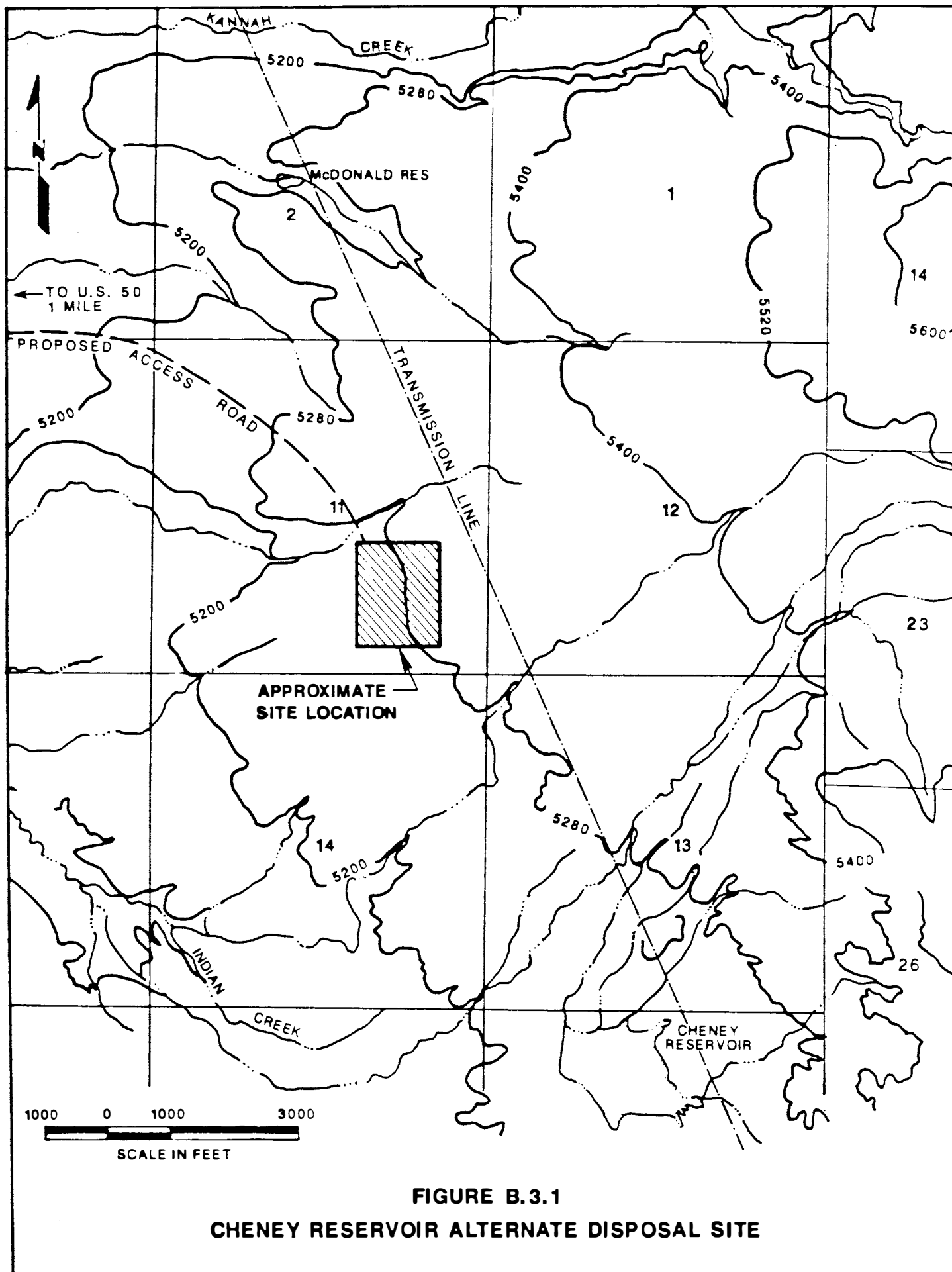


FIGURE B.3.1
CHENEY RESERVOIR ALTERNATE DISPOSAL SITE

- o Installation and operation of a waste-water treatment facility (if necessary) at the Grand Junction processing site to treat contaminated water prior to discharge into the Colorado River.
- o Protection (or relocation) of surface or subsurface utilities at the Grand Junction site during construction.
- o Construction of a truck wash station.
- o Upgrading and construction of the haul route, U.S. Highway 50, where required.
- o Excavation and loading of tailings and other contaminated material on-to trucks.
- o Restoration of excavated areas at the Grand Junction site.
- o Revegetation of disturbed areas at the Grand Junction site.

At the Cheney Reservoir site

- o Construction of an access road from U.S. Highway 50 to the Cheney Reservoir site (approximately two miles).
- o Construction of a truck wash station.
- o Excavation of materials at the Cheney Reservoir site and preparation of a low permeability soil layer.
- o Relocation of the tailings and other contaminated material to the Cheney Reservoir site.
- o Construction of the tailings embankment.
- o Construction of the final cover system over the tailings and contaminated material to inhibit water infiltration, radon exhalation, and wind and water erosion.
- o Restoration of borrow areas at the Cheney Reservoir site.
- o Revegetation of disturbed areas not included in the stabilized pile or access road at the Cheney Reservoir site.

Train and truck option

Construction design features under the train and truck option would be identical to those under the truck option with the exception of the following:

- o Construction of a railroad loadout spur at the Grand Junction site.

- o Construction of a railroad spur and offloading facility at Whitewater, Colorado.
- o Upgrading and construction of the haul route, U.S. Highway 50, from Whitewater, Colorado, to the disposal site.
- o Excavation and loading of tailings and other contaminated material onto train cars.
- o Relocation of tailings and contaminated material from train cars to trucks at Whitewater, Colorado.
- o Relocation of the tailings and other contaminated material by truck from Whitewater, Colorado, to the Cheney Reservoir site.

B.3.3 PERMANENT DESIGN FEATURES

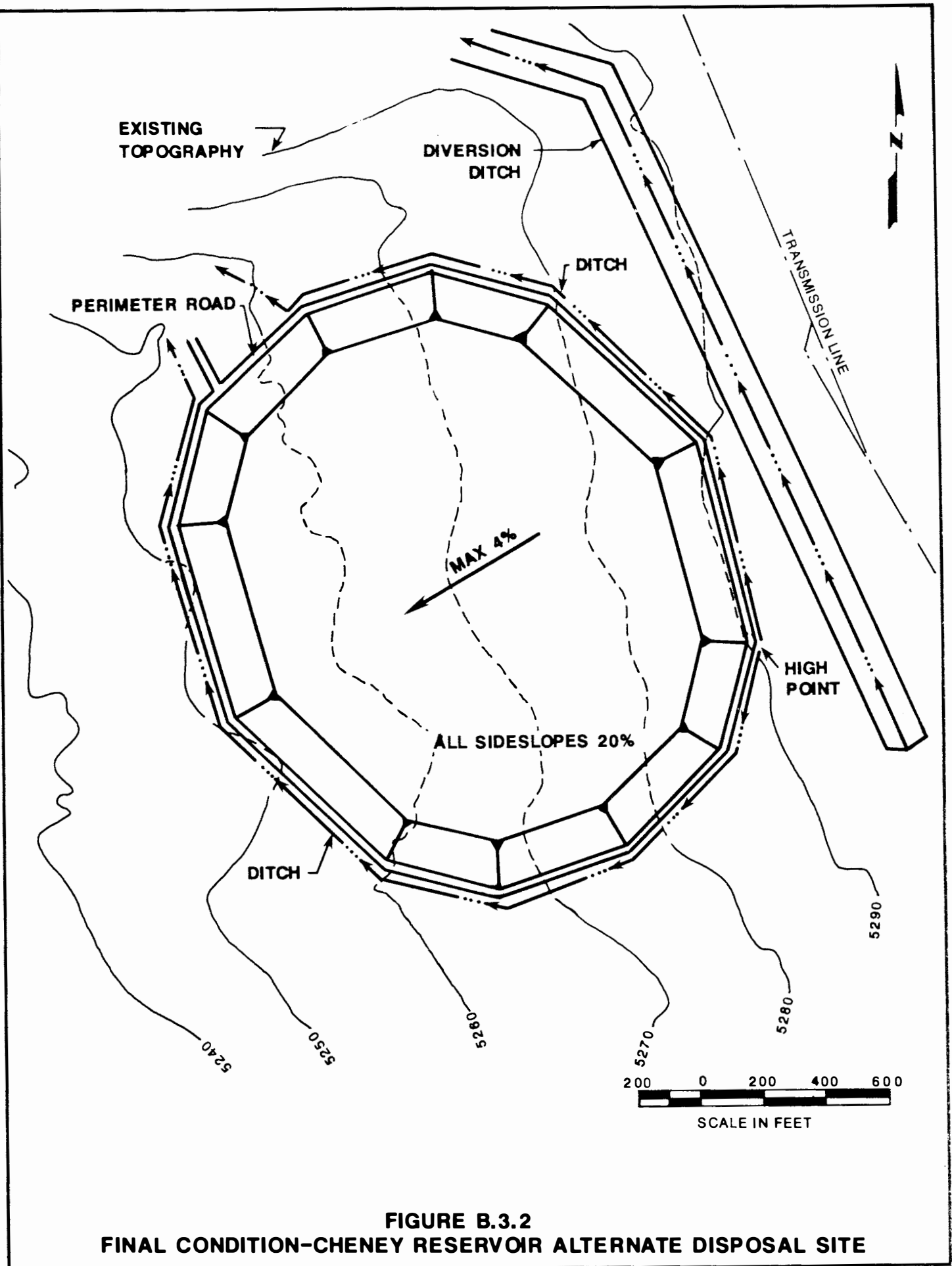
Description of final condition

The stabilized tailings pile would be sized to contain approximately 3.1 million cubic yards of tailings and contaminated material and would cover approximately 62 acres of the disposal site. The entire site would cover approximately 80 acres. The embankment would be constructed in the southeast 1/4 of Section 11, T3S R2E. The disposal site is approximately 18 road miles southeast of the Grand Junction site. The stabilized pile would be located approximately 1.8 miles northeast of U.S. Highway 50.

The tailings and contaminated material would be covered with an approximately five-foot-thick, compacted, earth cover obtained from the surface materials excavated from the disposal area. The stabilized tailings pile would have maximum sideslopes of 20 percent (5 horizontal to 1 vertical) and maximum topslopes of four percent. The entire embankment would be covered with a two-foot layer (including filter layers) of graded rock for erosion protection. The final stabilized pile would be a maximum of 35 feet above the surrounding terrain.

The rock erosion barrier would tie into an unpaved access road which would loop the toe of the stabilized tailings embankment. Drainage ditches adjacent to the pile and an interceptor ditch upstream of the pile would divert surface runoff around and away from the pile. Monuments would be established at set intervals designating the embankment as Federally owned property.

After completion of the stabilized tailings pile at the disposal site and decontamination of the former mill site, the disturbed areas at each site (as required) would be restored with uncontaminated soil to conform with the surrounding terrain, recontoured as necessary for surface drainage, and revegetated as necessary. The proposed final condition of the Cheney Reservoir site is shown in Figure B.3.2.



Decontamination and restoration

The mill area, tailings pile, evaporation ponds area, ore pad, and the State Repository for vicinity properties at the former Grand Junction processing site would be decontaminated by excavation of the contaminated material, demolition of existing structures, and consolidation of this material into the stabilized pile at the Cheney Reservoir site. Contamination exists at the Grand Junction site as described in Section B.2.2 and shown in Figure B.2.2.

After removal of all contaminated material, the areas of excavation on and around the Grand Junction site would be restored with uncontaminated fill to conform with the surrounding terrain, contoured as required for site drainage, and revegetated as necessary.

Tailings pile construction

The stabilized tailings pile would contain approximately 3.1 million cubic yards of contaminated material from the Grand Junction processing site and vicinity properties, and would be designed to provide long-term stability, and minimize radon emanation and ground-water contamination. The pile design would be located to most effectively utilize the natural topography of the area in order to reduce the potential effects of erosion. Details on design rationale are contained in Section B.3.6.

The below-grade excavation of the disposal area would extend to an average depth of 14 feet. Although selective screening would be required, all radon barrier and erosion protection material would be obtained from this excavation. The base of the excavation would be scarified, moisture conditioned, and recompacted. Prior to recompaction, zones of sandy soil would be removed and replaced with less pervious on-site silty or clayey soils.

Relocated tailings would be placed in lifts and compacted on top of the compacted low-permeability soil layer. This layer would reduce the amount and rate of possible contaminant migration. Because the tailings would be mixed during excavation and again during unloading, spreading, and compacting at the Cheney Reservoir disposal site, it is not expected that any extensive lenses of slimes would exist in the compacted tailings. Consequently, differential and total settlement should not adversely affect the long-term integrity of the pile.

Organic material such as wood demolition debris and grubbed vegetation would be evenly distributed throughout the embankment so that no more than five percent organics by volume are contained in any area of the pile. Rubble pieces would be placed in the lower portions of the pile and surrounded with compacted tailings. The procedures for this activity would be specified to ensure the material is placed to avoid concentration in any area and to ensure good compaction of material around the rubble.

Limiting the pile topslopes to a four percent grade and the sideslopes to a 20 percent grade would provide the necessary factor of

safety against embankment slope failure and would reduce the potential effects of erosion.

Cover construction

The tailings radon exhalation rate would be reduced to EPA standards by an approximately five-foot-thick compacted earth layer which would serve as a radon barrier. This cover or earth barrier would be protected by a two-foot-thick layer of rock designed to protect the earth cover and consequently prevent exposure of contaminated material and tailings for 1000 years. The compaction of the earthen barrier would produce an earth cover that retains moisture and retards radon gas diffusion. The rock cover would reduce the potential for drying of the compacted earth cover by trapping soil moisture. The bottom foot of the rock cover would be designed as a graded filter.

The rock layer would be placed over the earth cover and would resist erosion and gully formation thereby protecting the earth barrier and preventing it from being eroded away during any rainstorms that can be expected to occur. The rock layer would be designed to withstand the occurrence of the PMP. The rock layer would also protect the pile from wind erosion and would discourage plant root intrusion and burrowing animals.

A typical cross-section of the Cheney Reservoir pile is shown in Figure B.3.3.

Site drainage

The drainage pattern of the Cheney Reservoir area and the surrounding general site grading have been designed to ensure long-term pile stability. Runoff from the pile as well as surface runoff from surrounding areas would be directed away from and around the embankment by drainage ditches designed to carry the rainfall runoff resulting from the one-hour PMP storm event. A diversion ditch upstream of the pile would intercept flows from the drainage area above the site. Ditches adjacent to the pile would direct flows from the pile itself away from the site. The ditches would be lined with erosion resistant material. Because of the gentle gradient of the site, flow velocities would be non-erosive as flow is directed into the natural drainage patterns west of the disposal area. Sediment buildup in the ditches would be flushed during significant precipitation events, which would create velocities capable of moving sediment. The design of site drainage features is summarized in Section B.6.

Ground-water protection

The stabilized tailings pile would be designed to minimize ground-water contamination. The preparation of the subbase, placement of the tailings, and placement of the low-permeability earth cover would serve to prevent migration of contaminants to the ground-water system. Details are provided in Section B.3.8.

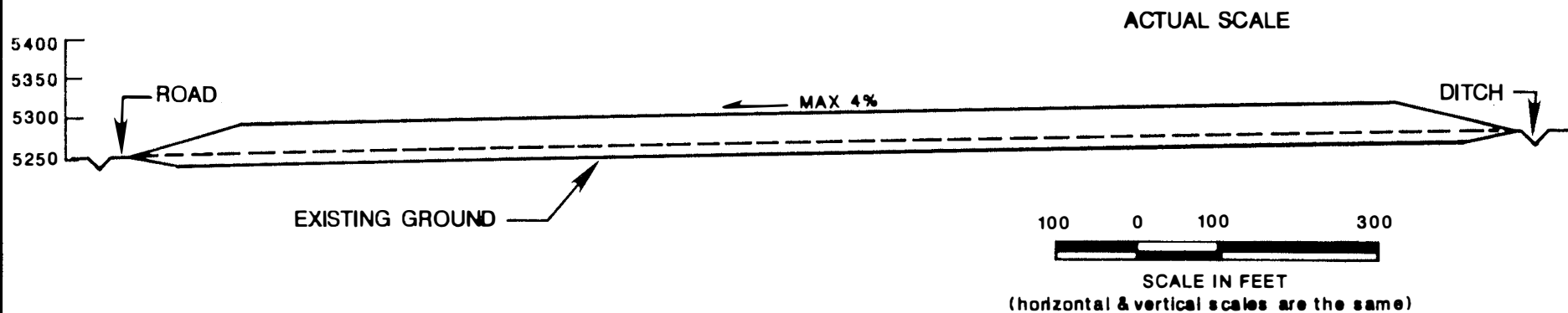
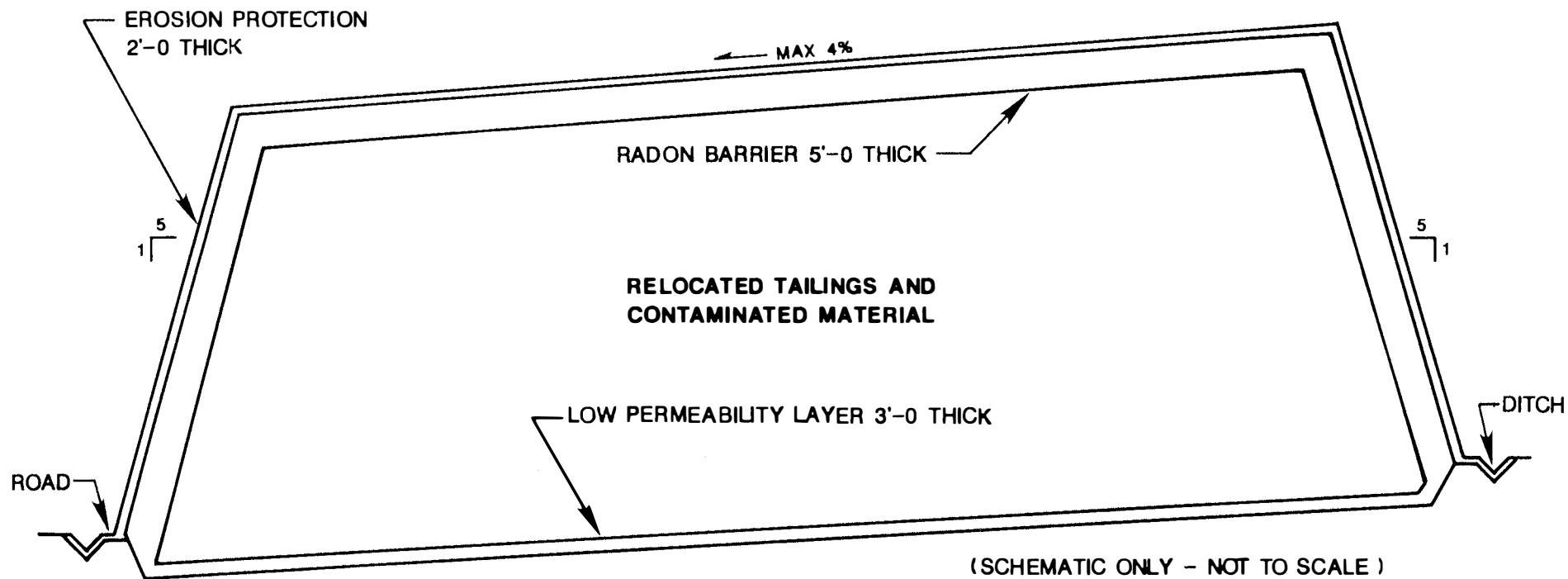


FIGURE B.3.3
TYPICAL CROSS-SECTION - CHENEY RESERVOIR ALTERNATE DISPOSAL SITE

Site access

After remedial action is complete, roads would be constructed along the perimeter of the embankment allowing access for custodial and inspection purposes.

B.3.4 MAJOR CONSTRUCTION ACTIVITIES

B.3.4.1 Layout

Truck option

Construction activities would take place at the processing and disposal sites, and along the haul road, where required.

The exact locations and sizes of all construction features such as the staging areas, decontamination facilities, temporary drainage ditches, and waste-water retention basins would be determined during final design. The following paragraphs present one possible layout and are provided to allow a better understanding of all aspects of the remedial action.

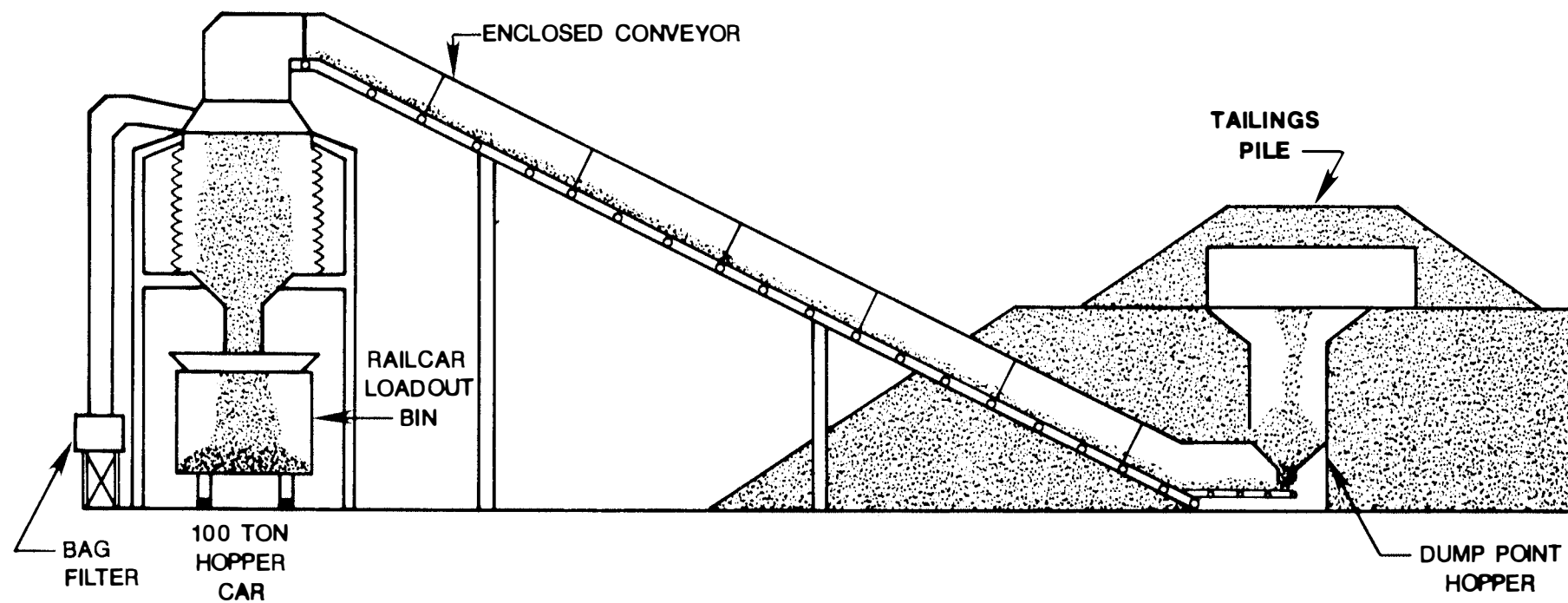
At the processing site, the staging area would be in the former mill area. An equipment decontamination facility would be located adjacent to the staging area. Ditches and berms surrounding the site would direct uncontaminated flows away from the site. Contaminated water would be directed to waste-water retention basins and a treatment facility constructed on the site. A construction fence would surround the area.

At the Cheney Reservoir site, the staging area would be located north of the proposed pile location. An equipment decontamination facility would be located north of the disposal site excavation. Drainage ditches would surround the site and collect all runoff on the site. Flow in these ditches would be channeled to a waste-water retention basin, located west of the pile area. Construction fences would enclose the entire site.

Train and truck option

Construction activities would take place at the processing site, the disposal site, Whitewater, Colorado, and where required along the haul road.

The layout at the processing site would be similar to that under the truck option with the exception of the rail spur, loadout facility, and the additional decontamination equipment (Figure B.3.4). A below grade hopper would be centrally located in the pile. An enclosed conveyor would trans-



(SCHEMATIC ONLY - NOT TO SCALE)

FIGURE B.3.4
TRAIN LOADOUT FACILITY - GRAND JUNCTION SITE (SCHEMATIC)

port the contaminated material from the hopper to the loadout facility. Approximately 9000 feet of rail siding would be required at the Grand Junction site.

Approximately 7000 feet of rail siding and the unloading equipment would be required at the Whitewater site, as well as decontamination facilities for trucks and trains. The unloading equipment would consist of a car positioner, rotary dumper, receiving hopper, and enclosed conveyor system. The unloading equipment would be housed in a prefabricated building equipped with dust suppression facilities. The receiving hopper would be located beneath the rotary dumper. An enclosed conveyor system would link the hopper to an interim storage silo equipped with dust control equipment and to the loadout facility where the trucks would be loaded directly by gravity with a rolling blade gate (Figure B.3.5).

B.3.4.2 Site access

Truck option

Equipment would be decontaminated prior to leaving the Grand Junction processing site and the tailings pile area at Cheney Reservoir. Construction fences would provide control of traffic entering and leaving either site and prevent unauthorized traffic from entering controlled areas.

Traffic would enter and leave the Cheney Reservoir site via a temporary access road constructed north of the tailings pile area. Access to the processing site would be northwest of the existing pile.

A detailed description of the transportation route is presented in Section B.3.4.5.

Train and truck option

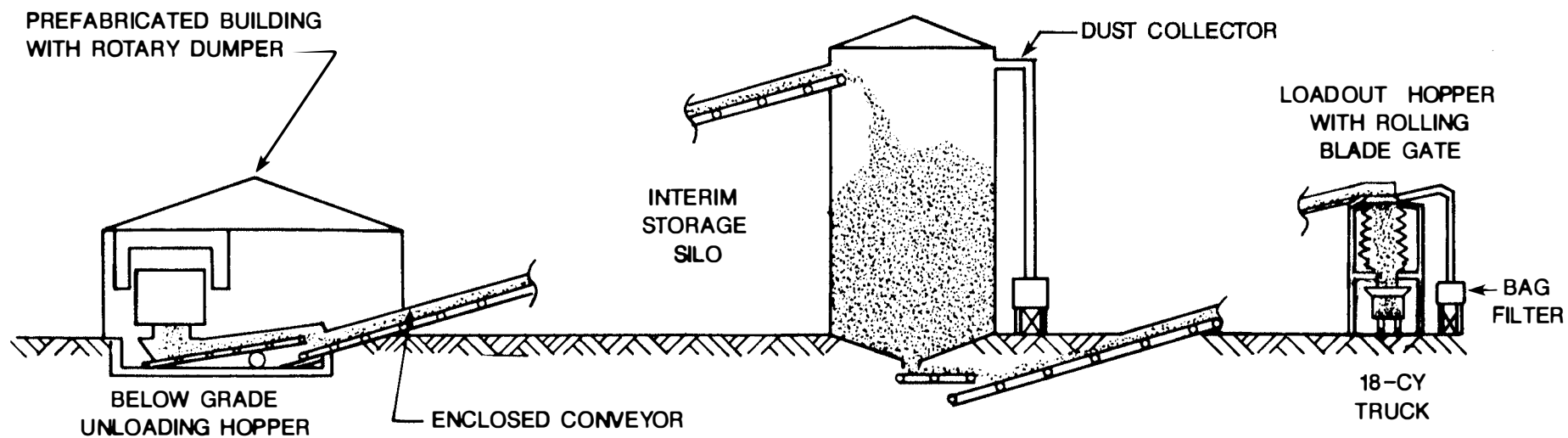
Under this option, a rail spur would enter the Grand Junction site from the northwest, turn approximately 90°, and extend east through the site to southeast of the existing mill building.

Construction fences would enclose the unloading facility at the Whitewater site restricting unauthorized traffic from entering controlled areas.

Site access at the Cheney Reservoir site would be identical to that in the truck option.

B.3.4.3 Staging area facilities

During construction operations, temporary facilities would be required for construction workers along with super-



(SCHEMATIC ONLY - NOT TO SCALE)

FIGURE B.3.5
TRUCK LOADOUT FACILITY, WHITEWATER, CO - SCHEMATIC

visory, engineering, administrative, security, and radiation monitoring personnel at both the processing and disposal sites. The facilities would consist of office space, showers and change facilities for all personnel working on the site, and would include provisions for laundering contaminated clothing. Portable construction toilets would be provided for on-site workers. On-site equipment would be stored in the staging areas. Parking areas would be constructed at all sites.

B.3.4.4 Utilities

All known existing utilities at the Grand Junction site would be protected during construction or would be relocated as necessary prior to construction. Construction activities at the Cheney Reservoir site would be planned so as to avoid the transmission line that traverses north to south, 500 feet east of the proposed disposal location.

Water for dust suppression on contaminated areas at both sites would be obtained from the tailings and subsoil dewatering or would be recycled water from the waste-water retention basins. Potable water, construction water, electricity, gas, and phone service at the Grand Junction site would be obtained from local suppliers.

At the Cheney Reservoir alternate disposal site, electricity could be available from the Grand Valley Rural Utility Company or the Colorado-Ute Electrical Association and telephone service is available from Mountain Bell. However, use of either of these utilities would require extension of existing lines. If this is not cost effective, electricity could be supplied by portable generators and telephone service by radio telephone.

There is no developed water supply at the Cheney Reservoir disposal site. Water for equipment decontamination, compaction, and dust control on the site may be developed from an on-site well drilled approximately 500 to 1000 feet deep or it may be hauled three miles from Kannah Creek or 1.5 miles from Cheney Reservoir. Potable water could be obtained from a city water line located on Kannah Creek, or hauled from the nearest commercial source.

B.3.4.5 Tailings transportation

Truck option

Under this option the tailings and contaminated material would be transported by 18-cubic-yard capacity trucks, equipped with gate seals to prevent leakage. The trucks would be loaded at the former processing site and the contaminated material would be covered with a tarpaulin. Trucks would be

decontaminated prior to leaving the Grand Junction site and would haul the tailings and contaminated material directly to the excavation at the Cheney Reservoir disposal site. The exact transportation route would be determined during final design; however, to allow a better understanding of the proposed action, one possible route is described herein.

After leaving the processing site, trucks would proceed north on 15th St. to D Road. The truck route would then extend east on D Road approximately five miles to the 32 Road (State Highway 146) intersection where the trucks would proceed south for approximately four miles to U.S. Highway 50. The trucks would travel southeast on U.S. Highway 50 to the Cheney Reservoir access road turn-off, approximately 10 miles, then proceed approximately 3.8 miles to the disposal site.

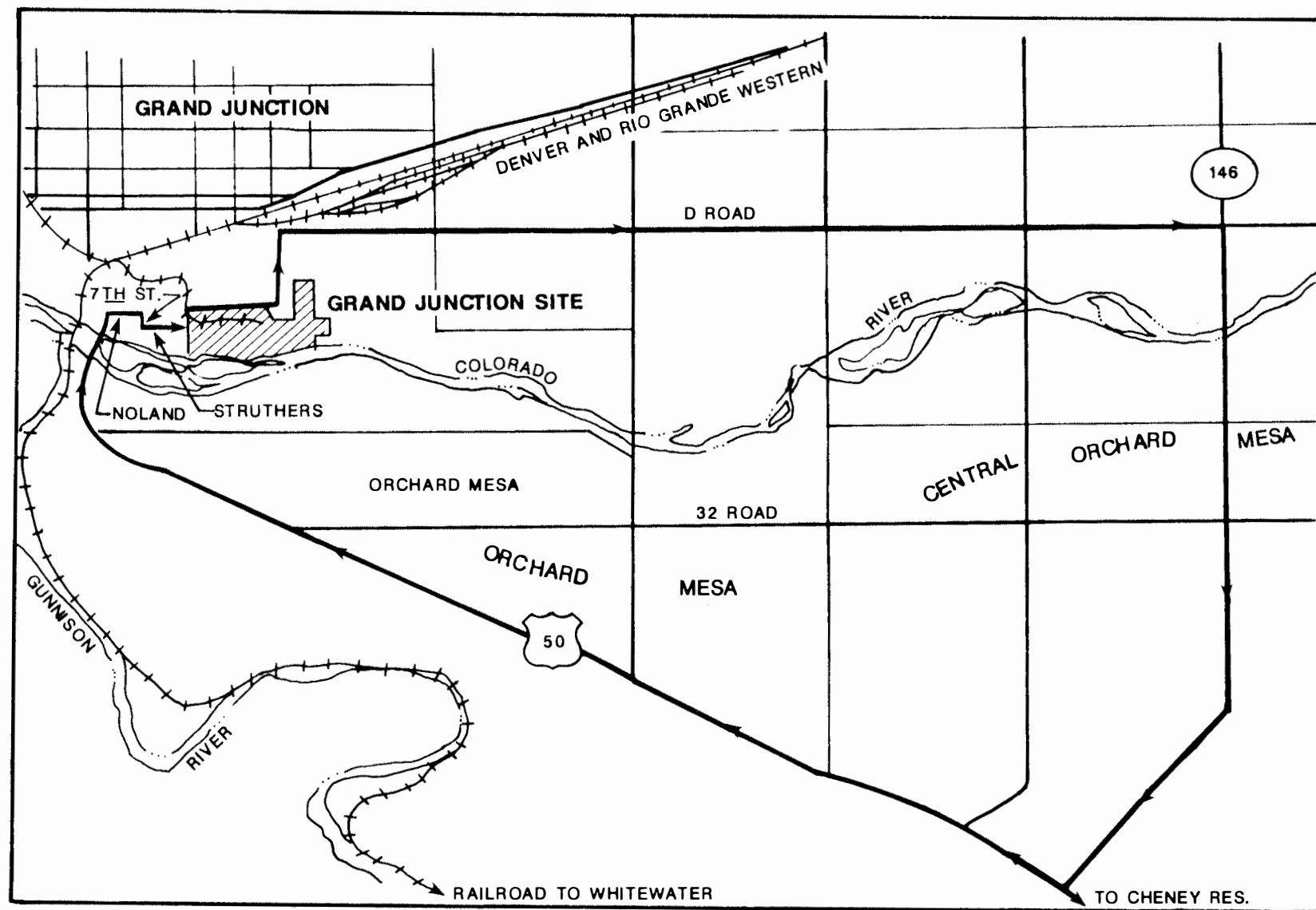
On the return trip, the trucks would drive from the disposal site to U.S. Highway 50. The trucks would proceed along U.S. Highway 50 beyond the bridge over the Colorado River, west of the processing site then turn east on Noland Avenue, south on 7th St., and east on Struthers Avenue to the processing site staging area. The proposed truck route is shown in Figure B.3.6.

Train and truck option

Under this option, the tailings would be transported using one train per day. Two trains of 60, 100-ton-capacity cars would be required. One would be loaded at the Grand Junction site daily while the other was being unloaded at the Whitewater site. The loaded train would be covered, decontaminated, and hauled to Whitewater in the evening. The locomotive engines would leave the loaded train at the Whitewater site and return to the loadout facility with the unloaded train.

Fifty-eight of the railroad cars (per unit train) would be rotary-coupled gondola cars which would be water and sand tight. Large pieces of rubble or other contaminated material which could not be handled by the loading and unloading system could be transported in two side-dump railcars fitted with door seals to prevent release of contaminated materials. To prevent windblown contamination during transport, railcars would be covered with a tarpaulin or canopy.

The tailings and contaminated material would be loaded into trucks at the Whitewater site. The trucks would be covered and decontaminated and would haul their loads directly to the disposal site. The haul route between Whitewater and the Cheney Reservoir site would be identical for both options. The empty train cars would be returned to the processing site.



LEGEND

— TRUCK ROUTE

-+ TRAIN ROUTE

FIGURE B.3.6
PROPOSED TRANSPORTATION ROUTE - CHENEY
RESERVOIR ALTERNATE DISPOSAL SITE

B.3.4.6 Drainage, erosion control, and waste-water retention basins

During remedial action, drainage from all sites would be effectively diverted from any waterways. Areas disturbed by construction activities would be graded to direct runoff into the waste-water retention basins. Drainage ditches would be lined with erosion-resistant materials. Runoff from land outside of affected areas would be diverted away from the site by diversion ditches designed and maintained to prevent overflow.

The waste-water retention basins would be designed to meet the specifications outlined under the stabilization on site option (Section B.2.3.5).

B.3.4.7 Waste-water treatment

Waste water generated from sources mentioned in Section B.2.3.5 would be directed to waste-water retention basins which would provide primary settling, along with flow and contaminant equalization. Some of this water would be utilized for dust control on contaminated areas. The remainder of the water at the processing site would be treated to meet acceptable Federal and Colorado Department of Health water-quality standards before discharge.

B.3.4.8 Dewatering (sheet piling)

Ground water at the Grand Junction site rises into the tailings. To facilitate handling, some of the tailings would require dewatering. Dewatering would be accomplished as discussed under the stabilization on site option (Section B.2.3.7).

Under the disposal at Cheney Reservoir option, it is also required that sheet piles be driven to competent bedrock to form a cutoff wall along the base of the existing pile adjacent to the river and along the southwest and southeast sides of the pile to reduce the dewatering effort and ensure stable excavation slopes.

B.3.4.9 Dust control

Dust generated by excavation, earth movement, vehicle use, temporary material stockpiling, and similar activities would be controlled and minimized by the use of water and water-based surfactants sprayed from hoses or trucks. Special care would be taken to control dust created by building decontamination or demolition and the temporary stockpiling or mixing of contaminated material.

Under the train and truck option, all loading and unloading facilities would be equipped with dust filters or similar dust suppression devices.

The sources for dust suppression water on contaminated areas would include recycled water from the waste-water retention basins, or water from tailings and subsoil dewatering. Uncontaminated water would be used for decontaminated areas.

The schedules for spraying the roads and pile areas may vary daily and would be determined on an hour-by-hour basis in accordance with applicable state permits.

B.3.4.10 Borrow areas

All radon cover, erosion protection, and processing site restoration material would be obtained from borrow areas at or near the disposal site excavation.

B.3.4.11 Restoration of the Grand Junction processing site

Following the removal of all contaminated material, the Grand Junction site would be restored with uncontaminated soil to conform with the surrounding terrain, recontoured to promote drainage, and revegetated. Cost effective measures would be incorporated into the reclamation of the decontaminated site which would be consistent with the long-term land use plans for the site.

Processing site restoration material would be composed of random fill obtained from the disposal site excavation. This material would be transported by truck to the processing site.

B.3.4.12 Construction sequence

The following construction sequence is proposed as a possible sequence for the remedial action. As with the layout (Section B.3.4.1), the final design would contain more detail and the construction subcontractor would be allowed the flexibility of executing his work as he desires, given certain constraints. Therefore, the actual construction sequence may differ from the following.

Each of the alternatives, except no action, was developed using a three-year construction schedule for remedial action. The construction schedule could be extended to four years, or longer, which would decrease the intensity and increase the duration of many of the environmental impacts associated with the project.

Initially, a site security system would be established at each site and coordinated with staging and vehicle decontamination areas. This would provide control of traffic entering and leaving each site and prevent unauthorized traffic from entering either site.

Sheet piling, to inhibit ground-water flow and therefore reduce the dewatering effort would then be driven (if necessary) along the base of the pile adjacent to the river and on the southeast and southwest sides of the pile.

A waste-water treatment facility would be installed and operated at the Grand Junction site to treat contaminated water and to protect against inadvertent contaminant release during construction.

The next major item of site preparation would consist of constructing retention ponds at each site. Materials excavated from each pond would be stockpiled for later use as fill. Site preparation would also include construction of drainage and erosion control measures.

Concurrent with these activities, construction of the access roads and any necessary upgrading of the haul road would begin. Under the train and truck option, all rail spurs and load-unload facilities would also be constructed during site preparation.

Once the initial site preparation at the Cheney Reservoir site is completed, preparation of the disposal area would begin. This would involve the excavation and stockpiling of surface materials to allow for the partially below-grade disposal of the tailings. As the required materials are excavated, the low-permeability layer would be constructed.

Concurrently, the building decontamination and demolition process would be performed. Dewatering activities would also begin at this time. Tailings would be excavated and moved and contaminated materials (as necessary) would be excavated from the windblown areas and evaporation ponds and consolidated into the disposal embankment. However, the movement of contaminated materials could not begin until upgrading of the haul and access roads or rail spurs and load-unload facilities had been completed and a sufficient area had been opened and prepared at the disposal area.

Uncontaminated cover material would be added to the relocated pile after the contaminated materials are in place. The uncontaminated cover material would be obtained from the surface materials excavated from the disposal area. Drainage ditches would be excavated around the stabilized tailings pile. The final stages would involve reestablishing overall site drainage, grading, monitoring for settlement, placement of rock over the stabilized tailings, revegetation of disturbed areas, and the construction of an access road and access barrier around the tailings.

Restoration at the processing site would involve the placement of uncontaminated fill in the excavated areas as required. Fill would be necessary to restore the excavated tailings area and provide drainage. The fill would be obtained from the surface materials excavated and stockpiled at the Cheney Reservoir disposal site. The final stages of restoration at the processing site would involve overall site drainage, grading, and revegetation.

Demobilization would consist of the removal of the remaining waste-water retention basins and temporary drainage ditches. The water would be treated and discharged while the bottom sludges and dikes would be transported to Cheney Reservoir for disposal in the embankment. All decontamination areas would be removed and the equipment cleaned for salvage. The staging areas would be dismantled with the contaminated items either cleaned or buried. All contractor equipment would be decontaminated and inspected prior to release from the contaminated areas.

Figure B.3.7 shows a construction schedule for the Cheney Reservoir option.

B.3.5 RADON CONTROL

Control of radon emissions from the stabilized embankment would be accomplished by placing a compacted, five-foot-thick soil cover over the tailings and other contaminated materials.

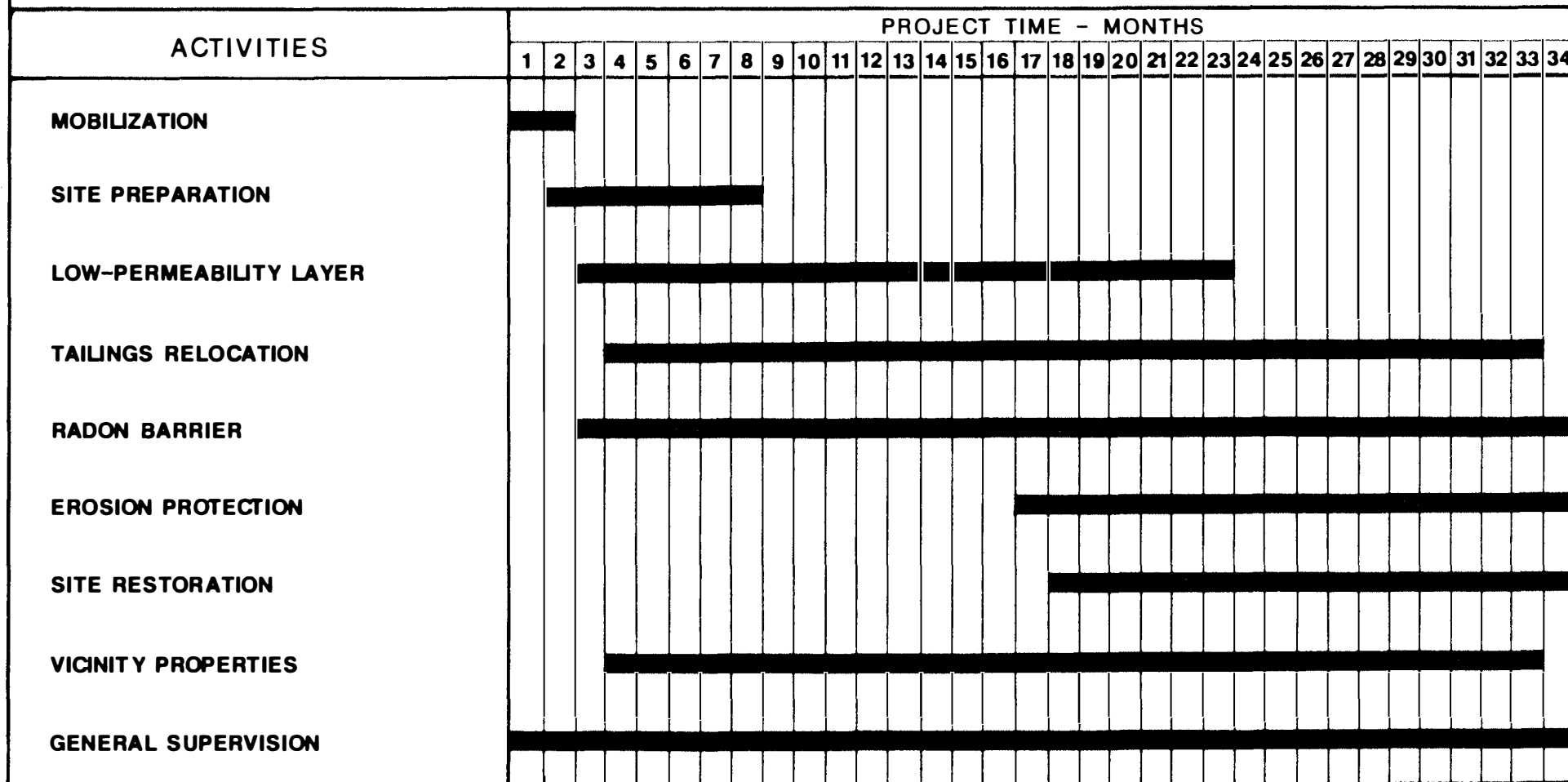
As in the stabilization on site option, data on the distribution of radium in the tailings, on the properties of the borrow material, and on the anticipated depth of excavation in areas to be restored were analyzed using the computer code RAECOM in order to develop an estimate of cover thickness. The actual thickness of the radon barrier may vary depending on additional borrow source evaluation and analyses to be performed during final design.

For purposes of this EIS, the radon barrier required to meet the EPA standard for the Cheney Reservoir tailings pile would be constructed of approximately five feet of material available from the disposal site excavation. Using this thickness and including the additional erosion barrier, radon emissions after remedial action are calculated to be less than 20 pCi/m²s. The data and analyses are available in the DOE UMTRA Project Office, Albuquerque, New Mexico.

B.3.6 DESIGN CONSIDERATIONS

The Cheney Reservoir site is located in a remote, relatively flat area. There are no perennially flowing waters adjacent to the site or elevated ground-water levels in the site area. Therefore, many of the design concerns associated with the stabilization on site option are not relevant for this option. However, since tailings and contaminated material would be relocated from a metropolitan area the issues associated

FIGURE B.3.7 REMEDIAL ACTION SCHEDULE: DISPOSAL AT CHENEY RESERVOIR SITE



with tailings transportation are a major concern. Also, the location and configuration of the pile were evaluated in order to minimize the quantity and size of erosion protection required and to take advantage of the shallow gradients in the site area.

The proposed location was determined in conjunction with the geomorphic analysis of the site. This location would avoid areas experiencing erosional processes, such as gullying or headcutting. The pile would be set back over 200 feet from the closest drainage channel and would not adjoin any areas undergoing headcutting.

Area restriction was not a design concern for this site. Therefore, the height of the sideslopes (20 percent) was limited to provide an extensive topslope area which would be sloped in the direction of the natural topography. This configuration would contain the large quantity of material involved and minimize visual impacts from the pile. Also, smaller rock sizes are required for erosion protection on the gentle four percent slopes than would be required on steeper slopes.

The original concept included a rectangularly shaped pile; however, the pile shape was modified so that the perimeter ditch slopes would provide flow velocities that would effectively drain the site as well as prevent sediment build-up. The upstream diversion ditch was included in the design because of the high runoff velocities and discharges associated with the watershed above the pile during the PMP analysis (see Section B.6).

The truck transportation route was proposed in an attempt to avoid congested areas and minimize left-hand turns. It is recognized that extensive haul road improvements would be required for this disposal option. These improvements and any mitigation efforts would be addressed during final design. Areas of concern include the entire route within the Grand Junction city limits, the two-lane reaches on U.S. Highway 50, and the junction of U.S. Highway 50 with the Cheney Reservoir site access road. The train route was determined to best utilize existing rail networks.

B.3.7 LONG-TERM STABILITY

Water erosion

Severe rainfall events have the potential to develop rills and gullies on the steeper (20 percent) sideslopes of the stabilized tailings pile and erode some or all of the radon cover in small, undefinable areas. One such potential rainfall event is commonly referred to as the PMP. For the Cheney Reservoir site, the local one-hour PMP storm was calculated to be 8.5 inches. Based on this one-hour intensity, a maximum five-minute intensity was calculated based on the time of concentration for flow off the pile. The intensity was then converted to an equivalent one-hour rainfall intensity of 45.9 inches per hour. This PMP would generate sheet flow rates ranging from 1.44 to 1.58 cfs/ft on the pile.

Rock sizes required to withstand sheet erosion on the pile top and sideslopes during a PMP event are shown in Table B.3.1. Discussions on the methodologies used to determine the PMP and the erosion protection requirements are contained in Section B.6.

Table B.3.1 Erosion protection requirements - Cheney Reservoir alternate disposal site

Location	Rock size requirements (inches)	Thickness ^a (inches)	Design flow
Topslopes (4%)	$D_{50} \geq 2.0$ inches	24	1.44 cfs/ft
	$D_{100} \leq 4.0$ inches		
Side-slopes (20%)	$D_{50} \geq 6.0$ inches	24	1.58 cfs/ft
	$D_{100} \leq 12.0$ inches		

^aIncluding filter layer.

To further reduce the potential for water erosion by surface runoff, additional control features were incorporated into the design to reduce surface runoff velocities. The slopes of the stabilized tailings pile would be limited to 5 horizontal to 1 vertical (20 percent). The top of the pile would be gently sloped (a maximum of four percent) to promote drainage.

It is anticipated that a filter layer would be required on the top and sideslopes. The gradations of the filter layer would be determined during final design using the criteria described for the stabilization on site option.

Wind erosion

High wind velocities could damage the radon cover of the stabilized tailings pile if left exposed. The same rock layers used to protect the pile from water erosion would provide sufficient protection of the pile from the effects of potentially erosive wind velocities.

Flood protection

The stabilized tailings pile would be surrounded by drainage ditches designed to protect the contaminated material from the discharge resulting from the occurrence of a PMP on the upstream watershed. A diversion ditch constructed upstream of the stabilized pile (Figure B.3.2) has been designed to intercept flows resulting from a PMP occurrence over the approximately 240-acre drainage area above the Cheney

Reservoir site. The design discharge for this diversion channel is 2600 cfs. The drainage ditches adjacent to the pile would direct flows from downstream of the diversion ditch and from the pile itself around the pile and into the natural drainage patterns west of the site.

The Cheney Reservoir site is situated on a drainage divide. The small ephemeral washes that drain the site area merge with Indian Creek, 0.1 to 0.5 mile downstream of the site. Indian Creek flows into Kannah Creek, four to five miles below the ephemeral wash confluences, and Kannah Creek empties into the Gunnison River about two miles below the Indian Creek confluence. Because of the high elevation of the site (approximately 200 feet above Indian Creek and 500 feet above the Gunnison River) and its distance from the river, the site would not be subject to river flooding. Additional details on surface-water hydrology for the Cheney Reservoir site are provided in Appendix F, Hydrology Report, Section F.1.

Geomorphology

Sheet wash and rill wash are the primary erosive forces currently active on the Cheney Reservoir site. Minor gullying, however, is occurring on the small ephemeral washes that flank the site. Moderate to intense gullying has been observed along Indian Creek. The pile would be located an adequate distance from all gullying. Overall the site is judged to have good long-term stability potential (CGS, 1982). The results of an extensive geomorphic evaluation of the Cheney Reservoir site are included in Appendix E, Soils, Geologic, and Seismic Information.

Slope stability/seismic risk

Slope failure due to slope instability under static and seismic loading is another phenomena that could affect the integrity of the stabilized tailings pile.

Several standard methods of stability analysis were performed for each loading condition to estimate factors of safety against slope failure. In particular, the seismic loading conditions were evaluated by applying the on-site horizontal acceleration resulting from a Maximum Credible Earthquake (MCE). The evaluation estimated an MCE which would generate an on-site effective peak horizontal bedrock acceleration of 0.34g. Details on the seismic analysis are included in Appendix E, Soils, Geologic, and Seismic Information. A discussion of the methodology involved in the slope stability analysis is presented in Section B.6.

The factors of safety against slope failure under both static and seismic loading for the designed slope meet or exceed the generally accepted limits of 1.5 and 1.1, respectively. The static and seismic safety factors calculated for disposal at the Cheney Reservoir site are 3.4 and 1.2, respectively. The short-term factor of safety, immediately following construction, is 3.5.

A principal seismic hazard to the stabilized tailings pile is the potential for slope failure due to seismically induced liquefaction of saturated tailings or underlying soils. The stabilized pile cover and low permeability layer beneath the pile would prevent saturation of the relocated tailings, thereby eliminating the potential for liquefaction of the pile itself. The foundation soils, composed of sandy-silt and clay with gravels, are currently saturated at a minimum depth of about 30 feet. The depth to ground water and the high standard penetration test results (34 blows/ft to refusal) virtually eliminate the potential for liquefaction below the pile.

Settlement and cover cracking

Differential settlement of the stabilized tailings pile has the potential hazard of cracking the cover due to horizontal strains and thus could affect the integrity of the pile. Differential settlement could also increase the potential for gullying action due to concentrations of surface runoff.

Due to the difficulty in controlling differential settlement of the relocated tailings pile, settlement monitoring devices would be installed to measure the total settlement of the tailings and underlying soils in the same manner as described for the stabilization on site option.

Frost heave/solifluction

The processes of frost heave and solifluction which are discussed in detail in Section B.2.6 pose a hazard to the long-term performance of any structure constructed to isolate the tailings.

As in the stabilization on site option, the remedial action design includes the use of sufficiently impermeable earth materials to restrict ice lens formation and a sufficiently porous surface aggregate layer, in conjunction with a continuous slope, to allow drainage across the embankment surface. This would restrict water buildup over the earth cover and eliminate the potential for frost heave (ice lens formation) and the prerequisite for solifluction (saturation).

Plant root, burrowing animals, and human intrusion

The tailings pile at the Cheney Reservoir site would be covered with a five-foot-thick layer of compacted, low permeability earthen material. This layer would then be covered with a two-foot-thick layer of rock erosion protection material (including filter layer).

This seven-foot-thick layer of rock and compacted soil would inhibit plant root intrusion into the contaminated material. The rock cover would also discourage intrusion by burrowing animals and would help prevent inadvertent human intrusion. The final embankment would be surrounded by monuments at set intervals designating the site as Federal property.

B.3.8 GROUND-WATER PROTECTION

The Cheney Reservoir site is a location where shallow ground water represents a minimal resource. Several features of the design for stabilization of the tailings would serve to minimize the potential for contaminant migration from the tailings to the ground water. Ground-water protection is provided both by the design features, and the placement of the tailings at a site where ground water represents a minimal resource.

Ground water at the site was found within unconsolidated deposits overlying the Mancos Shale. The zone of saturation is probably less than ten feet in thickness, and has a measured hydraulic conductivity in the range of 4.8×10^{-6} to 2.1×10^{-5} cm/sec. Because of the thinness and low permeability of the saturated zone, the shallow ground water has small potential as a water resource. The estimated yield of a well completed in the saturated zone is less than three gallons per day.

Ground-water quality upgradient of the site can be described as fresh, however, the quality degrades as the water moves downgradient in contact with the marine-origin Mancos Shale. At the probable recharge source, a diversion ditch approximately 3300 feet upgradient from the site, total dissolved solids (TDS) concentration is probably less than 250 mg/l. At a monitoring well at the upgradient boundary of the site, TDS was measured at a concentration of 3746 mg/l. The brackish quality of the ground water below the site, and the tendency of the Mancos Shale to degrade ground-water quality, also indicate that the potential value of the shallow ground water in the area is minimal.

The Mancos Shale is continuous beneath and adjacent to the site, and has an estimated thickness of more than 400 feet below the site. The thickness of the Mancos Shale effectively protects potential artesian aquifers underlying the shale. A complete description of the ground-water regime in the Cheney Reservoir site area is included in Appendix F, Hydrology Report.

Although the impacts to, and potential use of, ground water are low, two major design features which would also serve to mitigate potential ground-water contamination at the Cheney Reservoir site; one is the compacted low permeability earth cover above the tailings and the other is the compacted earth layer below the tailings. The compacted earth cover would be less permeable than the compacted layer below the tailings to avoid the possibility of a "bathtub" effect. This would be accomplished by compacting the earth cover to a higher density than the layer at the base of the tailings. The layer placed underneath the tailings would be composed of natural recompacted silt and clay soils (ML, SM, and CL designations in the unified soils classification system). These types of soils typically have high adsorption and ion exchange potential and thus would provide an attenuative capacity to restrict downward contaminant migration. The low permeability (hydraulic conductivity) of the soils in the earth cover would reduce infiltration of water through the tailings pile. Lab analyses of recompacted soils taken from test pits at the site indicate that the permeability (hydraulic conductivity) of the soils in the compacted earth cover would be approximately 10^{-6} cm/sec. The tailings would be compacted to below the optimum moisture

content to minimize drainage from the stabilized pile. Thus, infiltration, the driving force for leachate production, and mobilization of contaminants into the ground-water system will be minimal.

Presently the depth to ground water is greater than 30 feet beneath most of the disposal site; therefore, the tailings would be placed well above the water table. The unconsolidated deposits between the tailings and the water table would also have attenuative properties which would minimize contaminant migration.

B.4 DISPOSAL AT THE TWO ROAD ALTERNATE DISPOSAL SITE

B.4.1 INTRODUCTION

This section provides the information necessary to understand the proposed conceptual design for the relocation of the tailings from the former Climax Uranium Mill at Grand Junction, Colorado, to a disposal site identified as the Two Road site which is located approximately 33 miles west of the processing site (Figure B.4.1). Two methods of transporting the tailings are evaluated in this section; one includes the relocation of the tailings entirely by truck. Under this alternative, the trucks would be loaded at the former processing site and would deliver their loads directly to the disposal site excavation. The second method includes the relocation of the tailings by loading them onto train cars at the former processing site. The tailings would be transported by train to Mack, Colorado, where they would be transferred to trucks. The trucks would haul the tailings to the excavation at the Two Road alternate disposal site.

B.4.2 DESIGN FEATURES

The remedial action would stabilize the uranium mill tailings and contaminated material at the Two Road site in compliance with EPA standards. The principal feature of the design concept is the removal of all contaminated material from the Grand Junction site and consolidation of this material into a contoured embankment at the Two Road site. Major construction activities for this relocation alternative, including the method of transporting the tailings, are discussed in detail in Section B.4.4. Construction design features are listed below.

Truck option

- o Construction of waste-water retention basins at both sites to protect against release of contaminants during remedial action.
- o Installation of temporary security fencing at both sites.
- o Construction of drainage control measures to direct generated waste-water and storm-water runoff to the retention basins during construction activities.

At the Grand Junction site

- o Installation of sheet piling (if necessary) along the south and portions of the southwest and southeast perimeters of the existing pile to retard surface flows from the Colorado River and ground-water intrusion during excavation.
- o Implementation of measures to control erosion and sedimentation from disturbed areas during construction.

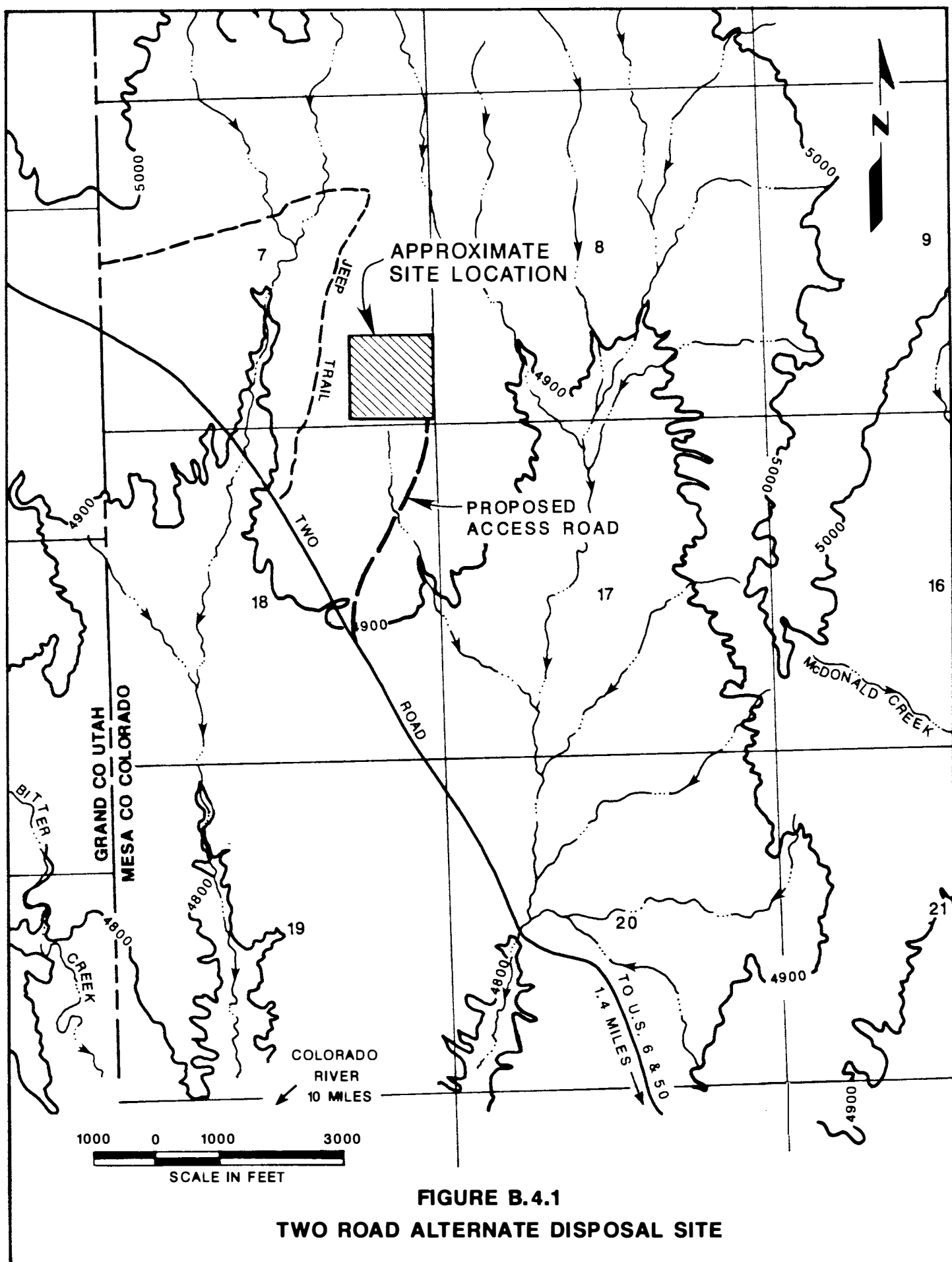


FIGURE B.4.1
TWO ROAD ALTERNATE DISPOSAL SITE

- o Installation and operation of a waste-water treatment facility (if necessary) at the Grand Junction processing site to treat contaminated water prior to discharge into the Colorado River.
- o Protection (or relocation) of surface or subsurface utilities at the Grand Junction site during construction.
- o Construction of a truck wash station.
- o Upgrading and construction of the haul route, U.S. Highway 6 & 50, where required.
- o Excavation and loading of tailings and other contaminated material on-to trucks.
- o Restoration of excavated areas at the Grand Junction site.
- o Revegetation of disturbed areas at the Grand Junction site.

At the Two Road site

- o Construction of an access road from Two Road to the Two Road site (approximately 0.5 mile).
- o Construction of a truck wash station.
- o Excavation of materials at the Two Road site and preparation of a low permeability soil layer.
- o Relocation of the tailings and other contaminated material to the Two Road site.
- o Construction of the tailings embankment.
- o Construction of the final cover system over the tailings and contaminated material to inhibit water infiltration, radon exhalation, and wind and water erosion.
- o Revegetation of disturbed areas not included in the stabilized pile or access road at the Two Road site.

At the Fruita borrow site

- o Excavation of erosion protection material and loading onto trucks.
- o Relocation of borrow material to the Two Road site.

Train and truck option

Construction design features under the train and truck option would be identical to those under the truck option with the exception of the following:

- o Construction of a railroad loadout spur at the Grand Junction site.
- o Construction of a railroad spur and offloading facility at Mack, Colorado.
- o Upgrading and construction of the haul route, U.S. Highway 6 & 50, from Mack, Colorado, to the disposal site, where required.
- o Excavation and loading of tailings and other contaminated material into train cars.
- o Relocation of tailings and contaminated material from train cars to trucks at Mack, Colorado.
- o Relocation of the tailings and other contaminated material by truck from Mack, Colorado, to the Two Road site.

B.4.3 PERMANENT DESIGN FEATURES

Description of final condition

The stabilized tailings pile would be designed to contain approximately 3.1 million cubic yards of tailings and contaminated material and would cover approximately 62 acres of the disposal site. The entire site would cover approximately 80 acres. The embankment would be constructed in the southeast 1/4 of Section T9S R104W. The disposal site is approximately 33 road miles west-northwest of the Grand Junction site. The stabilized pile would be located approximately 3.5 miles north of U.S. Highway 6 & 50 and approximately 2000 feet northeast of Two Road.

The tailings and contaminated material would be covered with an approximately five-foot-thick, compacted, earthen cover obtained from the surface materials excavated from the disposal area. The stabilized tailings pile would have maximum sideslopes of 20 percent (5 horizontal to 1 vertical) and topslopes a maximum of four percent. The entire embankment would be covered with a two-foot layer (including filter layers) of graded rock for erosion protection. The final stabilized pile would be a maximum of approximately 35 feet above the surrounding terrain.

The rock erosion barrier would tie into an unpaved access road which would loop the toe of the stabilized tailings embankment. Drainage ditches adjacent to the pile would divert surface runoff around and away from the pile. Monuments would be established at set intervals designating the embankment as Federally owned property.

After completion of the stabilized tailings pile at the disposal site and decontamination of the former mill site, the disturbed areas at each site (as required) would be restored with uncontaminated soil to conform with the surrounding terrain, recontoured as required for surface drainage, and revegetated as necessary.

The final condition of the Two Road disposal site is shown in Figure B.4.2.

Decontamination and restoration

The mill area tailings pile, evaporation ponds area, ore pad, and the State Repository for vicinity properties at the former Grand Junction processing site would be decontaminated by excavation of the contaminated material, demolition of existing structures, and consolidation of this material into the stabilized pile at the Two Road site. Contamination exists at the Grand Junction site as described in Section B.2.2 and shown in Figure B.2.2.

After removal of all contaminated material, the areas of excavation on and around the Grand Junction site would be restored with uncontaminated fill to conform with the surrounding terrain, contoured as required for site drainage, and revegetated as necessary.

Tailings pile construction

The stabilized tailings pile would contain approximately 3.1 million cubic yards of contaminated material from the Grand Junction processing site and vicinity properties, and would be designed to provide long-term stability, and to minimize radon emanation and ground-water contamination. The pile design would be located to most effectively utilize the natural topography of the area in order to reduce the potential effects of erosion. Details on design rationale are provided in Section B.3.6.

The below-grade excavation of the disposal area would extend to an average depth of nine feet. All radon barrier material would be obtained from this excavation. The base of the excavation would be scarified, moisture conditioned, and recompacted. Prior to recompaction, zones of sandy soil would be removed and replaced with less pervious on-site silty and clayey soils.

Relocated tailings would be placed in lifts and compacted on top of the compacted low permeability soil layer. This layer would reduce the amount and rate of possible contaminant migration. Because the tailings would be mixed during excavation and again during unloading, spreading, and compacting at the Two Road disposal site, it is not expected that any extensive lenses of slimes would exist in the compacted tailings. Consequently, differential and total settlement should not adversely affect the long-term integrity of the pile.

Organic material such as wood demolition debris and grubbed vegetation would be evenly distributed throughout the embankment so that no more than five percent organics by volume are contained in any area of the pile. Rubble pieces would be placed in the lower portions of the pile and surrounded with compacted tailings. The procedures for this activity would be specified to ensure the material is placed to avoid concentration in any area and to ensure good compaction of material around the rubble.

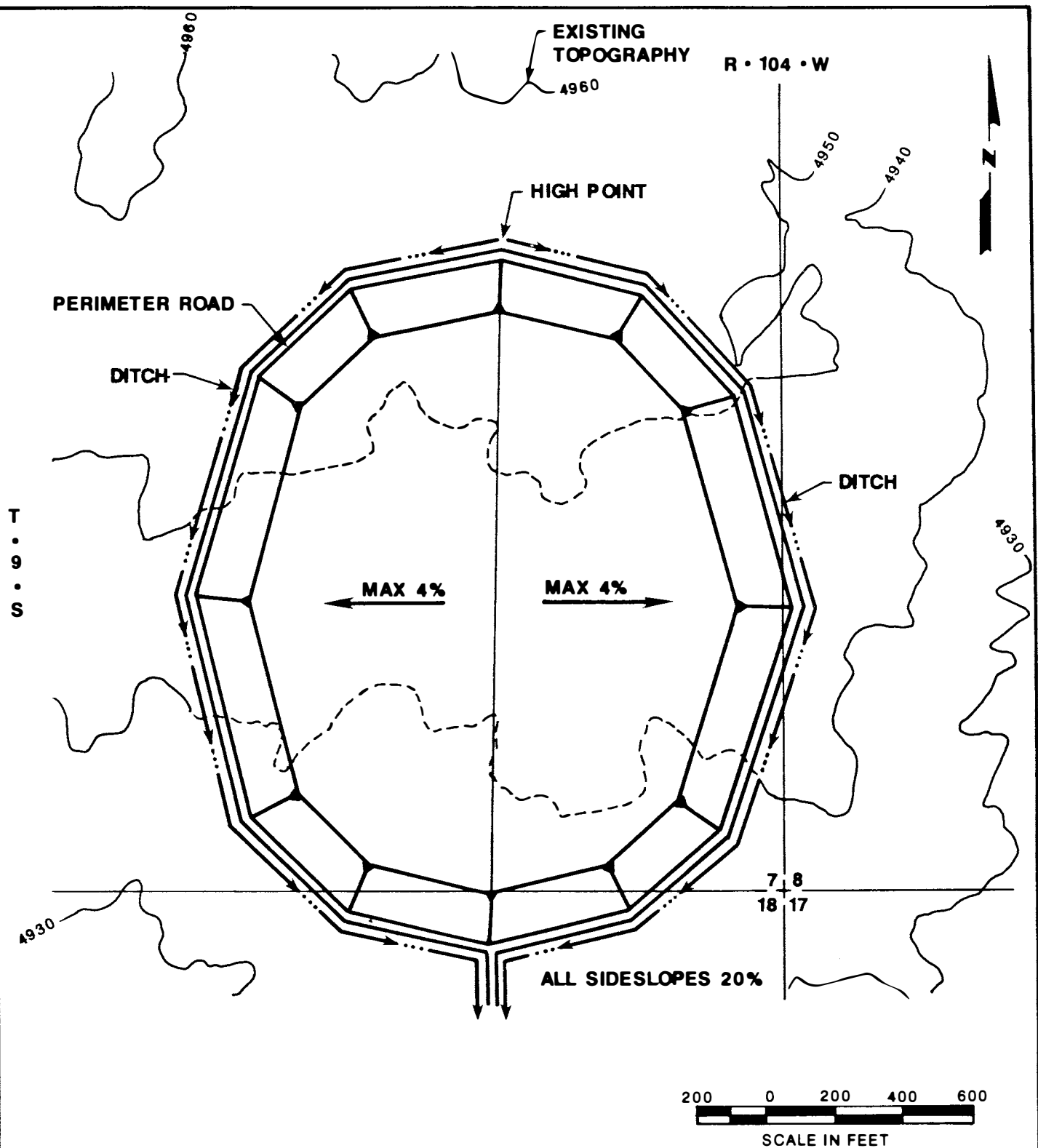


FIGURE B.4.2
FINAL CONDITION-TWO ROAD ALTERNATE DISPOSAL SITE

Limiting the pile topslopes to a four percent grade and the sideslopes to a 20 percent grade would provide the necessary factor of safety against embankment slope failure and would reduce the potential effects of erosion.

Cover construction

The tailings radon exhalation rate would be reduced to EPA standards by an approximately five-foot-thick compacted earth layer which would serve as a radon barrier. This cover or earth barrier would be protected by a two-foot-thick layer of rock designed to protect the earth cover and consequently prevent exposure of contaminated material and tailings for 1000 years. The compaction of the earthen barrier would produce an earth cover that retains moisture and retards radon gas diffusion. The rock cover would reduce the potential for drying of the compacted earth cover by trapping soil moisture. The bottom foot of the rock cover would be designed as a graded filter.

The rock layer would be placed over the earth cover and would resist erosion and gully formation thereby protecting the earth barrier and preventing it from being eroded away during any rainstorms that can be expected to occur. The rock layer would be designed to withstand the occurrence of the PMP. The rock layer would also protect the pile from wind erosion and would discourage plant root intrusion and burrowing animals.

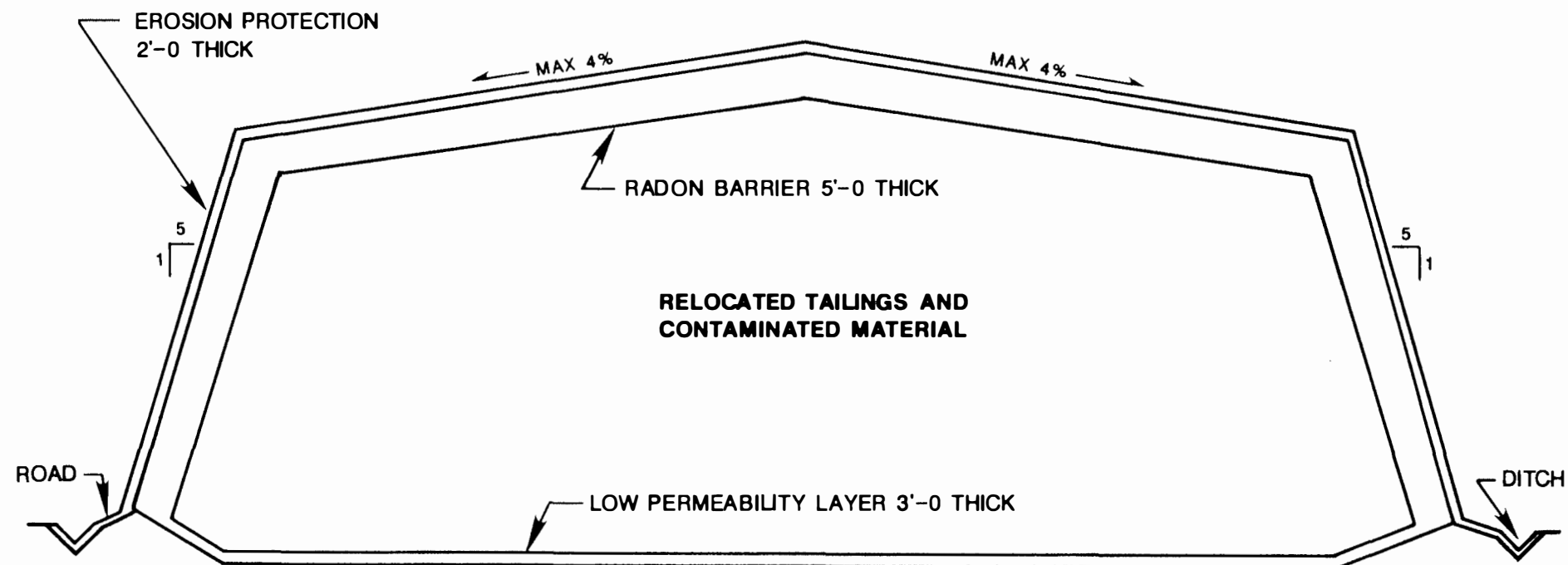
A typical cross section of the Two Road site is shown in Figure B.4.3.

Site drainage

The drainage pattern of the Two Road area and the surrounding general site grading have been designed to ensure long-term pile stability. Runoff from the pile as well as surface runoff from the surrounding area would be directed away from and around the embankment by drainage ditches designed to carry the rainfall runoff resulting from the one-hour PMP storm event. Ditches adjacent to the pile would direct flows from the drainage area upgradient of the pile and the pile itself away from and around the site. The ditches would be lined with erosion resistant material. Because of the gentle gradient of the site, flow velocities would be non-erosive as flow is directed into the natural drainage patterns southwest of the disposal area. Any sediment buildup in the ditches would be flushed during significant precipitation events which would create velocities capable of moving sediment. The design of site drainage features is summarized in Section B.6.

Ground-water protection

The stabilized tailings pile would be designed to minimize ground-water contamination. The preparation of the subbase, placement of the tailings, and placement of the low permeability earth cover would serve to prevent migration of contaminants to the ground-water system. Details are provided in Section B.4.8.



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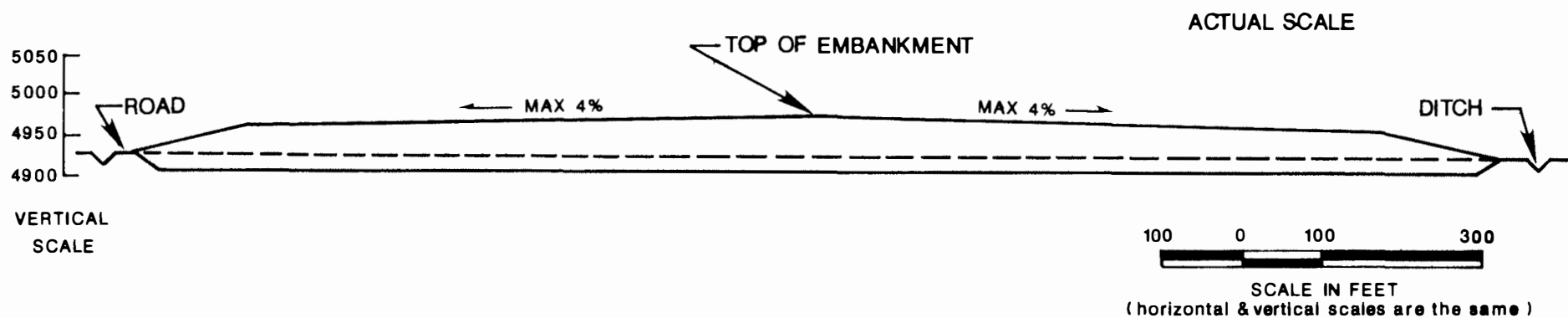


FIGURE B.4.3
TYPICAL CROSS-SECTION - TWO ROAD ALTERNATE DISPOSAL SITE

Site access

After remedial action is complete, roads would be constructed along the perimeter of the embankment allowing access for custodial and inspection purposes.

B.4.4 MAJOR CONSTRUCTION ACTIVITIES

B.4.4.1 Layout

Truck option

Construction activities would take place at the processing and disposal sites, and along the haul road, where required.

The exact locations and sizes of all construction features such as the staging areas, decontamination facilities, temporary drainage ditches, and waste-water retention basins will be determined during final design. The following paragraphs present one possible layout and are provided to allow a better understanding of all aspects of the remedial action.

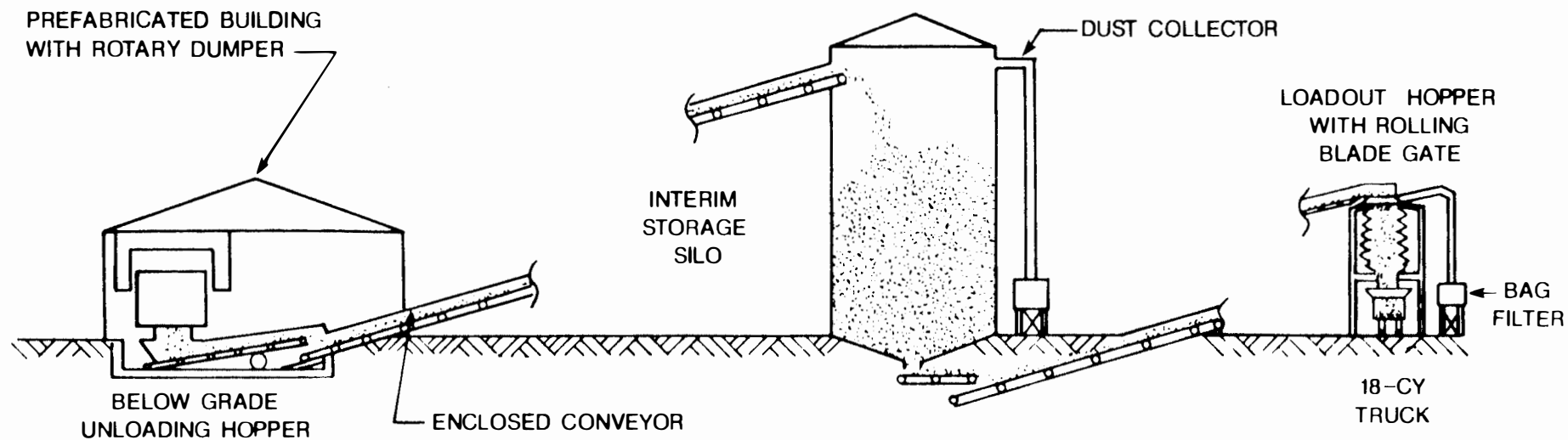
At the processing site, the staging area would be in the former mill area. An equipment decontamination facility would be located adjacent to the staging area. Ditches and berms surrounding the site would direct uncontaminated flows away from the site. Contaminated water would be directed to waste-water retention basins and a treatment facility constructed on the site. A construction fence would surround the area.

At the Two Road site, the staging area would be located southwest of the proposed pile location. An equipment decontamination facility would be located southwest of the disposal site excavation. Drainage ditches would surround the site and collect all runoff on the site. Flow in these ditches would be channeled to a waste-water retention basin, located south of the pile area. Construction fences would enclose the entire site.

Train and truck option

Construction activities would take place at the processing site, the disposal site, Mack, Colorado, and where required along the haul road.

The layout at the processing site would be similar to that under the truck option with the exception of the rail spur, loadout facility, and the additional decontamination equipment (Figure B.4.4). A below grade hopper would be centrally located in the pile. An enclosed conveyor would trans-



(SCHEMATIC ONLY - NOT TO SCALE)

FIGURE B.4.4
TRUCK LOADOUT FACILITY, MACK, CO - SCHEMATIC

port the contaminated material from the hopper to the loadout facility. Approximately 9000 feet of rail siding would be required at the Grand Junction site.

Approximately 7000 feet of rail siding and the unloading equipment would be required at the Mack site, as well as decontamination facilities for trucks and trains. The unloading equipment would consist of a car positioner, rotary dumper, receiving hopper, and enclosed conveyor system. The unloading equipment would be housed in a prefabricated building equipped with dust suppression facilities. The receiving hopper would be located beneath the rotary dumper. An enclosed conveyor system would link the hopper to an interim storage silo equipped with dust control equipment and to the loadout facility where the trucks would be loaded directly by gravity with a rolling blade gate (see Figure B.4.4).

B.4.4.2 Site access

Truck option

Equipment would be decontaminated prior to leaving the Grand Junction processing site and the tailings pile area at Cheney Reservoir. Construction fences would provide control of traffic entering and leaving either site and prevent unauthorized traffic from entering controlled areas.

Traffic would enter and leave the Two Road site via a temporary access road constructed southwest of the tailings pile area. Access to the processing site would be northwest of the existing pile.

A detailed description of the truck transportation route is provided in Section B.4.4.5.

Train and truck option

Under this option, a rail spur would enter the Grand Junction site from the northwest, turn approximately 90°, and extend east through the site to southeast of the existing mill building.

Construction fences would enclose the unloading facility at the Mack site restricting unauthorized traffic from entering controlled areas.

Site access at the Two Road site would be identical to that in the truck option.

B.4.4.3 Staging area facilities

During construction operations, the temporary facilities required for construction workers, supervisory, engineering,

administrative, security, and radiation monitoring personnel at both the processing and disposal sites would be identical to those described for the Cheney Reservoir disposal option.

B.4.4.4 Utilities

All known existing utilities at the Grand Junction site would be protected during construction or would be relocated as necessary prior to construction. Construction activities at the Two Road site would be planned so as to avoid the pipeline that is located approximately 4500 feet northwest of the proposed disposal location.

Water for dust suppression on contaminated areas at both sites would be obtained from the tailings and subsoil dewatering or would be recycled water from the waste-water retention basins. Potable water, construction water, electricity, gas, and phone service at the Grand Junction site would be obtained from local suppliers.

Electricity at the Two Road site would be available from the Grand Valley Rural Utility Company and telephone service would be available from Mountain Bell. However, the use of either of these utilities would require extension of existing lines. If this is not feasible, electricity could be supplied by portable generators and telephone service by radio telephone.

There is no developed water supply at the Two Road disposal site. Water for equipment decontamination, compaction, and dust control on the site may be developed from an on-site well that would have to be drilled to a depth in excess of 1000 feet. If this is not cost effective, compaction water may be trucked from East Salt Creek, approximately eight miles east of the Two Road site, or obtained through the Ute Water Conservancy District. Potable water could also be provided by the Ute Water Conservancy District.

B.4.4.5 Tailings transportation

Truck option

Under this option the tailings and contaminated material would be transported by 18-cubic-yard capacity trucks, equipped with gate seals to prevent leakage. The trucks would be loaded at the former processing site and the contaminated material would be covered with a tarpaulin. Trucks would be decontaminated prior to leaving the Grand Junction site and would haul the tailings and contaminated material directly to the excavation at the Two Road disposal site. The exact transportation route would be determined during final design; however, to allow a better understanding of the proposed action, one possible route is described herein.

Upon leaving the processing site, the trucks would proceed west on Struthers Avenue to 9th Street where they would turn north. The route would extend north on 9th Street to Ute Avenue and west on Ute Avenue to 1st Street (U.S. Highway 50). Trucks would travel northwest on 1st Street for approximately 5.5 miles to Interstate 70 and west on Interstate 70 for approximately 17 miles to the Mack exit. At Mack the trucks would proceed west on U.S. Highway 6 & 50 approximately 6.8 miles to Two Road, and north approximately 3.4 miles on Two Road to the access road turnoff. The disposal area would be located approximately 2000 feet northeast of Two Road.

The trucks would return to the Grand Junction processing site by the same route, except they would proceed east on Pitkin Avenue rather than Ute Avenue. The truck route is shown in Figure B.4.5.

Train and truck option

Under this option, the tailings would be transported using one train per day in the same manner as described for the Cheney Reservoir train and truck disposal option. However, the trains would be unloaded to trucks at Mack, Colorado. The haul route between Mack and the alternate disposal site would be the same as in the truck option. The arrangement of the railroad cars (per unit train) would also be identical to that described for the Cheney Reservoir disposal option.

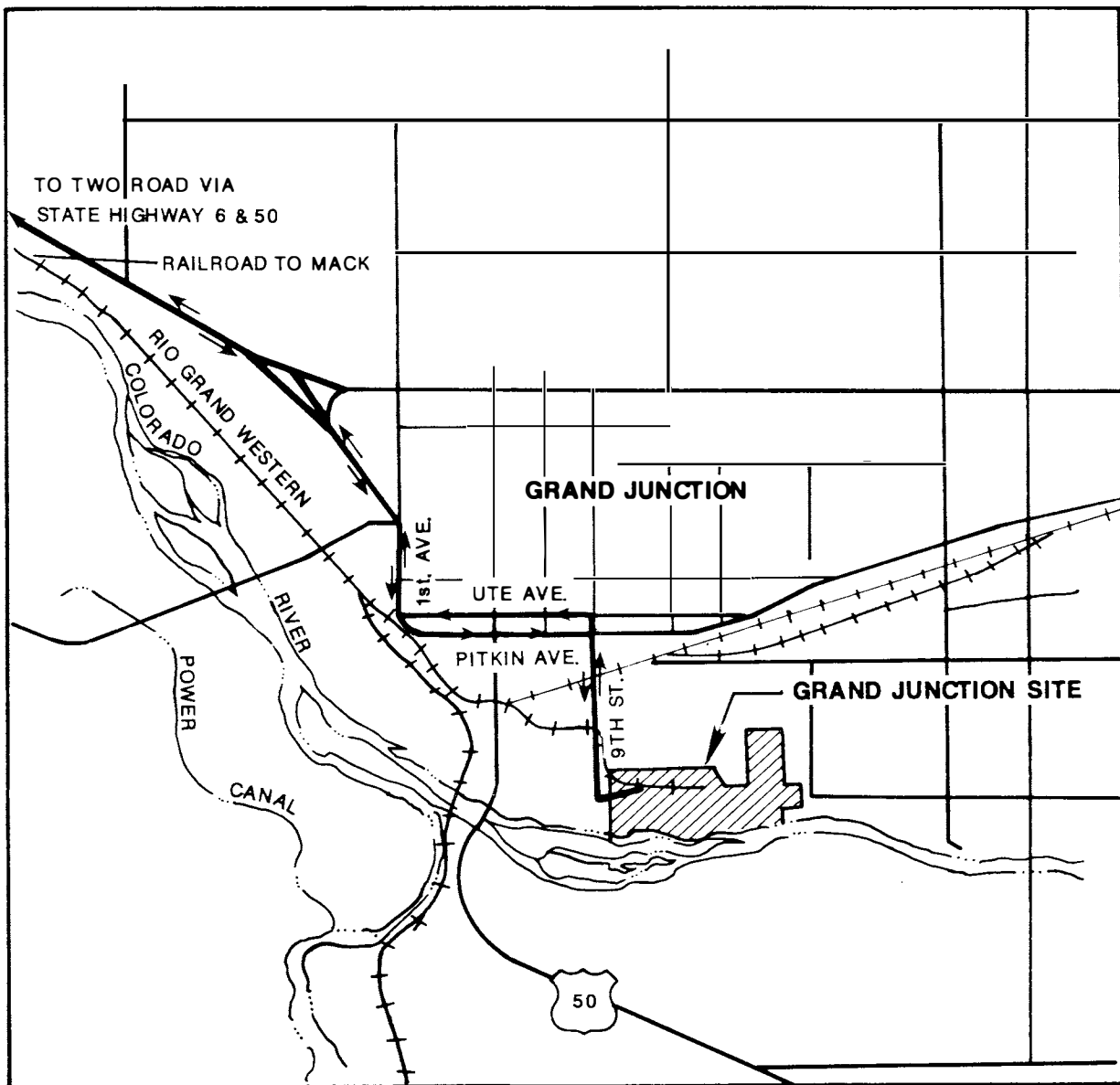
B.4.4.6 Drainage, erosion control, and waste-water retention basins

During remedial action, drainage from all sites would be effectively diverted from any waterways. Areas disturbed by construction activities would be graded to direct runoff into the waste-water retention basins. Drainage ditches would be lined with erosion-resistant materials. Runoff from land outside of affected areas would be diverted away from the site by diversion ditches designed and maintained to prevent overflow.

The waste-water retention basins would be designed to meet the specifications outlined under the stabilization on site option (Section B.2.3.5).

B.4.4.7 Waste-water treatment

Waste water generated from sources mentioned in Section B.2.3.5 would be directed to waste-water retention basins which would provide primary settling, along with flow and contaminant equalization. Some of this water would be utilized for dust control on contaminated areas. The remainder of the



LEGEND

- ← TRUCK ROUTE
- + + TRAIN ROUTE

FIGURE B.4.5

**PROPOSED TRANSPORTATION ROUTE - TWO ROAD
ALTERNATE DISPOSAL SITE**

water at the processing site would be treated (if necessary) to meet acceptable Federal and Colorado Department of Health water-quality standards before discharge.

B.4.4.8 Dewatering (sheet piling)

Ground water at the Grand Junction site rises into the tailings. To facilitate handling, some of the tailings would require dewatering.

Dewatering would be accomplished as discussed under the stabilization on site option (Section B.2.3.7).

As with the other disposal options, sheet piles would be driven (if necessary) to competent bedrock to form a cutoff wall along the base of the pile in order to reduce the dewatering effort and ensure stable excavation slopes.

B.4.4.9 Dust control

Dust generated by excavation, earth movement, vehicle use, temporary material stockpiling, and similar activities would be controlled and minimized by the use of water and water-based surfactants sprayed from hoses or trucks. Details on dust control are identical to those described in the other relocation option (Section B.3.4.9).

B.4.4.10 Borrow areas

All earth cover and processing site restoration material would be obtained from the disposal site excavation. Rock and gravel for use as erosion protection material would be obtained from commercial pits in Fruita, Colorado.

B.4.4.11 Restoration of the Grand Junction processing site

Following the removal of all contaminated material, the Grand Junction site would be restored with uncontaminated soil in the same manner as described for the Cheney Reservoir disposal option.

B.4.4.12 Construction sequence

The proposed construction sequence for the Two Road disposal option is identical to that proposed for the Cheney Reservoir option. As with the other disposal alternatives, the final design would contain more detail and the construction subcontractor would be allowed the flexibility of executing his work as he desires, given certain constraints.

Each of the alternatives, except no action, was developed using a three-year construction schedule for remedial action. The construction schedule could be extended to four years, or longer, which would decrease the intensity and increase the duration of many of the environmental impacts associated with the project.

Figure B.4.6 shows a construction schedule for this alternative.

B.4.5 RADON CONTROL

Control of radon emissions from the stabilized embankment would be accomplished by placing a compacted, five-foot-thick soil cover over the tailings and other contaminated material.

As in the other disposal options, data on the distribution of radium in the tailings, on the properties of the borrow material, and on the anticipated depth of excavation in areas to be restored were analyzed using the computer code RAECOM in order to develop an estimate of cover thickness. The actual thickness of the radon barrier may vary depending on additional borrow source evaluation and analyses to be performed during final design.

For purposes of this EIS, the radon barrier required to meet the EPA standard for the Two Road tailings pile would be constructed of approximately five feet of material available from the disposal site excavation. Using this thickness and including the additional erosion barrier, radon₂ emissions after remedial action are calculated to be less than 20 pCi/m²s. The data and analyses are available in the DOE UMTRA Project Office, Albuquerque, New Mexico.

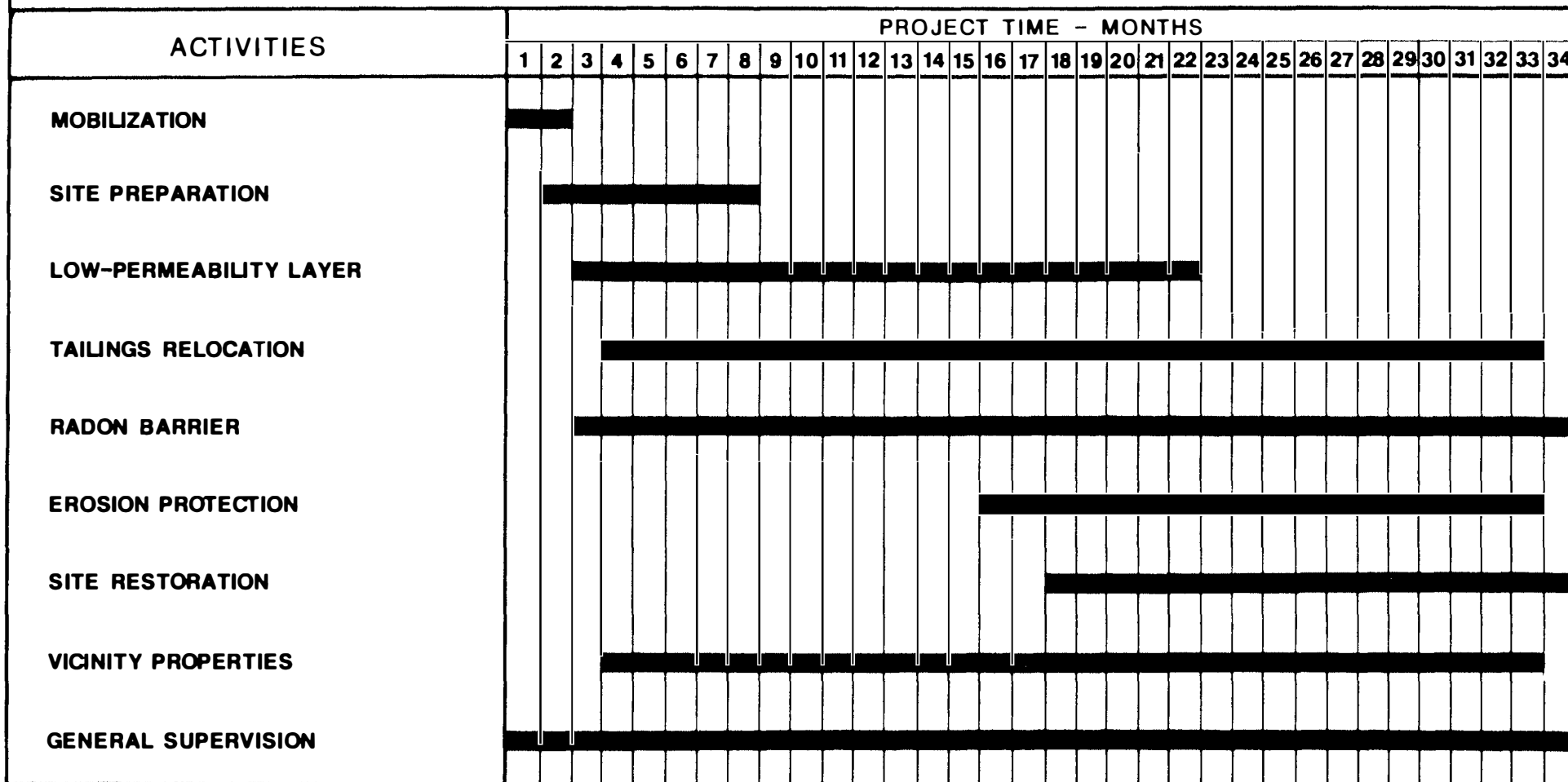
B.4.6 DESIGN CONSIDERATIONS

The major design considerations for the Two Road disposal options are similar to those discussed for the Cheney Reservoir site with certain exceptions. Since the upstream watershed is smaller at the Two Road site, PMP runoff would not require an upstream diversion ditch. The lack of gravel and cobble sized material at the site requires that erosion protection material would be obtained at a designated borrow site (Fruita). Therefore, the disposal site excavation would extend to only approximately nine feet to obtain the radon barrier material.

As in the Cheney Reservoir option, the pile would be located away from drainage channels undergoing erosion or headcutting. The pile would be pointed on the upstream end in order to split flows from the small upstream watershed. The topslopes would be crowned in order to minimize flow lengths and thereby reduce required rock sizes on the sideslopes and in the perimeter ditches.

Extensive haul road improvements and mitigation efforts would be required for this disposal option. These efforts would be concentrated along the haul route within the city limits of Grand Junction and along

FIGURE B.4.6 REMEDIAL ACTION SCHEDULE: DISPOSAL AT TWO ROAD SITE



U.S. Highway 6 & 50, and would be addressed in detail during final design. The proposed route was determined in an effort to avoid congested areas and minimize left-hand turns. The proposed train route would utilize existing rail networks.

B.4.7 LONG-TERM STABILITY

Water erosion

As in the other disposal options, severe rainfall events, such as the PMP, have the potential to develop rills and gullies on the steeper (20 percent) sideslopes of the stabilized tailings pile and erode some or all of the radon cover in small, undefinable areas. For the Two Road site, the local one-hour PMP storm was calculated to be 8.2 inches. Based on this one-hour intensity, a maximum five-minute intensity was calculated based on the time of concentration for flow off the pile. The intensity was then converted to an equivalent one-hour rainfall intensity of 44.3 inches per hour. This PMP would generate sheet flow rates ranging from 0.68 to 0.86 cfs/ft on the pile.

Rock sizes required to withstand sheet erosion on the pile top and sideslopes during a PMP event are shown in Table B.4.1. Discussions on the methodologies used to determine the PMP and the erosion protection requirements are provided in Section B.6.

Table B.4.1 Erosion protection requirements - Two Road alternate disposal site

Location	Rock size requirements (inches)	Thickness (inches)	Design flow
Topslopes (4%)	$D_{50} \geq 1.5$ inches	24	0.68 cfs/ft
	$D_{100} \leq 3.0$ inches		
Side-slopes (20%)	$D_{50} \geq 4.0$ inches	24	0.86 cfs/ft
	$D_{100} \leq 8.0$ inches		

^aIncluding filter layers.

To further reduce the potential for water erosion by surface runoff, additional control features were incorporated into the design to reduce surface runoff velocities. The slopes of the stabilized tailings pile would be limited to 5 horizontal to 1 vertical (20 percent). The top of the pile would be gently sloped (a maximum of four percent) to promote drainage.

It is anticipated that a filter layer would be required on the top and sideslopes. The gradations of the filter layer would be determined during final design using the criteria described for the other disposal options.

Wind erosion

High wind velocities could damage the radon cover of the stabilized tailings pile if left exposed. The same rock layers used to protect the pile from water erosion would provide sufficient protection of the pile from the effects of potentially erosive wind velocities.

Flood protection

The stabilized tailings pile would be surrounded by drainage ditches designed to protect the contaminated materials from the peak flows resulting from the occurrence of a PMP over the 34-acre drainage area above the Two Road site. These ditches would be lined with erosion resistant material and would direct flows from the drainage area and the pile around the pile and into the natural drainage patterns south of the site.

There are no major streams, lakes, springs, or irrigation ditches on or within two miles of the Two Road site. Several creeks occur in the area; however, according to the U.S. Geological Survey topographic maps, all are ephemeral. The site lies on a drainage divide between two unnamed ephemeral creeks. These creeks join Bitter Creek about 0.5 to one mile below the site. Bitter Creek, an ephemeral tributary, flows into the Colorado River over 10 miles from the site.

Because of the high elevation of the site (approximately 600 feet above the Colorado River) and its distance from the Colorado River (10 miles), the site would not be affected by river flooding.

Additional details on surface-water hydrology for the Two Road site are provided in Appendix F, Hydrology Report, Section F.1.

Geomorphology

Presently, sheet and rill wash occur on the site. However, the gravel cap (pediment material) has effectively prevented any severe erosion on the site. Because the site lies on a drainage divide, there is little potential for flash flooding on the site. The major known geologic factor that affects the long-term stability of the site relates to the areas of erosion potential along the ephemeral creeks adjacent to the site (DOE, 1984). The rate of erosion, however, is calculated to be a very slow process and should not pose a serious threat to the proposed pile during the design life.

An extensive geomorphic analysis of the Two Road site has been performed. This report is included in Appendix E, Soils, Geologic, and Seismic Information.

Slope stability/seismic risk

Slope failure due to instability under static and seismic loading is another phenomena that could affect the integrity of the stabilized tailings pile.

Stability analyses were performed for each loading condition to estimate factors of safety against slope failure. In particular, the seismic loading conditions were evaluated by applying the on-site horizontal acceleration resulting from an MCE. An MCE of magnitude 6.8 (Richter scale) would generate an on-site effective peak horizontal bedrock acceleration of 0.18g. The seismic analysis is provided in Appendix E, Soils, Geologic, and Seismic Information. A discussion of the methodology involved in the slope stability analysis is presented in Section B.6.

The factors of safety against slope failure under both static and seismic loading for the designed slope exceed generally accepted limits of 1.5 and 1.1, respectively. The static and seismic safety factors calculated for disposal at the Two Road site are 3.8 and 1.8, respectively. The short-term, immediately following construction, factor of safety is 4.5.

A principal seismic hazard to the stabilized tailings pile is the potential for slope failure due to seismically induced liquefaction of saturated tailings or underlying soils. The earthen cover and low permeability layer combined with the fact that the relocated contaminated material would be mixed and compacted would prevent saturation of the pile, thereby eliminating the potential for liquefaction of the tailings. Likewise, the potential for liquefaction of the foundation soils is slight because of the absence of a saturated zone below the proposed pile location.

Settlement and cover cracking

Differential settlement of the stabilized tailings pile has the potential hazard of cracking the cover due to horizontal strains and thus could affect the integrity of the pile. Differential settlement could also increase the potential for gully action due to concentrations of surface runoff.

Due to the difficulty in controlling differential settlement of the reshaped tailings pile, settlement monitoring devices would be installed to measure the total settlement of the tailings and underlying soils as in the other disposal alternatives.

Frost heave/solifluction

The processes of frost heave and solifluction, which are discussed in detail in Section B.2.6, pose a hazard to the long-term performance of any structure constructed to isolate the tailings.

As in the other disposal alternatives, the potential for frost heave (ice lens formation) and the prerequisite for solifluction

(saturation) would be eliminated by the use of sufficiently impermeable earth materials to restrict ice lens formation and a sufficiently porous surface aggregate layer, in conjunction with a continuous slope to allow drainage across the embankment surface that would restrict water buildup over the earth cover and eliminate saturation.

Plant root, burrowing animals, and human intrusion

The tailings pile at the Two Road site would be covered with a five-foot-thick layer of compacted, low permeability earth material. This layer would then be covered with a two-foot-thick layer of rock erosion protection material (including filter layer). As discussed for the other disposal alternatives, this seven-foot-thick layer of rock and compacted soil would inhibit plant root intrusion and discourage intrusion by burrowing animals or humans.

B.4.8 GROUND-WATER PROTECTION

There is no existing shallow ground water below the Two Road site. Unconsolidated deposits at the site are underlain by approximately 750 feet of Mancos Shale, effectively protecting deep potential aquifers. Thus, the potential for contamination of ground water at the site is extremely remote. However, the design features that would be used to minimize the potential for contaminant migration under the Cheney Reservoir disposal option would also be used for the tailings pile at the Two Road site. The two major design features which would serve to mitigate potential ground-water contamination at the Two Road site are the compacted low permeability earth cover above the tailings and the compacted earth layer below the tailings. Also, the tailings would be compacted to below the optimum moisture content to minimize drainage from the stabilized pile. A detailed description of the ground-water investigation and analysis for the Two Road site is contained in Appendix F, Hydrology Report.

B.5 CONSTRUCTION ESTIMATES

Estimates of equipment and personnel requirements; fuel, energy, and water consumptions; major earthwork volumes; and construction costs for each remedial action alternative are summarized in Tables B.5.1 through B.5.15.

Table 9.5.1 Equipment use - stabilization on-site

Type of equipment	Pieces of equipment per month of project time																																	Total equipment months by type	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33		
Compactor	0	0	2	4	4	5	5	5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	1	1	1	117		
Dozer-DB	0	0	11	11	6	10	10	13	13	8	8	8	8	8	8	8	8	8	8	8	4	4	4	4	4	4	4	4	4	11	8	7	7	231	
Crane	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4		
Drill	0	0	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	171	
Front end loaders	0	0	0	0	0	2	2	4	4	4	4	4	4	5	5	5	5	5	5	5	3	3	3	3	3	3	3	3	3	3	3	2	0	0	95
Grader	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	24	
Pile driver	0	0	3	3	3	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	
Scrapers	0	0	8	18	18	18	18	18	18	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	11	1	1	1	330
Hydromulcher	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	4	
Truck	0	0	44	44	33	54	54	70	70	49	49	49	49	56	56	56	56	56	56	36	25	25	25	25	25	25	25	25	25	57	40	33	33	1325	
Water truck	0	0	1	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	3	1	1	1	72	
Total pieces of equipment per month of project time	0	0	78	91	75	103	104	127	127	89	88	88	88	96	96	96	96	96	96	76	58	49	49	49	49	49	49	49	49	91	55	44	44	2394	

Table B.5.2 Personnel requirements - stabilization on site^a

Type of personnel	Number of personnel per month of project schedule																																	Total man months per type of personnel
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	
Truck drivers	0	0	45	46	35	56	56	73	73	52	52	52	52	59	59	54	59	59	59	39	27	27	27	27	27	27	27	27	27	60	41	34	34	1397
Equipment operators	0	0	33	45	40	47	48	54	54	37	36	36	36	37	37	37	37	37	37	37	31	22	22	22	22	22	22	22	22	31	14	10	10	997
Operators supervisors	0	0	8	10	8	11	11	13	13	9	9	9	9	10	10	10	10	10	10	8	6	5	5	5	5	5	5	5	5	10	6	5	5	250
Laborers	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	161
General supervision	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	363
Field services	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	24	19	942
Total man-months per month of project time	43	48	131	146	128	159	160	185	185	143	142	142	142	151	151	151	151	151	151	129	109	99	99	99	99	99	99	99	99	146	106	88	83	4110

^aPersonnel requirements based on one 8-hour shift per day, five days per week.Peak employment = 185
Average employment = 125

Table 8.5.3 Equipment use - Cheney Reservoir, truck alternative

Type of equipment	Pieces of equipment per month of project time																																		Total equipment months by type	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34		
Compactor	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	66	
Crane	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	
Dozer D-8	0	0	10	10	3	3	3	3	3	3	3	3	3	3	3	3	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6	147
Front end loaders	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	99	
Graders	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	32	
Hammer	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	
Scrapers	0	0	7	7	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	65
Hydromulcher	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	6
10-cy truck with 8-cy pup	0	0	6	6	53	53	53	53	53	53	53	53	53	53	53	53	54	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	1858
Water truck	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	54	
Total pieces of equipment per month of project time	0	0	31	31	66	66	67	67	67	66	65	65	65	65	65	65	65	67	85	85	84	84	84	82	82	82	82	82	82	82	82	82	86	86	86	2338

Table B.5.4 Personnel requirements - Cheney Reservoir, truck alternative^a

Type of personnel	Number of personnel per month of project schedule																																		Total man months per type of personnel
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
Truck drivers	0	0	8	8	55	55	55	55	55	55	55	55	55	55	55	56	71	71	70	70	70	70	69	69	69	69	69	69	69	69	69	69	69	69	1912
Equipment operators	0	0	23	23	11	11	12	12	12	11	10	10	10	10	10	10	11	14	14	14	14	14	13	13	13	13	13	13	13	13	13	17	17	17	424
Operator supervisors	2	2	4	4	7	7	7	7	7	7	7	7	7	7	7	7	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	258	
Laborers	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	166
General supervision	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	408
Field services	39	39	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	1166
Total man-months per month of project time	56	58	86	86	124	124	125	125	125	124	123	123	123	123	123	123	127	145	145	144	144	144	142	142	142	142	142	142	142	142	142	146	146	146	4334

^aPersonnel requirements based on one 10-hour shift, six days per week.Peak employment = 146
Average employment = 128

Table B.5.5 Equipment use - Cheney Reservoir, train and truck alternative

Type of equipment	Pieces of equipment per month of project time																																		Total equipment months by type	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34		
Compactor	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	66	
Crane	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	
Dozer D-8	0	0	10	10	3	3	3	3	3	3	3	3	3	3	3	3	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6	147	
Front end loaders	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	99	
Graders	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	32	
Hammer	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	
Scrapers	0	0	7	7	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	134	
Hydromulcher	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	6	
10-cy truck with 8-cy pup	0	0	6	6	29	29	29	29	29	29	29	29	29	29	29	29	31	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	1156	
Water truck	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	54	
Train cars	0	0	0	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	0	3600	
Total pieces of equipment per month of project time	0	0	31	151	164	164	165	165	165	164	163	163	163	163	163	163	166	184	184	183	183	183	182	182	182	182	182	182	182	182	182	182	185	185	185	5305

Table B.5.6 Personnel requirements - Cheney Reservoir, train and truck alternative^a

Type of personnel	Number of personnel per month of project schedule																																		Total man months per type of personnel
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
Truck drivers	0	0	8	8	31	31	31	31	31	31	31	31	31	31	31	31	33	48	48	47	47	47	46	46	46	46	46	46	46	46	46	46	46	46	1210
Equipment operators	0	0	23	23	13	13	14	14	14	13	12	12	12	12	12	12	13	16	16	16	16	16	16	16	16	16	16	16	16	16	16	19	19	19	493
Operator supervisors	2	2	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	196	
Laborers	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	166
General supervision	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	442
Field services	42	42	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	1268
Total man-months per month of project time	60	62	90	90	104	104	105	105	105	104	103	103	103	103	103	103	106	126	126	125	125	125	124	124	124	124	124	124	124	124	124	127	126	126	3775

^aPersonnel requirements based on one 10-hour shift, six days a week.

Peak employment = 127
Average employment = 112

Table 8.5.7 Equipment use - Two Road, truck alternative

Type of equipment	Pieces of equipment per month of project time																																		Total equipment months by type	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34		
Dozer-DB	0	0	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6	135	
Front-end loader	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	99	
10-cy truck with 8-cy pup	0	0	9	9	53	53	53	53	53	53	53	53	53	53	53	53	53	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	1846	
10-cy truck	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	72	
Compactor	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	64	
Scraper	0	0	6	6	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	63
Water truck	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	64	
Hydromulcher	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3
Crane	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Hammer	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Grader	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	32	
Total pieces of equipment per month of project time	0	0	27	27	66	66	67	67	67	66	65	65	65	65	65	65	70	87	87	87	87	87	86	86	86	86	86	86	86	86	86	86	89	89	89	2389

Table 8.5.8 Personnel requirements - Two Road, truck alternative^a

Type of personnel	Number of personnel per month of project schedule																																		Total man months per type of personnel
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
Truck drivers	0	0	11	11	55	55	55	55	55	55	55	55	55	55	55	55	59	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	1982
Equipment operators	0	0	16	16	11	11	12	12	12	11	10	10	10	10	10	10	11	14	14	14	14	14	13	13	13	13	13	13	13	13	13	16	16	16	407
Operator supervisors	0	0	3	3	7	7	7	7	7	7	7	7	7	7	7	7	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	250	
Laborers	0	0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	96	
General supervision	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	408	
Field services	39	39	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	1166	
Total man-months per month of project	51	51	79	79	122	122	123	123	123	122	121	121	121	121	121	121	126	145	145	145	145	145	144	144	144	144	144	144	144	144	144	147	147	147	4309

^aPersonnel requirements based on one 10-hour shift, six days a week.

Peak employment = 147

Average employment = 127

Table B.5.9 Equipment use - Two Road, train and truck alternative

Type of equipment	Pieces of equipment per month of project time																																		Total equipment months by type	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34		
Dozer-D8	0	0	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6	135
Front-end loader	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	99
10-cy truck with 8-cy pup	0	0	9	9	35	35	35	35	35	35	35	35	35	35	35	35	35	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	1306
10-cy truck	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	72
Compactor	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	64
Scraper	0	0	6	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	132
Water truck	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	64
Hydromulcher	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3
Crane	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Hammer	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Grader	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	32
Train cars	0	0	0	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	0	3600
Total pieces of equipment per month of project time	0	0	27	147	170	170	171	171	171	170	169	169	169	169	169	169	174	191	191	191	191	191	191	191	191	191	191	191	191	191	191	191	193	193	193	5518

Table 8.5.10 Personnel requirements - Two Road, train and truck alternative^a

Type of personnel	Number of personnel per month of project schedule																																		Total man months per type of personnel
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
Truck drivers	0	0	11	11	37	37	37	37	37	37	37	37	37	37	37	37	41	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	1442
Equipment operators	0	0	16	16	13	13	14	14	14	13	12	12	12	12	12	12	13	16	16	16	16	16	16	16	16	16	16	16	16	16	16	18	18	18	476
Operator supervisors	2	2	3	3	5	5	6	6	6	5	5	5	5	5	5	5	6	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	215
Laborers	3	5	5	5	5	5	5	5	5	5	5	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	166
General supervision	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	442
Field services	42	42	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	1268
Total man-months per month of project time	60	60	85	85	110	110	112	112	112	110	109	109	109	109	109	109	115	134	134	134	134	134	134	134	134	134	134	134	134	134	134	136	135	135	4009

^aPersonnel requirements based on one 10-hour shift, six days a week.

Peak employment = 136

Average employment = 118

Table B.5.11 Fuel consumption

Type of equipment	Fuel consumption (gal)				
	Stabilization on site	Cheney Reservoir truck alternative	Cheney Reservoir train and truck alternative	Two Road truck alternative	Two Road train and truck alternative
D8-Dozer	335,500	350,300	350,300	321,700	321,700
Front end loader	112,900	407,500	407,500	193,000	407,800
Compactor	216,200	200,100	200,100	194,200	194,200
Crane	4,200	6,900	6,900	6,900	6,900
Drill	180,600	--	--	--	--
Grader	19,000	41,600	41,600	41,600	41,600
Pile driver	22,100	12,200	12,200	12,200	12,200
10-cy truck	--	--	--	124,800	124,800
Scraper	566,300	183,000	377,400	177,500	371,800
Hydromulcher	3,200	7,800	7,800	3,900	3,900
10-cy truck with 8-cy pup	1,749,000	3,691,600	2,504,300	3,976,500	2,829,300
Locomotives	--	--	1,192,000	--	2,448,000
Water truck	38,000	46,800	46,800	55,500	55,500
Totals	3,247,000	4,947,800	5,146,860	5,107,800	6,818,000

Table B.5.12 Energy consumption

Facility	Kwh consumed				
	Stabilization on site	Cheney Reservoir truck alternative	Cheney Reservoir train and truck alternative	Two Road truck alternative	Two Road train and truck alternative
Field office	197,000	302,000	302,000	312,000	312,000
Change/shower trailer(s)	338,000	553,000	553,000	570,000	570,000
Laundry	225,000	276,000	276,000	285,000	285,000
Dewatering	864,000	144,000	144,000	148,000	148,000
Waste-water treatment plant	144,000	48,000	48,000	50,000	50,000
Totals	1,768,000	1,323,000	1,323,000	1,365,000	1,365,000

Table B.5.13 Water consumption

Facility	Consumption (gal x 1000)				
	Stabilization on site	Cheney Reservoir truck alternative	Cheney Reservoir train and truck alternative	Two Road truck alternative	Two Road train and truck alternative
Compaction					
o Site preparation	434	2,082	2,082	1,940	1,940
o Tailings place- ment and subbase preparation	40,702	36,720	36,720	36,720	36,720
o Radon cover	12,710	11,300	11,300	11,300	11,300
o Erosion pro- tection	6,772	--	--	--	--
o Restoration	<u>2,348</u>	<u>4,906</u>	<u>4,906</u>	<u>5,092</u>	<u>5,092</u>
Compaction Total	62,966	55,008	55,008	55,052	55,052
Potable consumption	1,089	1,886	1,650	1,871	1,738
Decontamination	177	5,254	6,047	5,254	6,047
Dust control	2,178	10,400	10,400	6,997	6,997
Total Consumption	<u>66,410</u>	<u>72,548</u>	<u>73,105</u>	<u>69,174</u>	<u>69,834</u>

Table B.5.14 Summary of major earthwork volumes - Grand Junction remedial action alternatives

Activity item	Estimated in-place volume (cubic yards)		
	Stabilization on site	Cheney Reservoir ^a	Two Road ^a
<u>Site preparation</u>			
o Site access roads			
1. Base course	--	45,000	47,000
2. Gravel	--	22,000	24,000
<u>Pile subbase preparation</u>			
o Backfill	982,000	--	--
o Low permeability layer: excavate, place, and compact	380,000	183,000	183,000
o Capillary break layer	126,000	--	--
<u>Tailings pile</u>			
o Excavate, haul, spread, and compact	3,058,000	3,058,000	3,058,00
o Stockpile, spread, and compact	782,000	--	--
<u>Radon cover</u>			
o Excavate and stockpile for site restoration	215,000	471,000	471,000
o Excavate, haul, spread and compact	540,000	480,000	480,000
<u>Erosion protection</u>			
o Cover	217,000	198,000	198,000
o Rock armor	269,000	--	--
<u>Site restoration</u>			
o Backfill excavations	183,000	400,000	400,000

^aEarthwork volumes are equivalent for truck and train and truck options under each alternative.

Table B.5.15 Summary of construction costs - Grand Junction remedial action alternatives

Activity item	Cost (\$000)				
	Stabilization on site	Cheney truck	Cheney train and truck	Two Road train and truck	Two Road Truck
Liner	9720	450	450	450	450
Site preparation	550	2980	5720	5650	2900
Decontamination facilities	120	860	860	1050	1050
Tailings earthwork and/or relocation	6770	25,170	52,630	59,300	39,100
Cover	2760	1340	1340	1340	1340
Erosion protection	2970	3560	3560	3720	3720
Flood protection	20,260	-0-	-0-	-0-	-0-
Site restoration	1350	2740	2740	3210	3210
Fencing	150	110	110	110	110
Supervisory and field services	11,400	11,040	15,930	18,400	14,580
Construction management	<u>9,330</u>	<u>8,050</u>	<u>9,830</u>	<u>13,460</u>	<u>11,020</u>
TOTAL	65,380	56,300	93,170	106,690	77,480

These estimates do not include the costs of:

- o Property acquisition.
- o Engineering design.
- o Overall project management.
- o Vicinity properties.
- o Long-term surveillance and maintenance.

B.6 CALCULATION SUMMARIES

B.6.1 SITE DRAINAGE

This section provides a discussion on the methodology used to determine the PMP, the times of concentration, and design flows used in determining site drainage features for each of the disposal alternatives. The results which were used to estimate the size of drainage ditches and as input in determining rock erosion protection material requirements (Section B.6.2), are also provided.

B.6.1.1 Methodology

The maximum PMP rainfall intensity was determined using charts and tables from Hydrometeorological Report No. 49 (DOC, 1977). A 72-hour general storm PMP was estimated by combining the convergence PMP with the orographic PMP. The maximum intensity determined by this method was compared with the local-storm PMP maximum intensity in order to determine the most critical PMP intensity for the study area.

Drainage areas, channel lengths, and slopes for the watersheds at each site were taken from the appropriate USGS topographic maps. Times of concentration were found using overland flow and basin characteristics and equations presented in Design of Small Dams (DOI, 1977). Rainfall intensity variations were determined using guidelines outlined in HMR 49; for times of concentration less than five minutes the percent of the one-hour PMP was extrapolated using recommendations provided by the NRC.

A detailed discussion of the PMF analysis for the Colorado River at the tailings site is provided in Appendix F, Hydrology Report.

Two methods were employed to determine design discharges for the three disposal alternatives. The rational method $Q = CiA$ (AISI, 1971), was used to determine the discharge for runoff from all piles and to design the permanent ditches for the stabilization on site option.

To design the permanent ditches for the relocation alternatives, runoff hydrographs were calculated using the Linear Reservoir Routing technique (Stubchaer, 1975) and Green-Ampt infiltration parameters (Rawls and Brakensiek, 1983). Under this method rainfall is subjected to infiltration losses, the magnitude of which depend on antecedent rainfall. The resulting rainfall excess is multiplied by the watershed area to obtain an instantaneous hydrograph which is routed through an imaginary linear reservoir with a routing constant equivalent to the time of concentration to obtain the final hydrograph. All rainfall losses are compared to precipitation such that losses are less than or equal to precipitation. Soil infil-

tration is accumulated after each specified time step; therefore, the Green-Ampt infiltration equation performs a soil moisture accounting and the resulting infiltration rate is a function of the existing soil moisture conditions. In order to obtain conservative discharge estimates, it is assumed that the watershed soils are initially close to saturation.

B.6.1.2 Results

Stabilization on site

Results of the flood analysis performed for the Colorado River at the site are contained in Appendix F, Hydrology Report. Flow depths and velocities used to determine rock erosion protection requirements for the rock armor wall are provided in Section B.6.2.

Typically, a remedial action would ensure that drainage ditches would be designed to convey the runoff due to a PMP off the site. This is a requirement for ensuring adequate erosion protection. However, this would be impractical at the Grand Junction site for two reasons: (1) the entire site lies within the PMF floodplain and construction of ditches to control the flow would be impractical, and (2) the rock armor wall would provide erosion protection to the depth of maximum scour (see Section B.2.7). Therefore, the permanent drainage ditches adjacent to the pile would be designed to convey the runoff resulting from a 100-year precipitation event in order to provide adequate drainage of the site area. The rainfall intensity for the one-hour, 100-year storm event (1.44 inches) was determined from the Precipitation-Frequency Atlas of the United States (Miller et al., 1973).

The local one-hour PMP for the Grand Junction site was calculated to be 8.1 inches. This value was converted to a maximum five-minute intensity based on the time of concentration for flow off the pile. This intensity was then converted to an equivalent one-hour rainfall intensity of 43.7 inches per hour.

The ditches would have triangular cross-sections with 5:1 (horizontal to vertical) sideslopes. Both ditches would direct flows south to the Colorado River. The top of the pile would be gently sloped to also direct flows toward the river. Table B.6.1 summarizes site drainage characteristics for the stabilization on site alternative. Ditch locations are shown in Figure B.6.1.

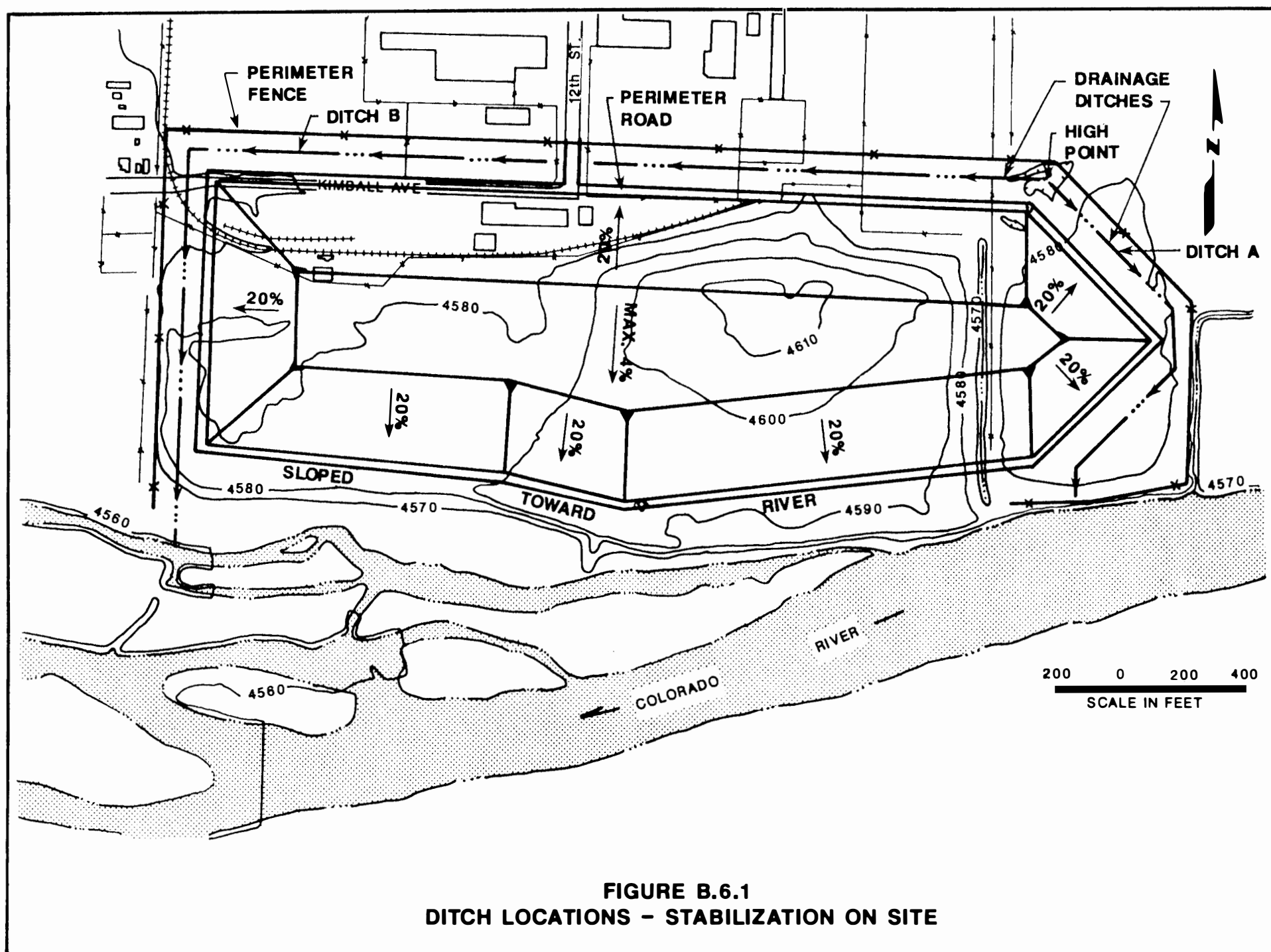


Table B.6.1 Site drainage - stabilization on site

	Slope (ft/ft)	Contributing area (acres)	Flow length (ft)	Flow depth (ft)	Velocity (fps)	Design discharge
Topslopes	0.04	--	400	0.1	2.4	0.40 cfs/ft
Sideslopes	0.20	--	690	0.1	3.6	0.70 cfs/ft
Ditch A	0.0045	104	1340	2.7	3.5	135 cfs
Ditch B	0.0023	59	3990	2.6	2.4	80 cfs

Disposal at the Cheney Reservoir alternate disposal site

The local one-hour PMP for the Cheney Reservoir site was calculated to be 8.5 inches. This value was converted to a maximum five-minute intensity based on the time of concentration for flow off the pile. This intensity was then converted to an equivalent one-hour rainfall intensity of 45.9 inches per hour.

Ditches adjacent to the pile would have triangular cross-sections with 5:1 sideslopes. The diversion ditch would have a trapezoidal cross-section with an eight-foot-wide base and 5:1 (horizontal to vertical) sideslopes. Table B.6.2 summarizes site drainage characteristics for this disposal alternative. Ditch locations are shown in Figure B.6.2.

Disposal at the Two Road alternate disposal site

The local one-hour PMP for the Two Road site was calculated to be 8.2 inches. This value was converted to a maximum five-minute intensity based on the time of concentration for flow off the pile. This intensity was then converted to an equivalent one-hour rainfall intensity of 44.3 inches per hour.

All ditches would have triangular cross-sections with 5:1 slopes.

Table B.6.3 summarizes site drainage characteristics for this disposal alternate. Ditch locations are shown in Figure B.6.3.

Table B.6.2 Site drainage - Cheney Reservoir alternate disposal site

	Slope (ft/ft)	Contributing area (acres)	Flow length (ft)	Flow depth (ft)	Velocity (fps)	Design discharge
Topslopes	0.04	--	1350	0.20	4.0	1.44 cfs/ft
Sideslopes	0.20	--	1500	0.18	4.8	1.58 cfs/ft
Ditch A	0.003	8.2	2420	3.5	3.4	211 cfs
Ditch B	0.011	4.6	1190	2.2	4.7	120 cfs
Ditch C	0.023	36	1200	3.7	9.6	661 cfs
Ditch D	0.013	36	1060	5.4	9.2	1327 cfs
Diversion ditch	0.006	240	2700	6.7	7.8	2190 cfs

Table B.6.3 Site drainage - Two Road alternate disposal site

	Slope (ft/ft)	Contributing area (acres)	Flow length (ft)	Flow depth (ft)	Velocity (fps)	Design discharge
Topslopes	0.04	--	650	0.2	2.4	0.68 cfs/ft
Sideslopes	0.20	--	850	0.2	3.3	0.86 cfs/ft
Ditch A1, A2	0.0078	50	2820	4.7	6.6	743 cfs
Ditch B1, B2	0.0092	50	2820	5.4	7.8	1118 cfs

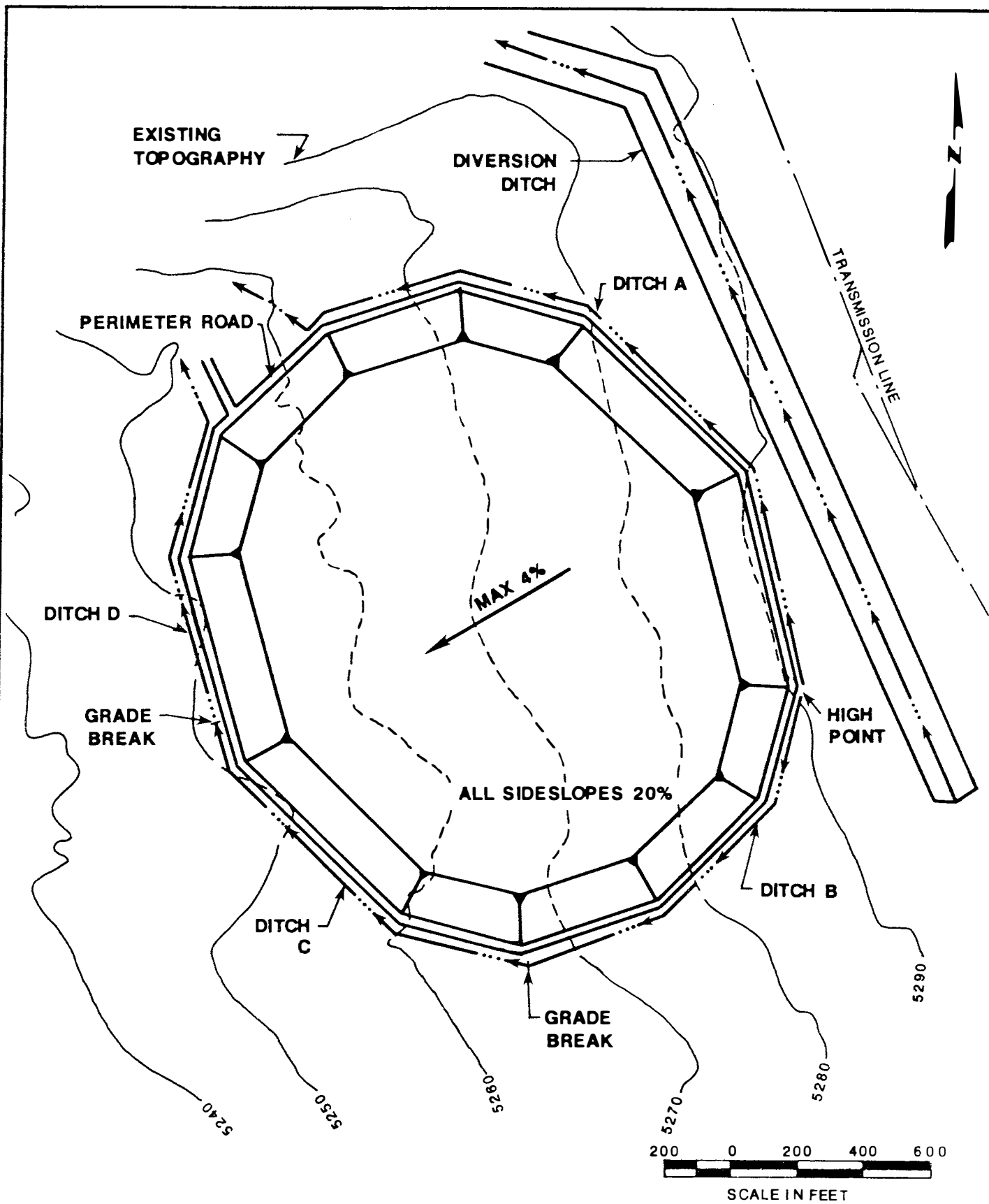
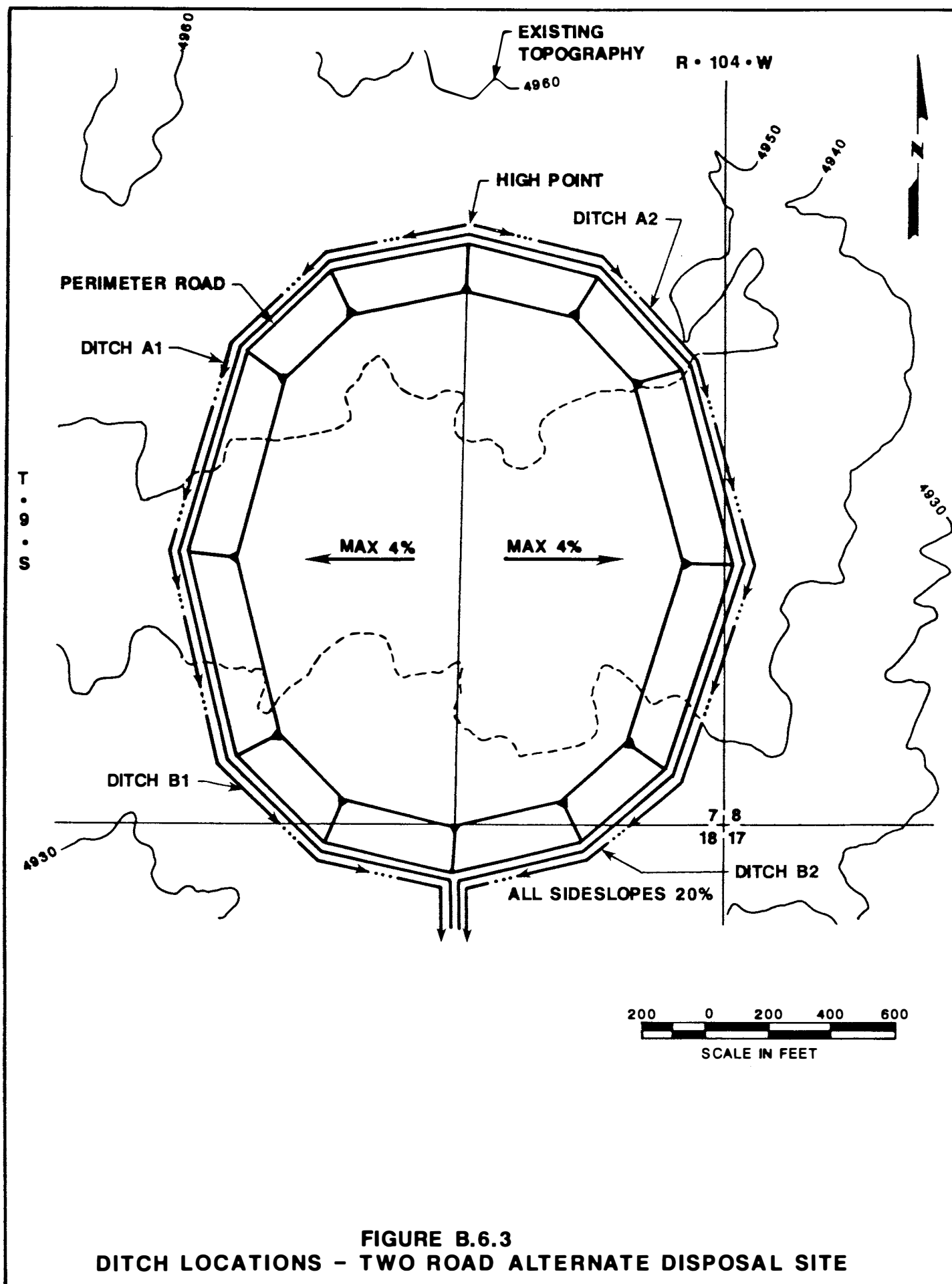


FIGURE B.6.2
DITCH LOCATIONS - CHENEY RESERVOIR ALTERNATE DISPOSAL SITE



B.6.2 EROSION PROTECTION

B.6.2.1 Methodology

The embankment designs for each site must include long-term protection against the effects of erosion. Specifically:

- o The rock layers on the embankment top and sideslopes would be designed to prevent erosion due to runoff resulting from a PMP on the embankment.
- o The rock layers on the embankment sideslopes and in the ditches would be designed to prevent erosion which would result from the flow adjacent to the stabilized pile due to the occurrence of a PMP.

The rock size on the embankment top and sideslopes were determined using the Safety Factors Method (Simons and Senturk, 1976) taking into account interstitial flow (flow through the rock layer). The rock size required to resist the expected sheet flow was set equal to the 50 percent finer rock diameter. The calculation was iterated for various rock sizes and the rock size for a safety factor greater than 1.0 was found. If the calculated rock size was less than 1.5 inches, the D_{50} rock size was set equal to 1.5 inches in order to inhibit intrusion by burrowing animals.

Flow hydraulics for the embankment topslopes and sideslopes were calculated using Manning's equation and U.S. Army Corps of Engineers (COE, 1970) methods which relate relative submergence of the roughness element and the hydraulic radius to the friction coefficient and boundary shear stress.

In order to calculate rock sizes for the ditches, flow depths and velocities at the ditch center line were determined. Flow hydraulics where the embankment perimeter ditches have the greatest slope were found using the method described in Section B.6.1. The point shear stress was found for the bottom of the ditch and for shallower points. The calculations were iterated to find rock sizes with factors of safety greater than 1.0. Ditch flow rates, depths, and velocities are provided in Tables B.6.1, B.6.2, and B.6.3.

Rock sizes at ditch junctions and bends would be determined during final design using EM-1110-2-1601 criteria (COE, 1970).

A summary of the PMF depths and mean channel velocities for the Colorado River at Grand Junction is provided in Appendix F, Hydrology Report. The results of this analysis indicate that an erosion protection barrier placed around the base of the pile to the maximum expected depth of scour is required to provide stability of the pile for the stabilization on site disposal alternative due to the potential for

river meander. The safety factors method described above was used to calculate rock protection requirements for this rock armor wall.

Filter layers would be required under any of the disposal options. The gradations of the filter layer would be determined during final design when the grain size distribution of the radon barrier and rock erosion protection are finalized. The following criteria would be used in the final design.

$$\frac{D_{15} \text{ filter}}{D_{85} \text{ base}} < 5$$

B.6.2.2 Results

Stabilization on site

As previously stated, the results of the PMF analysis for the Grand Junction site indicate that in addition to the erosion protection required to protect against a PMP occurring on the pile, a rock armor wall is required to protect against the PMF flows of the Colorado River. The rock armoring would extend from the maximum expected water elevation to the maximum depth of scour that would occur during a PMF. The rock armor wall would be constructed with 5:1 slopes above the ground surface and 2:1 slopes below the surface, and would be approximately six feet thick.

All rock erosion requirements for the stabilization on site alternative are provided in Table B.6.4.

Disposal at the Cheney Reservoir alternate disposal site

Rock erosion protection requirements for the Cheney Reservoir disposal alternative are summarized in Table B.6.5.

Disposal at the Two Road alternate disposal site

Rock erosion protection requirements for the Two Road disposal alternative are summarized in Table B.6.6.

B.6.3 SLOPE STABILITY ANALYSIS

B.6.3.1 Methodology

Stability

An idealized critical cross-section was selected through the proposed stabilized tailings pile at the processing site, Cheney Reservoir, and the Two Road site. Each proposed embankment was analyzed to determine the factors of safety under both static and dynamic (earthquake) loading over the life of the project.

Table B.6.4 Erosion protection requirements - stabilization on site

Location	Rock size (inches)	Thickness ^a (inches)	Design flow rate
Topslopes	$D_{50} \geq 1.5$ $D_{100} \leq 3.0$	24	0.40 cfs/ft
Sideslopes	$D_{50} \geq 4.0$ $D_{100} \leq 8.0$	24	0.70 cfs/ft
Rock armoring 5:1 slopes 2:1 slopes	$D_{50} \geq 20$ $D_{50} \geq 30$	144	40 ft deep 20 ft per sec
Ditch A ^b	$D_{50} \geq 1.5$ $D_{100} \leq 3.0$	12	135 cfs
Ditch B	$D_{50} \leq 1.5$ $D_{100} \leq 3.0$	12	80 cfs

^aIncludes bedding and filter layers.^bSee Figure B.6.1 for ditch locations.Table B.6.5 Erosion protection requirements - Cheney
Reservoir alternate disposal site

Location	Rock size (inches)	Thickness ^a (inches)	Design flow rate
Topslopes	$D_{50} \geq 2.0$ $D_{100} \leq 4.0$	24	1.44 cfs/ft
Sideslopes	$D_{50} \geq 6.0$ $D_{100} \leq 12.0$	24	1.58 cfs/ft
Ditch A ^b	$D_{50} \geq 2.0$ $D_{100} \leq 4.0$	12	211 cfs
Ditch B	$D_{50} \leq 2.5$ $D_{100} \leq 5.0$	12	120 cfs
Ditch C	$D_{50} \leq 8.0$ $D_{100} \leq 16.0$	24	661 cfs
Ditch D	$D_{50} \leq 8.0$ $D_{100} \leq 16.0$	24	1327 cfs
Diversion ditch	$D_{50} \leq 6.0$ $D_{100} \leq 12.0$	18	2190 cfs

^aIncludes bedding and filter layer.^bSee Figure B.6.2 for ditch locations.

Table B.6.6 Erosion protection requirements - Two
Road alternate disposal site

Location	Rock size (inches)	Thickness ^a (inches)	Design flow rate
Topslopes	$D_{50} \geq 1.5$ $D_{100} \leq 3.0$	24	0.68 cfs/ft
Sideslopes	$D_{50} \geq 4.0$ $D_{100} \leq 8.0$	24	0.86 cfs/ft
Ditch A1, A2 ^b	$D_{50} \geq 4.0$ $D_{100} \leq 8.0$	18	743 cfs
Ditch B1, B2	$D_{50} \leq 5.0$ $D_{100} \leq 10.0$	18	1118 cfs

^aIncludes bedding and filter layer.

^bSee Figure B.6.3 for ditch locations.

The computer program STABL (Siegel, 1978) was used to calculate the factor of safety of the embankments. The program calculates over 100 failure surfaces in each slope analyzed, and ranks each according to the lowest safety factor. The stability analyses discussed in the following paragraphs, and the respective figures depicting the results of the stability analyses, present only the most critical surface (lowest factor of safety) of the 100 calculated.

The factor of safety is defined as the ratio of the strength available along a given surface divided by the force necessary to ensure static equilibrium of the mass above the surface being evaluated. Thus it is presumed that when the factor of safety is below 1.0 the slope will fail. The U.S. Army Corps of Engineers (COE, 1970) has established recommended minimum factors of safety for slopes immediately following construction (short-term analyses) to be 1.3 and slopes under dynamic loading in the long-term condition to be 1.1. The accepted minimum safety factor for slopes analyzed under long-term static conditions is 1.5.

As the tailings embankment is constructed, the stability of the embankment itself is gradually reduced due to loading of the foundation soils until it reaches a minimum immediately following its completion. In order to determine the factor of safety against slope failure for the period immediately following the construction of the embankment, it was assumed that the tailings and evaporation pond materials would be placed at 90 percent of the maximum dry density as determined by the standard Proctor test at about two percent below optimum moisture content. The cover will be placed at 95 percent of the

maximum dry density as determined by the standard Proctor test at two to three percent above optimum moisture content. Since the tailings will be placed unsaturated, the effective stress state from the consolidated-undrained triaxial test state was assumed to be representative of valid strength parameters for this material in this loading state. For the cohesive foundation soils and the radon cover material, a friction angle (ϕ) and cohesive value based on unconsolidated-undrained strength parameters was assumed to represent soil conditions under this loading condition.

In order to estimate the factor of safety for long-term conditions, it was assumed that the dry density remained the same while the moisture content would be represented by the long-term moisture content. Effective shear strengths were estimated from the results of the "Rapid" (consolidated-undrained) triaxial test with pore pressure measurements. These test results are conservative in that they assume saturation of the tested material, a condition which will not be present in the embankment. Also, any cohesion measured during the test was assumed to be zero in the stability analysis. These strength parameters were used for both the static analysis and pseudo-static seismic analysis. The design accelerations used in the seismic analysis for each site are stated in the individual site discussion sections to follow. A detailed discussion of each site's seismic risk is presented in Appendix E, Soils, Geologic, and Seismic Information. Section B.6.3.2 presents the results of each site's stability analyses performed under the various loading conditions previously described.

Liquefaction potential

Liquefaction and/or cyclic mobility can only occur in saturated cohesionless soils (sands and silts) due to cyclic loading. This is usually caused by earthquake induced pore water pressure buildup as the particles mobilize and attempt to reduce the void ratio of the soil. When this occurs the soils become essentially a viscous fluid, lose their shear strength, and thus fail catastrophically. Cyclic mobility, on the other hand, occurs in denser soils. The pore pressure buildup causes a reduction in shear strength, but results in a limited amount of shear strain (generally not greater than 15 percent) before pore pressures are reduced and shear strength is regained.

There are several factors which are important in assessing the potential for liquefaction and/or cyclic mobility. Of these the most important are: (1) the ratio of earthquake induced shear stresses in the soil to the vertical effective stress; and (2) the relative density (D_r) of the soil.

There is a practical maximum acceleration and, thus, a maximum shear stress, that can be produced by the largest earthquakes. This means that as the soil in question gets

deeper, the ratio of maximum possible shear stress to effective stress tends to become smaller. This factor generally precludes liquefaction and/or cyclic mobility at depths greater than approximately 50 feet below the ground surface.

Also, most researchers agree that there is a relative density beyond which liquefaction cannot occur. Liquefaction can generally only occur in soils with a relative density (D_r) less than 40 percent (Seed, 1976). Generally, beyond a D_r of 70 percent neither liquefaction nor cyclic mobility can occur (Casagrande, 1975).

Based on the similarity of the embankment designs, the liquefaction potential is not expected to vary significantly for the three disposal alternatives. The soils in the tailings embankments would be compacted to 90 percent of standard Proctor density (greater than 70 percent relative density) upon placement. In addition, the soils would not be saturated when placed and would not be expected to be saturated during the life of the structure. Thus, no liquefaction or cyclic mobility would occur in the embankment.

The liquefaction potential for the foundation material for each site is discussed in more detail in Section B.6.3.2. No detailed analyses were required for any of the three sites since the potential for liquefaction at each site is low.

Ground settlement

When the stress on a given soil layer is increased (or decreased) due to an increased (or excavated) load, the soil layer tends to compress (or expand) according to one or both of the mechanisms of elastic response and consolidation (rebound). Elastic response occurs in all soils and occurs immediately upon loading. Consolidation generally occurs in fine-grained saturated, or nearly saturated soils. When the load is first applied, the pore water takes the load by an increase in pore pressure. In fine-grained soils it takes time, depending on soil permeability and the degree of saturation, for the load generated pore pressures to dissipate. As this pressure dissipates, settlement occurs. Consolidation settlement is thus time dependent and may or may not be immediate depending on the soil as well as the construction schedule. Coarse-grained material, for example, is capable of pore pressure dissipation immediately following loading. It is therefore assumed that for foundations of unsaturated clay, highly overconsolidated clay, and saturated or unsaturated coarse grained (nonplastic) soils, the immediate elastic settlement constitutes the significant portion of the total settlement.

Based on the similarity of the embankment designs, the settlement characteristics of the tailings are not expected to vary significantly for the three alternatives. The engineered placement of the tailings, cover material, and low permeability basal layer would both maximize stability and minimize settlement.

Compaction of the tailings, and other contaminated fill, would be to 90 percent of standard Proctor density. The radon barrier (cover material) and low permeability basal layer would be compacted to 95 percent of standard Proctor density. In addition, the unsaturated, homogeneous characteristics of the reworked tailings pile would allow the small amount of expected settlement to occur immediately following construction.

Foundation settlement at each site must be evaluated individually for influence on the tailings pile. Section B.6.3.2 summarizes settlement for each disposal alternative. The total settlement occurring in both the foundation material and the tailings, may occur in either a uniform or a differential fashion across each site. However, blending of the tailings during placement would minimize differential settlement within the tailings pile. Although a significant portion of the settlement is expected to be immediate, the embankment would be monitored for settlement before final grading of the radon covering material occurs. This monitoring would be done in an effort to minimize the potential for the radon barrier to crack as a result of any delayed differential settlement induced tensile strain. Calculations were performed to determine the total settlement expected in both the foundation and tailings material for all three disposal alternatives.

B.6.3.2 Pile stability analysis and results

Stabilization on site

Figure B.6.4 illustrates the design embankment profile with the most critical failure surface in the short-term static condition. The embankment is expected to extend to the edge of the Colorado River, hence the presence of the water table. Additional discussion of the embankment design is presented in Section B.2.

As noted in Figure B.6.4, the minimum factor of safety in the static short-term condition is 4.2. This far exceeds the previously discussed recommended minimum factor of safety of 1.3 and is therefore considered to be safe. The individual material properties used in this analysis are presented in Figure B.6.4.

Figure B.6.5 is the same representation of the slope under long-term static conditions. This minimum factor of safety is 4.0 which well exceeds the recommended minimum of 1.5. The individual material properties used in this analysis are also presented with the slope configuration in Figure B.6.5.

Figure B.6.6 presents the stability analysis of the embankment under a horizontal acceleration of 0.34g, which is the recommended seismic bedrock acceleration based on an MCE event (see Appendix E, Soils, Geologic, and Seismic Information). The minimum factor of safety is reduced to 1.3, which is still considered safe based on the recommended COE minimum of 1.1.

SOIL I.D. NO	MATERIAL TYPE	COHESION (PSF)	FRICTION ANGLE (DEGREES)	TOTAL UNIT WT. (PCF)
1	ARMOR	.0	40.0	120.0
2	LOW PERMEABILITY CLAYEY BARRIER	790.0	12.5	124.4
3	TAILINGS	.0	35.0	111.4
4	ENGINEERED ALLUVIAL BACKFILL	.0	39.0	128.0
5	ALLUVIUM	.0	39.0	128.0
6	WEATHERED SHALE	2000.0	.0	112.0
7	MANCOS SHALE	10000.0	.0	145.0

MOST CRITICAL FACTOR OF SAFETY = 4.163
 RADIUS OF CIRCLE = 432.689 FT
 E.Q. = .000 G

FEET HORIZONTAL SCALE
 50'

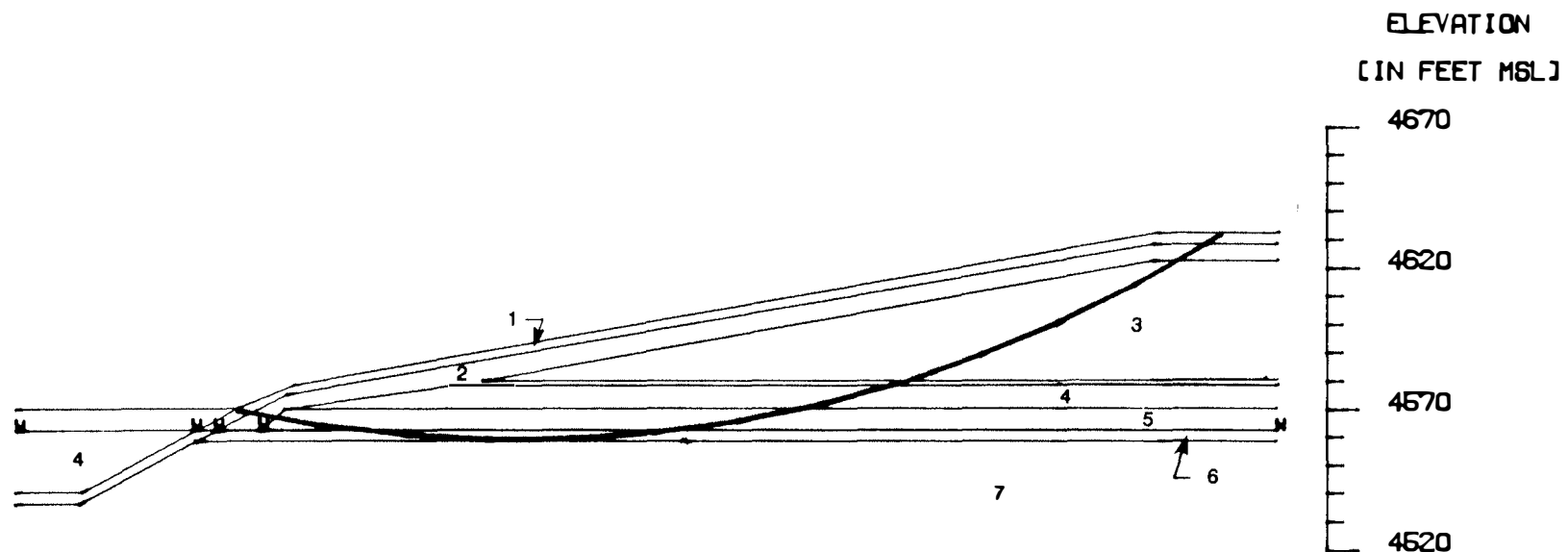


FIGURE B.6.4
 SHORT-TERM ANALYSIS - STABILIZED ON SITE, GRAND JUNCTION

SOIL I.D. NO	MATERIAL TYPE	COHESION (PSF)	FRICTION ANGLE (DEGREES)	TOTAL UNIT WT. (PCF)
1	ARMOR	.0	40.0	120.0
2	LOW PERMEABILITY CLAYEY BARRIER	.0	36.0	121.0
3	TAILINGS	.0	36.0	106.4
4	ENGINEERED ALLUVIAL BACKFILL	.0	39.0	128.0
6	ALLUVIUM	.0	39.0	128.0
6	WEATHERED SHALE	.0	30.0	112.0
7	HANDS SHALE	10000.0	.0	146.0

MOST CRITICAL FACTOR OF SAFETY = 4.006
 RADIUS OF CIRCLE = 170.107 FT
 E.Q. = .000 G

FEET HORIZONTAL SCALE
 60'

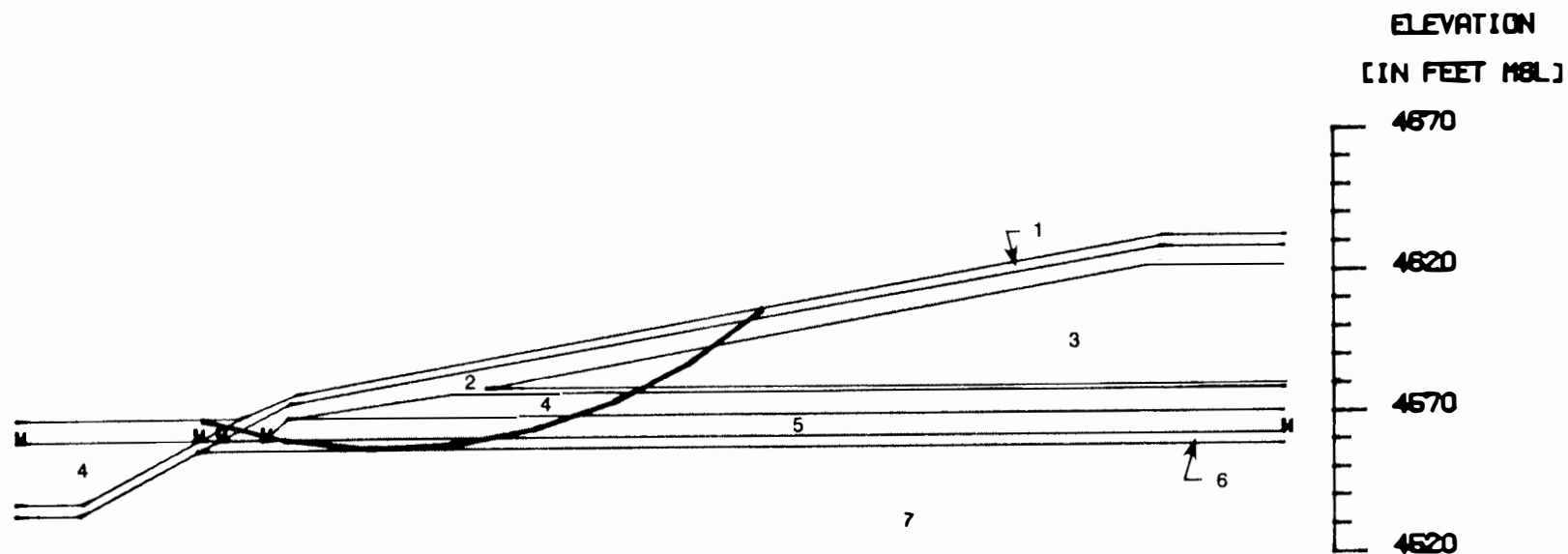


FIGURE B.6.5
 LONG-TERM ANALYSIS - STABILIZED ON SITE, GRAND JUNCTION

SOIL I.D. NO	MATERIAL TYPE	COHESION (PSF)	FRICTION ANGLE (DEGREES)	TOTAL UNIT WT. (PCF)
1	ARMOR	.0	40.0	120.0
2	LOW PERMEABILITY CLAYEY BARRIER	.0	35.0	121.0
3	TAILINGS	.0	35.0	106.4
4	ENGINEERED ALLUVIAL BACKFILL	.0	39.0	128.0
5	ALLUVIUM	.0	39.0	128.0
6	WEATHERED SHALE	.0	30.0	112.0
7	MANCOS SHALE	10000.0	.0	145.0

MOST CRITICAL FACTOR OF SAFETY = 1.299
RADIUS OF CIRCLE = 1343.392 FT
E.Q. = .340 G

FEET HORIZONTAL SCALE
50'

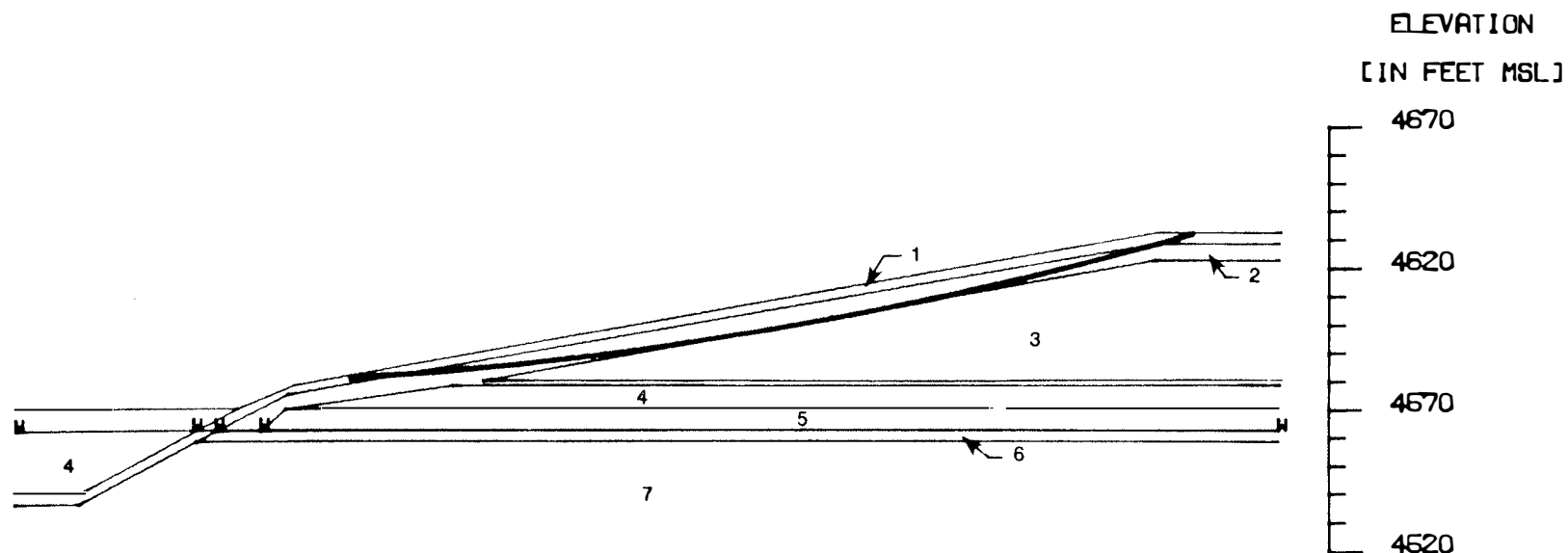


FIGURE B.6.6

DYNAMIC ANALYSIS - STABILIZED ON SITE, GRAND JUNCTION

Disposal at the Cheney Reservoir alternate disposal site

Figure B.6.7 illustrates the design embankment profile of the Cheney Reservoir site with the most critical failure surface in a short-term static condition. As presented, the minimum factor of safety in this condition is 3.5, which exceeds the recommended minimum of 1.3. The individual material properties used in this analysis are presented in Figure B.6.7.

Figure B.6.8 illustrates the minimum factor of safety of the embankment in the long-term static condition. The calculated safety factor in this state is 3.4, which exceeds the recommended minimum of 1.5. The material properties used in this analysis are also presented in Figure B.6.8.

Figure B.6.9 presents the same embankment under a horizontal acceleration of 0.34g, which is also the seismic bedrock acceleration for this site based on an MCE event. This minimum factor of safety is 1.2. The material properties used in this analysis, which are the same ones used in the static condition, are also presented in Figure B.6.9.

Disposal at the Two Road alternate disposal site

Figure B.6.10 illustrates the design embankment profile of the Two Road site with the most critical failure surface in the short-term static condition. As presented, the minimum factor of safety in this condition is 4.5, which exceeds the recommended minimum of 1.3. The material properties used in this analysis are presented in Figure B.6.10.

Figure B.6.11 depicts the minimum factor of safety of the embankment and the individual material properties used in the analysis of the long-term static condition. The calculated safety factor in this state is 3.8, which exceeds the recommended minimum of 1.5.

Figure B.6.12 presents the same embankment under a horizontal acceleration of 0.18 gravity, which is also the design seismic bedrock acceleration for this site based on an MCE event. This minimum factor of safety is 1.8, which exceeds the recommended minimum criteria as discussed previously. Figure B.6.12 also presents the individual material properties used in the analysis.

B.6.3.3 Liquefaction potential

Stabilization on site

Liquefaction potential in the foundation material is expected to be low for the processing site because of the dense condition of the soil. The high blow counts from the standard penetration tests (SPT) suggest that the relative density of the alluvium is greater than 70 percent. The few isolated

SOIL I.D. NO	MATERIAL TYPE	COHESION (PSF)	FRICTION ANGLE (DEGREE6)	TOTAL UNIT WT. (PCF)
1	ARMOR	.0	40.0	120.0
2	LOW PERMEABILITY CLAYEY BARRIER	900.0	11.3	118.6
3	TAILINGS	.0	35.0	111.4
4	LOW PLASTICITY CLAY	2000.0	.0	110.8
5	LOW PLASTICITY SILT AND CLAY	2000.0	.0	113.0
6	WEATHERED SHALE	2000.0	.0	112.0
7	MANCOS SHALE	10000.0	.0	145.0

MOST CRITICAL FACTOR OF SAFETY = 3.513
RADIUS OF CIRCLE = 81.532 FT
E.Q. = .000 G

FEET HORIZONTAL SCALE

25

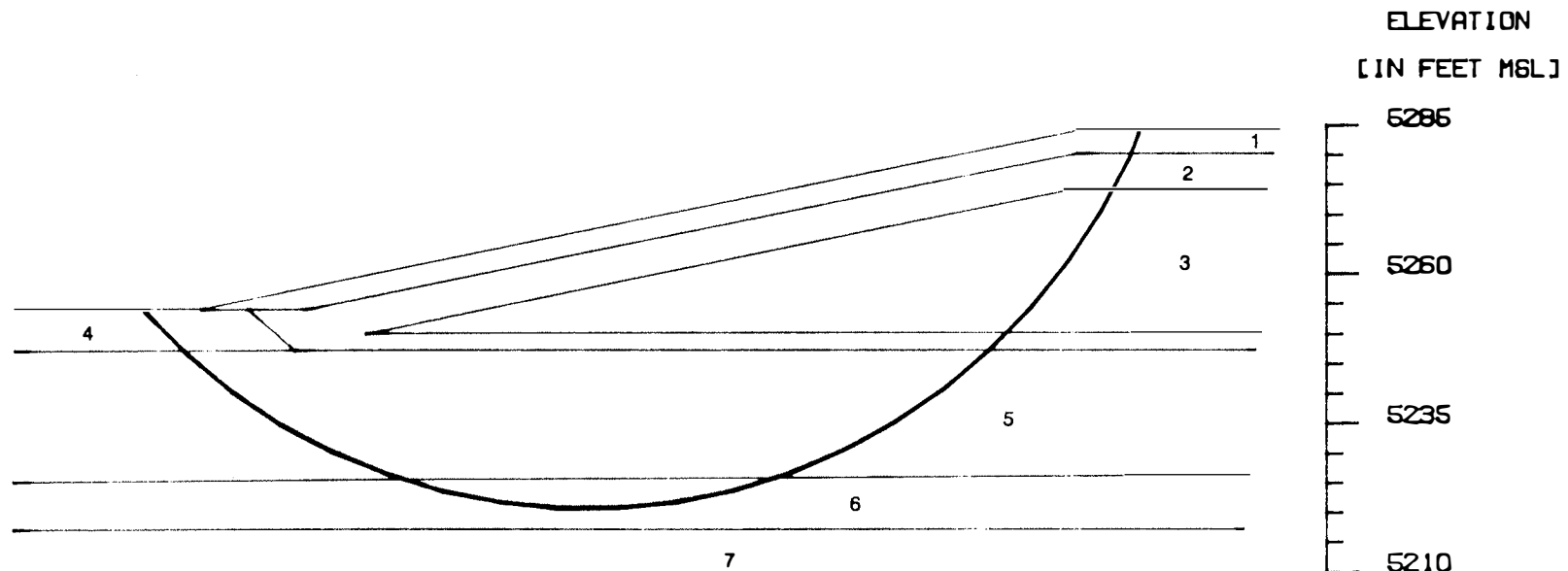


FIGURE B.6.7

SHORT-TERM ANALYSIS - CHENEY RESERVOIR ALTERNATE DISPOSAL SITE

SOIL I.D. NO	MATERIAL TYPE	COHESION (P6F)	FRICTION ANGLE (DEGREES)	TOTAL UNIT WT. (PCF)
1	ARMOR	.0	40.0	120.0
2	LOW PERMEABILITY CLAYEY BARRIER	.0	33.0	116.2
3	TAILINGS	.0	35.0	106.4
4	LOW PLASTICITY CLAY	.0	34.0	110.8
5	LOW PLASTICITY SILT AND CLAY	.0	34.0	113.0
6	WEATHERED SHALE	.0	30.0	112.0
7	MANCOS SHALE	10000.0	.0	146.0

MOST CRITICAL FACTOR OF SAFETY = 3.363
RADIUS OF CIRCLE = 301.380 FT
E.Q. = .000 G

FEET HORIZONTAL SCALE

25

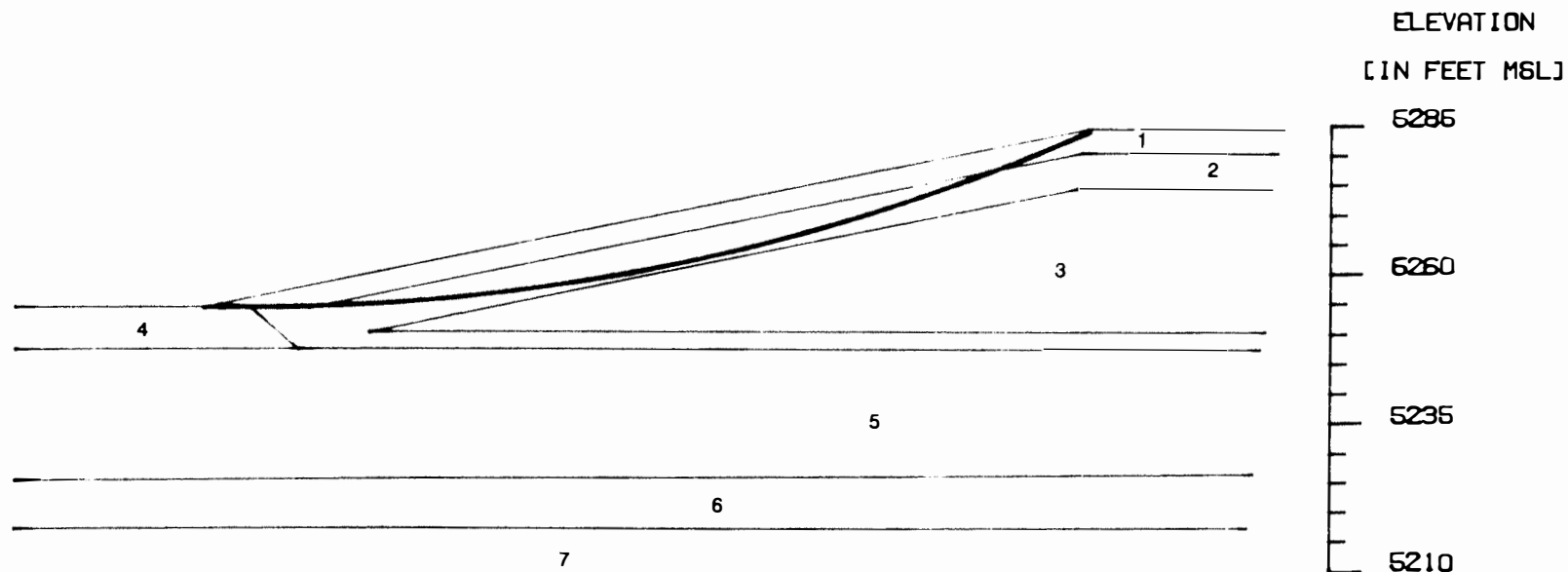


FIGURE B.6.8

LONG-TERM ANALYSIS - CHENEY RESERVOIR ALTERNATE DISPOSAL SITE

SOIL I.D. NO	MATERIAL TYPE	COHESION (PSF)	FRICTION ANGLE (DEGREES)	TOTAL UNIT WT. (PCF)
1	ARMOR	.0	40.0	120.0
2	LOW PERMEABILITY CLAYEY BARRIER	.0	33.0	115.2
3	TAILINGS	.0	35.0	105.4
4	LOW PLASTICITY CLAY	.0	34.0	110.8
5	LOW PLASTICITY SILT AND CLAY	.0	34.0	113.0
6	WEATHERED SHALE	.0	30.0	112.0
7	MANCOS SHALE	10000.0	.0	145.0

MOST CRITICAL FACTOR OF SAFETY = 1.163
RADIUS OF CIRCLE = 148.822 FT
E.Q. = .340 G

FEET HORIZONTAL SCALE

25

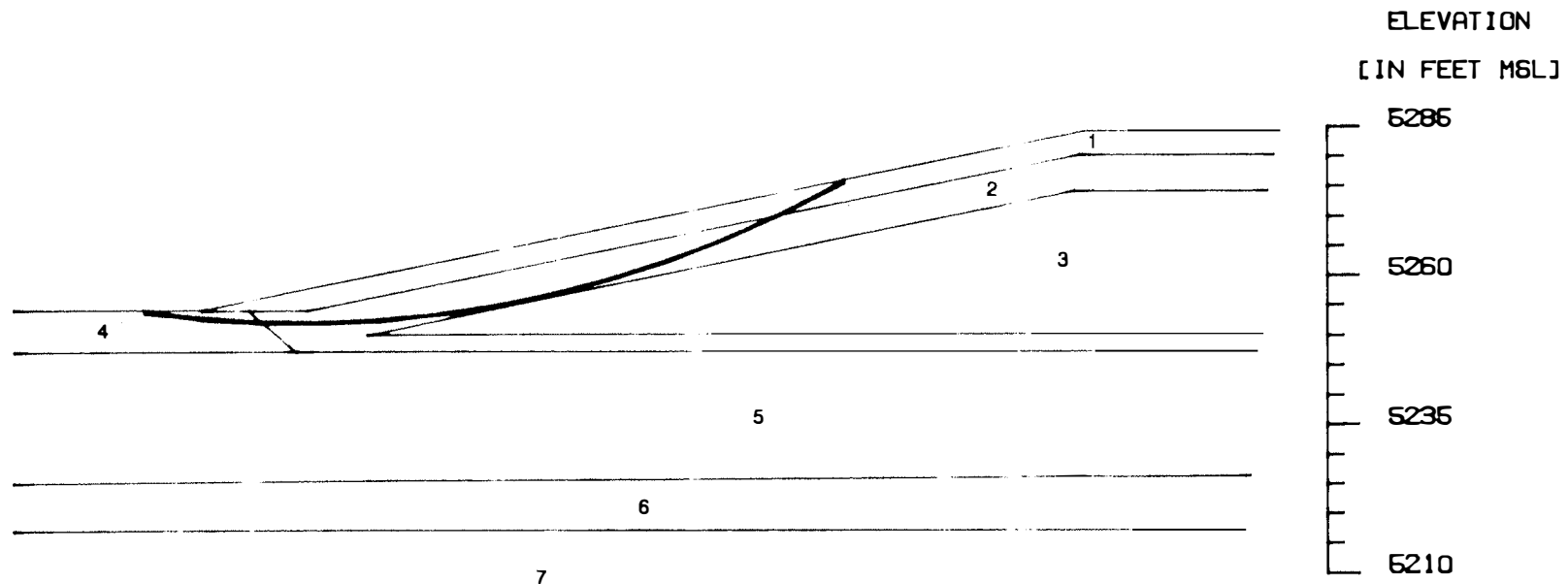


FIGURE B.6.9

DYNAMIC ANALYSIS - CHENEY RESERVOIR ALTERNATE DISPOSAL SITE

SOIL I.D. NO	MATERIAL TYPE	COHESION (PSF)	FRICTION ANGLE (DEGREES)	TOTAL UNIT WT. (PCF)
1	ARMOR	.0	40.0	120.0
2	LOW PERMEABILITY CLAYEY BARRIER	1500.0	9.1	125.4
3	TAILINGS	.0	36.0	106.4
4	LOW PLASTICITY SILT	2000.0	.0	104.5
5	SILTY SAND	.0	36.0	107.1
6	MANCOS SHALE	10000.0	.0	146.0

MOST CRITICAL FACTOR OF SAFETY = 4.466
 RADIUS OF CIRCLE = 133.466 FT
 E.Q. = .000 G

FEET HORIZONTAL SCALE

50

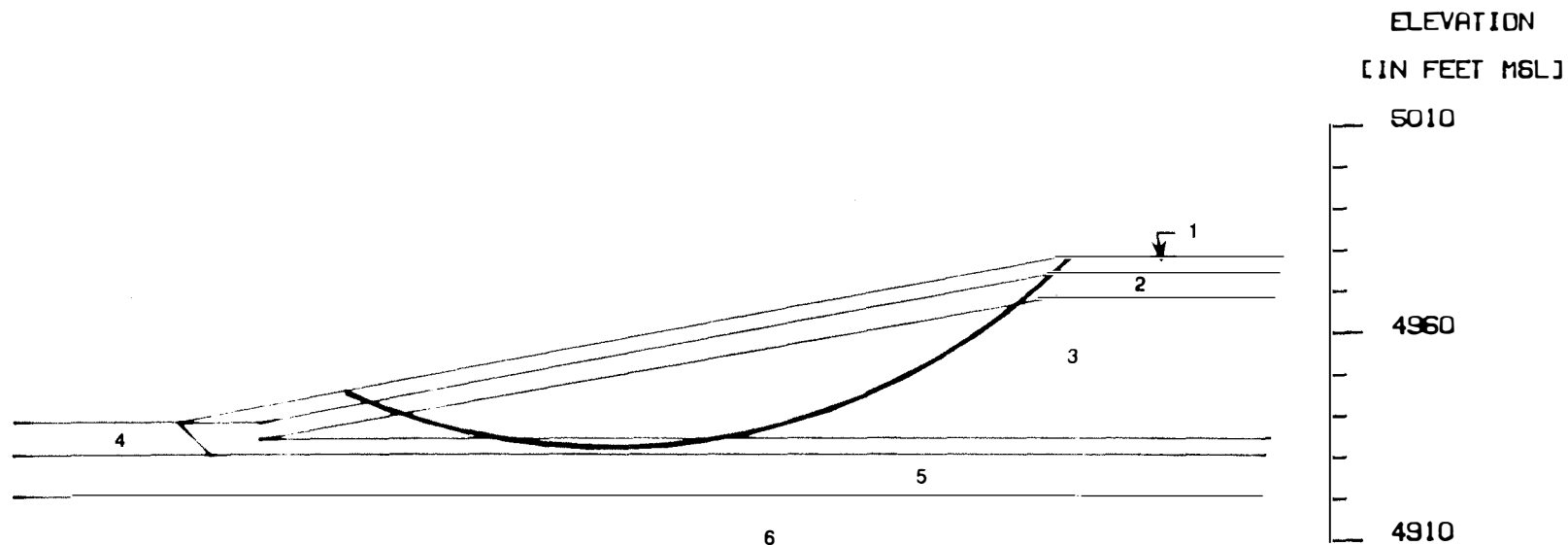


FIGURE B.6.10

SHORT-TERM ANALYSIS - TWO ROAD ALTERNATE DISPOSAL SITE

SOIL I.D. NO	MATERIAL TYPE	COHESION (PSF)	FRICTION ANGLE (DEGREES)	TOTAL UNIT WT. (PCF)
1	ARMOR	.0	40.0	120.0
2	LOW PERMEABILITY CLAYEY BARRIER	.0	34.0	118.8
3	TAILINGS	.0	36.0	106.4
4	LOW PLASTICITY SILT	.0	33.0	104.6
5	SILTY SAND	.0	36.0	107.1
6	MANCUS SHALE	10000.0	.0	146.0

MOST CRITICAL FACTOR OF SAFETY = 3.768
 RADIUS OF CIRCLE = 352.756 FT
 E.Q. = .000 G

FEET HORIZONTAL SCALE
 50'

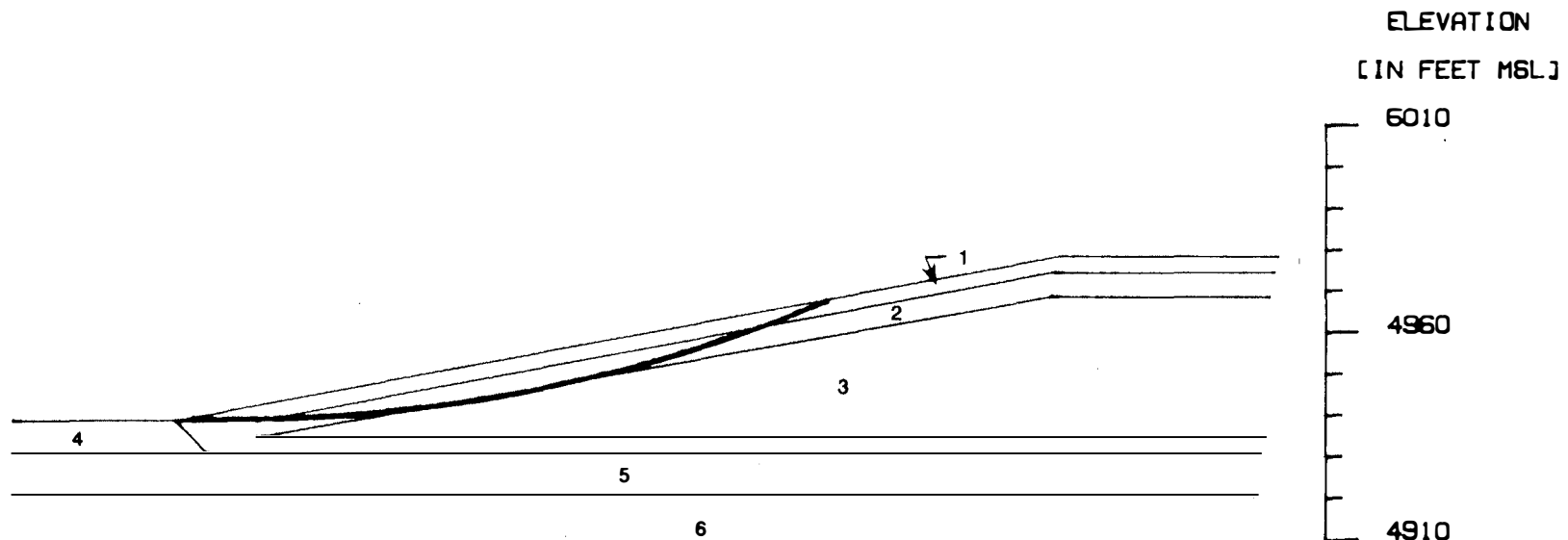


FIGURE B.6.11
 LONG-TERM ANALYSIS - TWO ROAD ALTERNATE DISPOSAL SITE

SOIL I.D. NO	MATERIAL TYPE	COHESION (PSF)	FRICTION ANGLE (DEGREES)	TOTAL UNIT WT. (PCF)
1	ARMOR	.0	40.0	120.0
2	LOW PERMEABILITY CLAYEY BARRIER	.0	34.0	118.8
3	TAILINGS	.0	36.0	105.4
4	LOW PLASTICITY SILT	.0	33.0	104.6
5	SILTY SAND	.0	36.0	107.1
6	MANCOS SHALE	10000.0	.0	145.0

MOST CRITICAL FACTOR OF SAFETY = 1.848
 RADIUS OF CIRCLE = 352.756 FT
 E.Q. = .180 G

FEET HORIZONTAL SCALE
 50

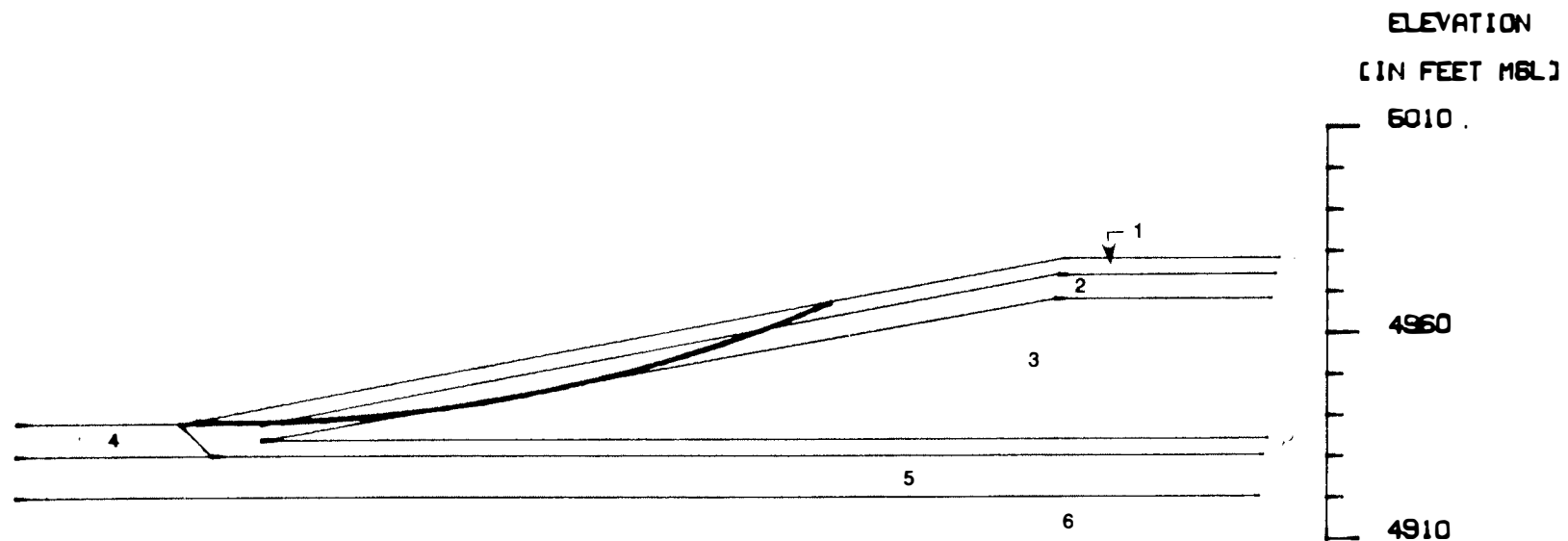


FIGURE B.6.12
 DYNAMIC ANALYSIS - TWO ROAD ALTERNATE DISPOSAL SITE

zones of weaker material that may be susceptible to liquefaction would be removed and replaced with an alluvial fill compacted to 95 percent standard Proctor density prior to placement of the embankment. Therefore, liquefaction is not expected to pose a significant threat to a properly designed embankment at the processing site.

Disposal at the Cheney Reservoir alternate disposal site

Liquefaction potential in the foundation material is also expected to be low for the Cheney Reservoir site for two reasons. First, the consistently high blow counts from the SPT suggest that the foundation silts, sands, and clays are very dense and hard (greater than 70 percent relative density). Second, ground water was not encountered until a depth of 30 feet during the site investigation. Since the soils are predominantly hard, low permeability, fine grained silts and clays, they are not expected to become saturated during, or after, construction. Although liquefaction is possible at a depth of 30 feet in a relatively loose, coarse-grained profile, liquefaction would not pose a threat to the Cheney Reservoir site due to the presence of the hard, fine-grained silts and clays in the saturated zone. In addition, the ground water is restricted to the portion of the profile immediately above the Mancos Shale, thereby not saturating the shallow sandy silts and silty sands.

Disposal at the Two Road alternate disposal site

Liquefaction potential in the foundation material at the Two Road site is expected to be low for the same two reasons mentioned in the Cheney Reservoir site discussion. First, the soil is characterized as very dense to hard based on high blow counts from the SPT. Second, no ground water was encountered in the foundation profile during the site investigation and the dry soils are not expected to become saturated during, or after, construction. Therefore, liquefaction would not pose a threat to the potential stability of the embankment of the Two Road site either.

B.6.3.4 Ground settlement results

Stabilization on site

The natural foundation material at the processing site is characterized by up to 15 feet of dense, sandy, gravelly alluvium underlain by the Mancos Shale. A more detailed description of the subsurface conditions will be presented in the Remedial Action Plan (RAP) for Grand Junction and Section 7.0 of the text of this DEIS.

As discussed in Section B.2, the pile foundation would be elevated in order to keep the tailings above the Probable Maximum Flood (PMF) level of the adjacent Colorado River. The elevated foundation would consist of approximately eight feet of alluvial fill compacted to 95 percent of standard Proctor maximum dry density. In addition, the settlement analysis for the processing site conservatively assumed a ground-water level at the base of the foundation footing when calculating total settlement.

The settlement analysis for the foundation material was made using elastic theory. The procedure used is for coarse-grained material and is outlined in detail in NAVFAC DM 7.1-211 (1982). A relative density of 70 percent was conservatively assumed based on the consistently high blow counts from the SPT and boring log descriptions. The amount of settlement calculated for the foundation material is 0.06 foot. This settlement is expected to occur immediately.

The final tailings pile design for the processing site includes an embankment height of approximately 55 feet. The material would be blended to a homogeneous sand-slime mixture and compacted to 90 percent standard Proctor density (greater than 70 percent relative density) upon placement. The final tailings mixture is expected to be nonplastic, free draining, and unsaturated, thereby allowing settlement to occur immediately following construction.

The settlement analysis for the tailings embankment was made using conventional consolidation theory in conjunction with the equation and procedure described by Lambe and Whitman (1969). The virgin compression index (C_c) of 0.13, rebound index (C_r) of 0.01, and consolidation^c pressure of 2000 lbs/ft² were all determined by laboratory analyses of the tailings from the individual sites referenced. The amount of settlement expected from the tailings material is approximately 1.3 feet, and is expected to occur immediately following construction.

The total settlement for the site, therefore, is expected to be approximately 1.4 feet. This settlement includes both the tailings and the foundation materials, and as previously discussed, is expected to occur immediately following construction. Additional settlement from the five-foot radon barrier is not expected to be significant since the material will be compacted to 95 percent of standard Proctor density and placed in an unsaturated condition.

Disposal at the Cheney Reservoir alternative disposal site

The foundation material at the Cheney Reservoir site is characterized by between 23 and 42 feet of interlayered clay, silt, sand, and gravel. Ground water was encountered during the site investigation immediately above the Mancos Shale at a

depth of 30 feet. A more detailed description of the subsurface conditions will be presented in the Disposal Site Characterization Report for Cheney Reservoir and is summarized in Section 7.0 of the text of this DEIS.

The settlement analysis for the foundation material was made using elastic theory. Because of the large amount of clay material interlayered in the foundation profile, the settlement analysis conservatively assumed the site to be unsaturated, cohesive (fine-grained) material to bedrock. The settlement analysis for this type of material is outlined in NAVFAC DM 7.1-209. The site material was characterized as being "very stiff" to "hard" based on the high blow counts from the standard penetration test (SPT) and boring log descriptions. In addition, the over-consolidation ratio (OCR) of the clay material is estimated to be approximately eight, which would further reduce the expected settlement. The calculated amount of settlement for the foundation material is 0.1 foot. Due to the unsaturated state of the clayey material, and the high OCR, the settlement is expected to occur immediately following construction.

The total settlement for the site, therefore, is expected to be approximately 0.5 foot. This settlement includes both the tailings and the foundation material, and as previously discussed, is expected to occur immediately following construction. Additional settlement from the five-foot radon barrier is not expected to be significant since the material will be compacted to 95 percent of standard Proctor density and placed in an unsaturated condition.

Disposal at the Two Road alternate disposal site

The foundation material at the Two Road site is characterized by between 15 to 30 feet of sandy silts and clayey, gravelly sands. This material is underlain by Mancos Shale. A more detailed description of the subsurface conditions will be presented in the the Disposal Site Characterization Report for the Two Road site and is summarized in Section 7.0 of the text of this DEIS.

The settlement analysis for the foundation material was made using elastic theory. The procedure used is outlined in detail in NAVFAC DM 7.1-211. This analysis assumed the foundation profile to unsaturated, coarse-grained, and nonplastic material to bedrock. A relative density of 70 percent was conservatively assumed based on the high blow counts from the SPT and boring log descriptions. The amount of settlement calculated for the foundation material is 0.02 foot. As previously stated for the other two alternatives, this settlement is expected to occur immediately following construction.

The final tailings pile design for the Two Road site includes an embankment height of 35 feet. Since the tailings characteristics and embankment height are identical to the Cheney Reservoir site, the amount of settlement calculated for the tailings material would also be approximately 0.4 foot. This settlement would also be expected to occur immediately following construction.

The total settlement for the Two Road site, therefore, is expected to be approximately 0.42 foot. This settlement includes both the tailings and the foundation material.

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APPENDIX C
ALTERNATIVES ELIMINATED
FROM DETAILED STUDY

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C.1 SUMMARY

The process by which the alternate disposal sites were selected involved the public, the State of Colorado, and the U.S. Department of Energy (DOE). Colorado searched the Grand Junction area for potential disposal sites and identified 30 areas which appeared to have conditions suitable for tailings disposal. These 30 areas were evaluated against a 13-point exclusionary criteria which resulted in the selection of nine potential disposal sites. These nine sites were then arithmetically rated with a technical grading matrix. Public hearings were held to solicit public participation in the alternate disposal site nomination process. A Candidate Site Review Committee, consisting of city, county, and state officials, met in public session and nominated four sites for further analysis and consideration by the DOE. These four sites were East Salt Creek, 6 & 50 Reservoir, Cheney Reservoir, and Lucas Mesa (Figure C.1.1). The Lucas Mesa site was included as a potential site only for the colocation of the Grand Junction tailings and the tailings located at Rifle, Colorado.

The DOE evaluated the four sites nominated by Colorado against a technical suitability criteria consisting of five categories: environmental, geologic, hydrologic, land ownership and land use restrictions, and engineering economics. Through this process the DOE, with the concurrence of Colorado, selected the 6 & 50 Reservoir, Cheney Reservoir, and Lucas Mesa sites. Lucas Mesa was included only if the Grand Junction and Rifle tailings sites were to be colocated. The Salt Creek site was eliminated from further consideration because it was nearly identical to the 6 & 50 Reservoir site.

Following the collection of environmental data and preliminary engineering, the DOE, with the concurrence of Colorado, eliminated from further consideration the alternative of colocating the Grand Junction and Rifle tailings at Lucas Mesa because the environmental impacts and costs of this alternative were very high. In addition, the DOE, with the concurrence of Colorado, replaced the 6 & 50 site with the Two Road site because the two sites are nearly identical; however, the Two Road site is less susceptible to erosion and is therefore a better site for tailings disposal.

An additional site screening process was conducted to identify a site in the Grand Junction area that was both technically suitable and less costly than the other alternatives. The 32 Road site, located one mile southwest of Grand Junction, was selected for detailed study. Following the preparation of initial cost estimates and discussions with local officials, this alternative was eliminated from further consideration.

Therefore, the Cheney Reservoir and Two Road alternate disposal sites are addressed in this Environmental Impact Statement (EIS).

Since railroad lines run between Grand Junction and the general vicinity of both the Cheney Reservoir and Two Road sites, both rail transportation and truck transportation of the tailings to the alternate sites are addressed as separate alternatives in this EIS.

Reprocessing the tailings prior to stabilization was rejected because the costs of reprocessing greatly exceeded the value of the resources produced.

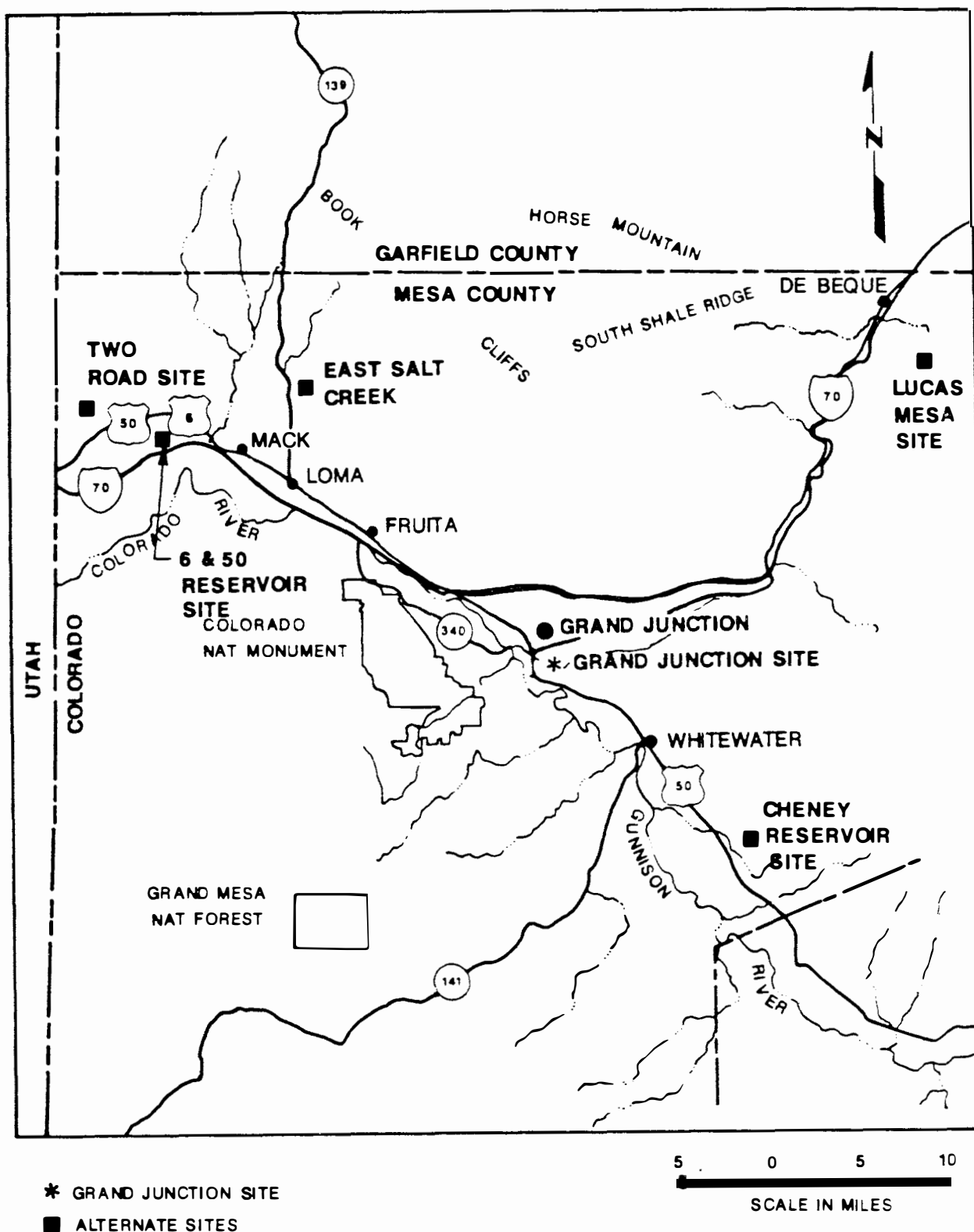


FIGURE C.11
THE GEOGRAPHICAL LOCATION OF THE TAILINGS PILE
AND THE ALTERNATE DISPOSAL SITES

Returning the tailings to the mines from which the ore was mined was rejected because the environmental conditions at many of the mines are not conducive to tailings disposal and because many of the underground mines have collapsed and are inaccessible.

The following sections of this appendix contain additional details on the alternatives selected for inclusion in this EIS.

C.2 STATE OF COLORADO ALTERNATE DISPOSAL SITE NOMINATION PROCESS

The following description of Colorado's alternate disposal site nomination process was obtained from the report entitled Potential Sites Suitable for Reclamation and/or Reprocessing of the Grand Junction and Rifle Uranium Mill Tailings Piles, issued in 1982 (CGS, 1982).

The State of Colorado established general placement objectives, conducted a regional survey to identify potential disposal sites, and evaluated the potential sites to select the best sites for nomination.

To ensure the safe, long-term containment of uranium tailings material, a number of general placement objectives were established for tailings disposal in Colorado. These placement objectives, which are compatible with the preferred method of tailings disposal (below grade and dewatered), were as follows:

- o Tailings or waste disposal areas should be located at a relatively remote site so as to reduce potential population exposures and the likelihood of human intrusions to the maximum extent reasonably achievable.
- o Tailings or waste disposal areas should be located at a site where disruption and dispersion by natural forces are eliminated or reduced to the maximum extent reasonably achievable.
- o Tailings and waste should be placed below grade, in trenches or pits excavated into relatively impervious shale.
- o Tailings and waste should be covered with a minimum of three meters of earthen materials that are designed to reduce surface exhalation of radon from the tailings or waste to less than two picocuries per square meter per second above background levels, are designed to reduce root or animal penetration and salt migration, and are constructed to minimize erosion.
- o Reclamation of the tailings or waste areas should include a full, self-sustaining vegetative cover or riprap to minimize wind and water erosion. The final contour slopes should be as close as possible to the natural surface, but not steeper than a ratio of five horizontal to one vertical.
- o Seepage of toxic materials to the ground or surface waters should be minimized to the maximum extent reasonably achievable so that ground water and other natural systems will not be degraded. Seepage control measures should include consideration of both physical and geochemical methods.
- o Tailings and waste should not adversely affect important mineral resources or unique historic, archaeologic, wildlife, or ecologic areas.
- o Tailings or waste should be confined to a single area to preclude the proliferation of numerous, small disposal areas.

- o The final disposition of the tailings and waste should be such that on-going active maintenance is not necessary to preserve isolation and that monitoring will be minimized to the maximum extent reasonably achievable.

These objectives can be achieved and candidate sites can be identified and compared through a two-phase selection process. Phase I of this process consisted of a series of elimination or filtering steps in which "potential sites" were delineated within a specific area around a particular tailings pile of interest. For this investigation, an area with a 15-mile radius around each tailings pile, and a 20-mile-wide corridor along the railroad from the Utah-Colorado line to Glenwood Springs and from Grand Junction south to the Mesa-Delta County line were inventoried. Phase II involved review and evaluation of these potential sites by an appropriate committee that was to select three to five candidate sites for further detailed study by the DOE.

PHASE I: The first step in Phase I was to determine the geologic formations that possess acceptable permeability, thickness, and lateral lithologic continuity. The formation should have beds of low or very low permeability that are at least 150 feet thick and are laterally persistent for many square miles. Formations with these characteristics are herein called "suitable formations." Certain other geologic formations in Colorado may in part meet this criterion, but they generally are not as thick and as laterally persistent, or may contain aquifers. These formations are not obvious host formations, but are herein called "possibly suitable formations." In areas where there is insufficient area underlain by "suitable formations," the "possibly suitable formations" may become important and in such cases should receive thorough evaluation. Detailed studies may eventually prove that some areas underlain by "possibly suitable formations" do meet the specified siting requirements.

In the study area only one formation, the Mancos Shale, meets the criteria for suitable formations. The Mancos Shale, a thick, laterally persistent, Cretaceous marine shale, is generally acceptable as a host formation for a tailings repository. The uppermost part of the formation, however, complexly interfingers with several sandstone beds. Similarly, the lower part of the Mancos contains limy beds and transitional silty and sandy zones. No sites were selected in either of these parts of the Mancos Shale.

One formation in the area, the Wasatch Formation, was classified as a possibly suitable formation. The Wasatch Formation consists of continental deposits of claystone with occasional sandstone and limestone beds. The middle part of the Wasatch Formation in the vicinity of DeBeque is particularly sandy. No sites were selected in the middle part of the Wasatch Formation.

The Green River Formation was initially considered as a likely candidate for designation as a possibly suitable formation because it contains thick sequences of shale, much of which is oil-rich. Additional evaluation, however, showed that the formation should not be so designated. The rationale for excluding this formation involved several factors, including (1) a site within the Green River Formation could inhibit future oil shale mining; and (2) the formation crops out only in steep cliff areas that are unacceptable for a tailings repository.

The second step of Phase I consisted of delineating areas of favorable slope that are underlain by suitable formations or, where necessary, by possibly suitable formations. The most favorable slopes range from two to five percent, but slopes of five to 10 percent or less than two percent were also considered acceptable. Areas that were underlain by suitable formations or potentially suitable formations and that had acceptable slopes and size were considered to be "target areas." A target area may contain more than one potential site.

Thirty target areas were selected for the Grand Junction-Rifle study area. These were the State Line, West Salt Creek, Dry Canyon, Camp Gulch, East Salt Creek, Coyote Wash, Dry Gulch, Lipan Wash, Mack East, Persigo Wash, Leach Creek, Indian Wash, Halls Basin, Whitewater Creek, Indian Creek, Windger Flats, Black Mountain, Place Mesa, Pyramid Rock, Roan Creek, Mesa, Monument Gulch, Parachute, North Rifle, Flatiron Mesa, Mamm-Divide Creek, Cactus Valley, Grass Valley, New Castle, and Garfield Creek target areas.

The third step of Phase I involved the evaluation of target areas with regard to the following criteria and selection of potential sites by excluding areas that did not meet the criteria. All of the following areas were disqualified as potential sites:

- o Areas of insufficient size.
- o Areas subject to extensive river flooding.
- o Areas of critical ground-water resources or recharge.
- o Areas of complex geologic structure (e.g., abundant faulting, folding, and jointing).
- o Areas susceptible to geologic hazards that could disrupt the repository (e.g., active faulting, subsidence, and unstable slopes).
- o Areas with severe erosion potential or unstable landforms.
- o Areas of Quaternary glacial or igneous activity.
- o Areas with critical mineral, geothermal, archaeologic, cultural, historic, wildlife, or ecologic resources.
- o Areas of critical surface water, springs, and present or planned large bodies of water.
- o Areas of concentrated human habitation or future growth areas--towns, subdivisions, and densely populated rural areas.
- o National Parks, National Monuments, Wildlife Refuges, wilderness areas, and wild and scenic river areas.
- o Areas of prime, irrigated agricultural lands.
- o Areas with severe transportation safety aspects.

Consideration of these criteria in regard to the target areas resulted in the selection of "potential sites." A number of sites within target areas received further consideration during this study, but were not recommended as potential sites. The potential sites recommended to the Candidate Site Review Committee for the relocation and/or reprocessing of the Grand Junction and Rifle uranium mill tailings piles from west to east, were as follows:

- o Two Road site.
- o McDonald Creek site.
- o 6 & 50 Reservoir site.
- o Camp Gulch site.
- o East Salt Creek site.
- o Halls Basin site.
- o Cheney Reservoir site.
- o Lucas Mesa site.
- o Flatiron Mesa site.

The fourth and final step of Phase I was the geotechnical evaluation and ranking of the potential sites by use of a grading matrix. To use the grading matrix, shown in Table C.2.1, scores were assigned to a number of geologic, hydrologic, and meteorologic factors for each site. Each factor was assigned a rank value from zero to four in the matrix based on the characteristics of the particular site being evaluated. Some factors are more important than others, and they are weighted accordingly. The total site score was calculated by adding all factor scores. A maximum score of 152 was possible.

PHASE II: Potential sites were reviewed and further evaluated during Phase II by the Candidate Site Review Committee. Members of the Committee included:

Rahe Junge - Colorado Geological Survey.
Richard Gamewell - Colorado Department of Health, Radiation Control Division.
Betsy Moen - University of Colorado, Institute of Behavioral Sciences.
James E. Morris - Colorado Division of Wildlife.
Richard Lessner - City Manager, Rifle.
George VanSlyke - Colorado Division of Water Resources, State Engineer's Office.
Pat Gormley - Remedial Action Lay Advisory Committee, Grand Junction.
Ned Noack - Colorado Department of Health, Waste Management Division.
Jim Pendleton - Colorado Mined Land Reclamation Division.
Tom Souville - Mesa County Health Department.
John Blair - Colorado Department of Health, Water Quality Control Division.
Barbara Chocoi - Colorado Department of Highways.
Darrell Lowder - City of Grand Junction.
David Ouimette - Colorado Department of Health - Epidemiology Division.
James Drinkhouse - Garfield County Commissioner.

The Committee was required to recommend three to five potential sites to be candidate sites for further detailed analysis by the DOE. Recommendations by the Committee were based not only on the currently available geotechnical data, but also on other important additional factors that must be considered for an acceptable disposal site. These factors included, but were not limited to, transportation elements, land use, land ownership, wildlife, archaeologic, cul-

Table C.2.1 An example of the geotechnical rating matrix used to comparatively rate potential sites:
Rank x weight = Factor Score; 0 = low rank; 4 = highest rank; highest possible score = 152.

Site designation: _____

Site location: _____

Factor	Rank					Weight	Factor score
	0	1	2	3	4		
1. Land slope	>10%		<2% or 5% to 10%		2% to 5%	1	
2. Surficial materials lithology	Gravel or sand	Very fine sand or sandy silt	Silt	Silty clay	Clay	1	
3. Surficial materials thickness (if clay or silty clay, site ranks 4)	>20 ft	10 to 20 ft	5 to 10 ft	2 to 5 ft	0 to 2 ft	2	
4. Host rock lithology	Sandstone, limestone, or conglomerate	Very fine sandstone or sandy siltstone	Siltstone	Silty shale or claystone	Shale or claystone	2	
5. Host rock thickness (if conglomerate or sandstone, site ranks 0)	<50 ft	50 to 75 ft	75 to 100 ft	100 to 200 ft	>200 ft	2	
6. Presence of fracturing (joints and shear zones)	Very high	High	Moderate	Low	Very low	1	
7. Seismic risk	Very high	High	Moderate	Low	Very low	1	

Table C.2.1 An example of the geotechnical rating matrix used to comparatively rate potential sites:
Rank x weight = Factor Score; 0 = low rank; 4 = highest rank; highest possible score = 152 (Continued)

Site designation: _____

Site location: _____

Factor	Rank					Weight	Factor score
	0	1	2	3	4		
8. Susceptibility to natural slope failures, subsidence, or hydro-compaction	Moderate to high		Low		Very low	4	
9. Present erosional/depositional setting	Intense gullyng	Moderate gullyng	Minor gullyng	Sheet or rill wash	No erosion or undergoing deposition	4	
10. Long-term geomorphic stability	Very poor	Poor	Moderate	Good	Excellent	4	
11. Conflict with mineral resources	Serious conflicts		Moderate conflicts		No or minor conflicts	1	
12. Aquifer characteristics of surficial material	Produces large amounts of good quality water	Produces minor-mod. amounts of good quality water	Produces large amounts of poor quality water	Produces minor-mod. amounts of poor quality water	Produces little or no water	4	
13. Aquifer characteristics of host rock	Produces large amounts of good quality water	Produces minor-mod. amounts of good quality water	Produces large amounts of poor quality water	Produces minor-mod. amounts of poor quality water	Produces little or no water	4	

Table C.2.1 An example of the geotechnical rating matrix used to comparatively rate potential sites:
Rank x weight = Factor Score; 0 = low rank; 4 = highest rank; highest possible score = 152 (Concluded)

Site designation: _____

Site location: _____

Factor	Rank					Weight	Factor score
	0	1	2	3	4		
14. Depth to 1st underlying important bedrock aquifer	<50 ft	50 to 75 ft	75 to 100 ft	100 to 200 ft	>200 ft	2	
15. Distance to nearest major spring, perennial stream, perennial lake, or major irrigation ditch	On site	0 to 1/2 mile	1/2 to 1 mile	1 to 2 miles	>2 miles	2	
16. Size of drainage basin above site	>2 sq miles	1 to 2 sq miles	1/2 to 1 sq mile	0 to 1/2 sq mile	at head of drainage	2	
17. Evaporation to precipitation ratio	<1		1 to 2		>2	1	
Total Site Score _____							

tural, and ecologic impacts, local attitudes toward particular sites, reclamation potential, economics, and site remoteness. The Committee incorporated such important factors into the final selection of candidate sites. The findings and recommendations of the Committee were then submitted to the Colorado Department of Health for review and submittal to the DOE.

It must be emphasized that this report was a reconnaissance evaluation of the potential sites. The types of information needed to thoroughly examine all the relevant geotechnical, environmental, economic, political, and social parameters can only be obtained by detailed studies. The reconnaissance data provided a suitable foundation for the committee members to satisfactorily select three to five candidate sites.

The nine sites were ranked by the Candidate Site Review Committee as follows:

<u>Site</u>	<u>Point Score</u>
Two Road site	128
McDonald Creek site	121
Camp Gulch site	120
East Salt Creek site	117
Cheney Reservoir site	116
Flatiron Mesa site	112
6 & 50 Reservoir site	109
Lucas Mesa site	108
Halls Basin site	105

The Candidate Site Review Committee identified the following positive and negative aspects of these sites.

Two Road site

Good long-term (10,000 years) stability; excellent geotechnical characteristics, but the possibility of recent structural deformation needs further evaluation; riprap may need to be hauled to the site; very remote; fairly long truck haul route, but the road is not heavily used; possible conflict with Bureau of Reclamation desalinization project; moderate potential for conflicts with oil and gas development.

McDonald Creek site

Good long-term stability; good geotechnical characteristics, but the possibility of recent structural deformation needs further evaluation; very remote; riprap may need to be hauled to the site; fairly long haul route, but roads not heavily used; slightly over one mile to a perennial creek which is in a different drainage; possible conflict with Bureau of Reclamation desalinization project; moderate potential for conflicts with oil and gas development.

6 & 50 Reservoir site

Moderate long-term stability; acceptable geotechnical characteristics; moderate gullyng on the site; remote; reservoir with good wildlife habitat that is

used for hunting is less than one mile from the site; moderate potential for conflicts with oil and gas development; near small parcel of private land.

Camp Gulch site

Moderate long-term stability; good geotechnical characteristics; geologic structures in the area may increase bedrock fracturing; riprap may need to be hauled to the site; very remote; considerable road construction needed to reach the site; truck route through Loma area; near gas field with moderate potential for conflicts; possible conflicts with proposed Colorado-Ute power plant.

East Salt Creek site

Good long-term stability; good geotechnical characteristics; geologic structures in the area may increase bedrock fracturing; riprap may need to be hauled to the site; remote; near gas field with moderate potential for conflicts; truck route through Loma area.

Halls Basin site

Moderate long-term stability; acceptable geotechnical characteristics; intense gully on the site but this can be readily mitigated through proper engineering and construction; good riprap sources adjacent to the site; irrigation ditch less than 0.5 mile away; very remote; considerable road construction required to reach the site; moderate highway safety hazard associated with truck haul from Grand Junction; surrounded by private land that may experience future subdivision development.

Cheney Reservoir site

Good long-term stability; good geotechnical characteristics; good riprap source on the site; less than one mile to the reservoir and creek with excellent wildlife habitat; very remote; considerable road construction required; moderate highway safety hazard associated with truck haul from Grand Junction; near private land.

Lucas Mesa site

Good long-term stability; acceptable geotechnical characteristics, but the erosion rates of the mesa flank must be carefully evaluated; good riprap on the site; just over one mile to an irrigation ditch and the Colorado River; very remote; very steep haul route; possible to use a conveyor; near private lands.

Flatiron Mesa site

Good to excellent long-term stability; good geotechnical characteristics, but the erosion rates of the mesa flank must be carefully evaluated; good riprap on the site; less than one mile to Beaver Creek, a public water supply for Rifle; very remote; very steep haul route; direct truck haul from Rifle is feasible; possible to use a conveyor; near private lands.

None of the sites were completely ideal when all relevant factors are considered. The Candidate Site Review Committee compared and weighed the advantages and disadvantages of each site to determine which sites were the most favorable for continued evaluation for long-term containment of the uranium tailings. It must be emphasized that this investigation was of a regional nature. Detailed evaluation of all relevant factors would be necessary during later studies by the DOE.

The Candidate Site Review Committee held public hearings to solicit public impact into the nomination of three to five sites and met in public session to nominate the following sites for further evaluation by the DOE.

- o East Salt Creek.
- o Cheney Reservoir.
- o 6 & 50 Reservoir.
- o Lucas Mesa (for colocation of the Grand Junction and Rifle tailings only).

C.3 U.S. DEPARTMENT OF ENERGY ALTERNATE DISPOSAL SITE SELECTION PROCESS

The following description of the DOE's alternate disposal site selection process was obtained from the report entitled Preliminary Evaluation of Alternative Disposal Sites for the Grand Junction, Old Rifle, and New Rifle Uranium Mill Tailings, issued in March, 1983 (DOE, 1983).

C.3.1 EVALUATION CRITERIA

The DOE evaluated the sites nominated by the State of Colorado against a technical evaluation criteria. The Department of Energy recommended 25 evaluation criteria in five categories. The evaluation criteria were based on site characteristics that affect suitability for a tailings repository. The five categories are (1) environmental criteria, including land use and wildlife characteristics; (2) geologic characteristics pertinent to the long-term stability of the site; (3) hydrologic characteristics that control the potential for contaminating ground and surface water; (4) land ownership and land-use restrictions; and (5) engineering economics. The two engineering-economics criteria were combined for this evaluation. Therefore, a total of 24 criteria were used.

The DOE defined the ideal and the least desirable site characteristics for each criterion. The perfect disposal site would be rated "ideal" for all of the 24 criteria. The five categories of criteria are discussed below.

Environmental criteria

This category included six evaluation criteria (Table C.3.1). The first three are related to land uses on and around the disposal site. These criteria are important because the long-term impacts of the disposal site depend on how people use the surrounding land.

The remaining three criteria relate to the National Environmental Policy Act and to three environmental review laws: the Fish and Wildlife Coordination Act, the National Historic Preservation Act of 1966, and the Endangered Species Act of 1973. By using these criteria, the intent of these three laws is included in the site-selection process.

Geologic criteria

All but one of the six geologic criteria (Table C.3.2) relate to the long-term stability of the disposal site. In order to meet the requirements of the EPA for long-term stability, the disposal site must not be subject to erosion by wind or water, or disturbances by landslides, subsidence, caving, or earthquakes.

Table C.3.1 Environmental criteria

Criterion	Ideal	Least desirable
Population density	<u>Low</u> : characteristic of rangeland area or wilderness area	<u>High</u> : location in an urban area
Potential for use as farmland	<u>None</u> : no soil present, or poor soil quality	<u>High</u> : soils well developed and suitable for farm location, in existing farmlands
Potential for use as a transportation corridor	<u>Low</u> : location in open terrain, not on line of sight between settlements or in natural corridors	<u>High</u> : location in a corridor (valleys, canyons) connecting urban areas
Presence of antiquities and historical sites	<u>None present</u> : within 1 mile	<u>Some present</u> : at the site
Presence of endangered, threatened, or rare species	<u>None present</u> : no critical habitats	<u>Some present</u> : habitat critical in survival of wildlife species
Scenic and recreational values	<u>None or low</u> : barren, monotonous landscape surrounds site	<u>High</u> : scenic and recreational areas located within 1 mile

Table C.3.2 Geologic criteria

Criterion	Ideal	Least desirable
Presence of economic mineral resources	<u>None present:</u> absence of development and interest in development, as shown by records of ownership, mineral leasing rights, and the like	<u>Some present:</u> mineral developments exist or are proposed for site or lands adjacent to site
Potential for erosion by winds	<u>Negligible:</u> sheltered from wind or location in deposition region for soils sediments	<u>High:</u> evidence of blowouts, sandblasting, or scouring
Potential for erosion by water	<u>Negligible:</u> as evidenced by slope, drainage pattern, and absence of arroyo cutting	<u>High:</u> evidence of sheet erosion and arroyo cutting; degrading slopes; location in floodplain
Potential for landslides	<u>Negligible:</u> nearly level terrain; unconsolidated soil layers well integrated with bedrock	<u>High:</u> steep terrain; evidence of rockslides or mudslides
Potential for subsidence, caving	<u>Negligible:</u> absence of near-surface mines or natural voids beneath site; water table below level of bedrock	<u>High:</u> mines, caverns, voids under site; evidence of subsidence from underground drainage or other causes
Seismic risk	<u>Low:</u> location in zones of no earthquake damage or minor damage of surface structures	<u>High:</u> location in zone of major damage to surface structures

The other geologic criterion is the presence of economic mineral resources. In some circumstances, the presence of tailings on the site could hinder the development of mineral resources under the site.

Hydrologic criteria

All of the hydrologic criteria are environmental characteristics that affect the likelihood of ground and surface water being contaminated by the tailings repository. These criteria are presented in Table C.3.3.

Criteria related to land ownership and land-use restrictions

Two factors that could prevent the disposal of tailings at a site are land ownership and land-use restrictions. These factors are considered in the site-selection process by the criteria given in Table C.3.4.

Criteria related to engineering economics

An important consideration in selecting a disposal site is the cost of tailings disposal in a manner that is environmentally sound. The DOE suggested two criteria that would be indicators of these costs: distance by road or rail from the existing pile, and distance by road or rail to sources of cover, cap, and other construction materials.

The costs of disposal were estimated and the cost estimates for five categories of construction activities were used instead of the DOE criteria to evaluate engineering economics. The costs used in the evaluation were for the following activities:

- o Disposal site preparation.
- o The loading of tailings from the existing pile.
- o Haulage to the disposal site.
- o The handling of tailings at the disposal site.
- o The construction of the cover for the repository.
- o Capital costs.

C.3.2 EVALUATION METHOD

The criteria presented in the preceding section were used to determine the suitability of the alternate sites for the disposal of uranium mill tailings. This section describes the mathematical method used to calculate a score for each site.

Weighted-score method

Each criterion was assigned to an expert in the related technical discipline. For instance, a ground-water expert was assigned the "depth

Table C.3.3 Hydrologic criteria

Criterion	Ideal	Least desirable
Precipitation	<u>Low</u> : less than 7 inches per year	<u>High</u> : more than 20 inches per year
Evapotranspiration	<u>High</u> : exceeds precipitation by more than 15 inches per year (arid)	<u>Low</u> : precipitation exceeds evapotranspiration (humid)
Distance to rivers, lakes, or perennial streams	<u>Large</u> : more than 10 miles	<u>Small</u> : rivers, ditches, lakes, or streams near the site
Depth of water table	<u>Large</u> : more than 500 feet	<u>Small</u> : less than 10 feet
Unsaturated-zone materials	Unweathered and unfractured clays, shales, or rocks of low permeability and high sorptive capacity	Gravel, sand, or highly fractured rock
Horizontal ground-water speed (near water table)	<u>Low</u> : less than 0.1 meter per year	<u>High</u> : more than 1 meter per year
Quality of uppermost ground water	<u>Poor</u> : more than 10,000 parts per million total dissolved solids	<u>Excellent</u> : potable water (0 to 1000 parts per million total dissolved solids)
Saturated-zone materials (near water table)	Unfractured shales, clays, or materials containing zeolite minerals	Gravel, sand, or highly fractured rocks, clay material with high organic content
Potential for flowing artesian wells	<u>None</u> : hydraulic head much less than surface elevation	<u>High</u> : hydraulic head exceeds surface elevation

Table C.3.4 Criteria related to land ownership and land-use restrictions

Criterion	Ideal	Least desirable
Land ownership	Federal Government	Private owners (many owners less desirable than a single owner)
Legal encumbrances and covenants regarding land use	None	Many

of water table" criterion. Before the scoring began, these experts collected as much information as possible about the sites.

The scoring began by assigning a range of possible scores for each criterion. The experts were allowed to select any range, an example being one to 10. A score within the selected range was then assigned to each site. The highest score was given to the best site as determined by that criterion.

For some criteria the site scores are subjective; they were based on the available data and information obtained by visiting the sites. For example, the scores for the "scenic and recreational values" criterion were based on first-hand observation.

For most of the criteria, however, the scores were determined directly from some quantitative measure. For example, the ground-water expert based the scores for the "depth of water table" criterion on the expected depth of the water table at each site. In this example the range of scores would be 30 to 500, with 30 feet being the minimum depth of the water table. The site score would be the expected depth of the water table. In this case, the highest quantitative value (i.e., water table at 500 feet) would result in the highest score.

For a few criteria, the site with the highest quantitative measure received the lowest score, an example being the cost of moving the tailings from the site with the highest moving costs receiving the lowest score. The example that follows illustrates the scoring process for this type of criterion and explains how the quantitative measures were inverted to obtain a score.

A meteorologist selected a scale of one to 10 for scoring the precipitation criterion. He then determined the amount of precipitation expected at each of the four sites, as shown in Table C.3.5. As indicated in Table C.3.5, an ideal site would have less than seven inches of precipitation per year, whereas the least desirable site would have more than 20 inches per year.

Table C.3.5 An example of site scoring

Site	Inches of precipitation (Q)	Score (S)	Normal score (NS)	Weighted score (WS)
1	8	9.3	92	1.8
2	12	6.5	61	1.2
3	16	3.8	31	0.6
4	18	2.4	16	0.3

The site scores, also shown in Table C.3.5, were calculated by using the following formula:

$$S = \frac{(LD - Q)}{(LD - I)}(U - L) + L$$

where

S = the site score for a criterion.

LD = the least desirable quantitative measure for the criterion (i.e., 20 inches of precipitation per year).

I = the ideal quantitative measure for the criterion at a site (i.e., the precipitation expected at the site).

U = the upper limit of the range of scores (in this case 10).

L = the lower limit of the range of scores (in this case one).

This initial scoring process yielded scores for each criterion but with different scales. The meteorologist may have used a scale of one to 10, whereas the ground-water expert used one to two. In order to compile the various scores, it was necessary to place them on a uniform scale of 10 to 100. This was done by means of the following formula:

$$NS = \frac{S - L}{U - L} 100$$

where

NS = is a normalized score for the criterion at a site and the other items are as defined previously.

For each site, the scores for the 24 criteria can be summed and the totals for each site compared. For a perfect site (i.e., all criteria score 100) the total would be 2400. Comparing the totals of these scores gives equal weight to each category: precipitation would be as important as transportation costs.

Weighting factors

The scoring process was then taken one step further. Weighting factors, which describe the relative importance of the criteria, were incorporated by using the following equation:

$$WS = NS \frac{WF}{TW}$$

where

WS = the weighted score for the criterion at a site.

WF = the weighting factor for the criterion.

TW = the sum of all weighting factors.

In the precipitation example, the weighting factor is two, with the sum of all weighting factors being 100. This means that two percent of the total score will be attributed to precipitation. When the weighted scores for each site are summed, the sums will be between zero and 100, with 100 being an ideal site. The weighting factors used in this evaluation are given in the next section.

The weighting factors used in this analysis are given in Table C.3.6. Except for the engineering-economics criteria, they are based on the factors recommended by DOE. In proposing these factors, DOE recognized that it would be impractical to impose a uniform weighting system for all candidate sites and encouraged rational modifications to these factors. After careful consideration, it was decided that the recommended weighting factors do indeed apply to the four sites being considered for the disposal of the Grand Junction and Rifle tailings.

C.3.3 ALTERNATIVES SELECTED

The weighted scores assigned to the alternative sites for site suitability criteria are presented in Table C.3.7.

The weighted scores for the environmental criteria range from 3.2 to 7.1 out of a possible 11 points. None of the sites is ideal in terms of these criteria. Three of the alternative sites--East Salt Creek, 6 & 50 Reservoir, and Lucas Mesa--received similar scores for these criteria. The score for the Cheney Reservoir site is about three points lower than those of the other sites; the lower score is attributable mainly to the higher population of the area and the site's higher potential for use as farmland.

All four sites were scored about the same for the geologic criteria--about 22 points out of a possible 28. Although not ideal, all of these sites are very suitable in terms of geologic conditions. Their scores support the results reported by the Colorado Geological Survey in its siting report.

Table C.3.6 Weighting factors

Criterion	Weight
Environmental criteria	
Population density	4
Potential for use as farmland	2
Potential for use as transportation corridor	2
Presence of antiquities, etc.	1
Presence of endangered or threatened species	1
Scenic and recreational values	<u>1</u>
Subtotal	11
Geologic criteria	
Presence of economic mineral resources	3
Potential for wind erosion	8
Potential for water erosion	8
Potential for landslides	3
Potential for subsidence and caving	3
Seismic risk	<u>3</u>
Subtotal	28
Hydrologic criteria	
Precipitation	2
Evapotranspiration	2
Distance to rivers, lakes, etc.	
Depth of water table	4
Unsaturated-zone materials	4
Horizontal ground-water speed	2
Quality of uppermost ground water	2
Saturated-zone materials	2
Potential for artesian wells	<u>1</u>
Subtotal	21
Criterion related to engineering economics: disposal cost	30
Criteria related to land ownership and use restrictions	
Land ownership	8
Legal encumbrances	<u>2</u>
Subtotal	10
Total	100

Table C.3.7 Weighted scores for site-suitability criteria

Criterion	East Salt Creek	6 & 50 Reservoir	Cheney Reservoir	Lucas Mesa
Environmental criteria				
Population density	2.7	2.7	0.9	1.8
Potential for use as farmland	1.1	1.3	0.4	0.9
Potential for use as transportation corridor	0.4	0.7	0.4	1.6
Presence of antiquities, etc.	0.7	0.9	0.3	0.5
Presence of endangered and threatened species	0.8	0.8	0.8	0.7
Scenic and recreational values	<u>0.7</u>	<u>0.7</u>	<u>0.4</u>	<u>0.4</u>
Subtotal	6.4	7.1	3.2	5.9
Geologic criteria				
Presence of economic mineral resources	2.1	2.4	1.8	1.5
Potential for wind erosion	4.0	4.0	4.0	7.0
Potential for water erosion	7.9	7.5	7.8	6.7
Potential for landslides	2.7	3.0	3.0	1.5
Potential for subsidence and caving	3.0	3.0	3.0	3.0
Seismic risk	<u>2.4</u>	<u>2.4</u>	<u>2.4</u>	<u>2.7</u>
Subtotal	22.1	22.3	22.0	22.4
Hydrologic criteria				
Precipitation	1.8	1.8	1.8	3.6
Evapotranspiration	1.7	1.7	1.7	0.4
Distance to rivers, lakes, etc.	0.5	0.1	0.2	0.3
Depth of water table	4.0	1.5	2.3	1.5
Unsaturated-zone materials	3.6	3.2	3.6	3.6
Horizontal ground-water speed	1.8	1.6	1.6	1.2
Quality of uppermost ground water	1.0	1.0	1.0	1.0
Saturated-zone materials	1.8	1.4	1.4	1.0
Potential for artesian wells	<u>0.0</u>	<u>0.0</u>	<u>0.0</u>	<u>0.5</u>
Subtotal	16.2	12.3	13.6	10.1
Land ownership and land use restrictions				
Land ownership	8.0	8.0	4.8	3.2
Legal encumbrances	<u>2.0</u>	<u>2.0</u>	<u>2.0</u>	<u>2.0</u>
Subtotal	<u>10.0</u>	<u>10.0</u>	<u>6.8</u>	<u>5.2</u>

The weighted scores for the hydrologic criteria range from 10.1 to 16.2 points out of a possible 21 points, with East Salt Creek receiving the highest score of 16.2 points. The 6 & 50 Reservoir and Cheney Reservoir sites were rated about the same, with 12.3 and 13.6 points, respectively; they received a lower score than did East Salt Creek mainly because the water table is closer to the surface at these two sites. The lowest score, 10.1, was assigned to Lucas Mesa, mainly because this site has a shallow water table, more rainfall, and a lower evapotranspiration rate.

The environmental, geologic, and hydrologic criteria are related to the stability of the site and the degree to which a tailings repository at the site could affect the human environment. The scores for these criteria indicate that the East Salt Creek and the 6 & 50 Reservoir sites would be the two best disposal sites. However, the difference between the highest and the lowest scores for these criteria is only seven points out of a possible 60.

The scores indicate that all four sites are suitable for tailings repositories.

The scoring for land ownership and legal restrictions on land use resulted in the same site ranking as the first three categories of site suitability criteria. The East Salt Creek and the 6 & 50 Reservoir sites received a perfect score of 10 for these criteria. Cheney Reservoir and Lucas Mesa received lower scores because of possible conflicts with other land owners. Therefore, in terms of all criteria except cost, East Salt Creek and the 6 & 50 Reservoir would be considered most suitable for a tailings repository. The total point difference between the highest and the lowest scores for the site-suitability criteria is 11 points out of a possible 70.

Engineering economics

The scores for engineering economics were based on relocating (1) only the Grand Junction tailings, (2) only the Rifle tailings, and (3) the combined tailings by different modes of transportation. Consequently, six different scores for engineering economics were assigned to East Salt Creek, the 6 & 50 Reservoir, and Cheney Reservoir, where either truck transport or rail and truck transport were considered, and nine scores for Lucas Mesa, where a conveyor system was considered as well.

On the basis of costs alone, moving the Grand Junction tailings to Cheney Reservoir and the Rifle tailings to Lucas Mesa would be preferable. Cheney Reservoir and Lucas Mesa are closest to Grand Junction and Rifle, respectively, and the cost of transportation, which is the major component of the total cost, depends on distance.

Three other conclusions can be drawn from the evaluation of engineering economics:

- o Truck transportation is less expensive than other modes in all cases.

- o Moving all of the tailings to one site is more expensive than many of the other options.
- o If rail transport is used at Lucas Mesa, conveying the tailings up the front of the mesa is less expensive than trucking the material.

Total weighted scores

The total weighted scores for all criteria are presented in Table C.3.8. They indicate that East Salt Creek and the 6 & 50 Reservoir would be preferable for all transportation modes regardless of which tailings piles are relocated. However, the significance of the differences in site scores depends on which tailings are moved and on the mode of transportation.

Table C.3.8 Total weighted scores for the alternate sites

Source of tailings	Transportation method	East Salt Creek	6 & 50 Reservoir	Cheney Reservoir	Lucas Mesa
Grand Junction	Truck	78.5	76.0	72.7	64.7
	Rail and truck	63.0	59.8	54.6	47.5
	Rail and conveyor	--	--	--	51.5
Rifle	Truck	72.9	70.3	66.0	69.3
	Rail and truck	60.4	57.2	52.0	54.7
	Rail and conveyor	--	--	--	--
Grand Junction and Rifle	Truck	77.3	74.8	71.8	71.2
	Rail and truck	60.5	57.2	52.4	51.9
	Rail and conveyor	--	--	--	55.7

If the Grand Junction tailings are to be moved to a separate disposal site, East Salt Creek, 6 & 50 Reservoir, or Cheney Reservoir would be suitable. The total score of 6 & 50 Reservoir is about three points (about four percent) lower than that for East Salt Creek. The score for the Cheney Reservoir site is about three points (against about four percent) lower than that for the 6 & 50 Reservoir. The total weighted score for Lucas Mesa is much lower: five to nine points lower than the score for the next best site--Cheney Reservoir. Therefore, the Lucas Mesa site should not be chosen for the disposal of the Grand Junction tailings alone.

If the Rifle tailings are to be moved to a separate disposal site, any of the four alternatives with the possible exception of Cheney Reservoir should be selected. The maximum difference in score is eight points. However, in view of the large differences in cost, Lucas Mesa

should be considered the prime site for the disposal of the Rifle tailings. The Cheney Reservoir site is the lowest-ranking site for the Rifle tailings. In addition, the Rifle tailings would have to be transported through Grand Junction (a circumstance not considered in the site scoring). On this basis, Cheney Reservoir should not be considered for the disposal of the Rifle tailings alone.

Although not economically attractive, joint disposal of the tailings at a single site may be considered. In this case, the East Salt Creek and the 6 & 50 Reservoir sites would be preferable.

In summary, Lucas Mesa should not be considered for the disposal of the Grand Junction tailings alone, and Cheney Reservoir should not be considered for the disposal of the Rifle tailings alone.

DOE initially selected, with the concurrence of the State of Colorado, the Cheney Reservoir, 6 & 50 Reservoir, and Lucas Mesa (for codisposal of the Grand Junction and Rifle tailings only) for inclusion in this EIS. The East Salt Creek site was eliminated because it was close to and nearly identical to the 6 & 50 Reservoir site and the inclusion of both sites would be redundant.

Following initial engineering and environmental data collection and impact assessment, DOE concluded and the State of Colorado concurred, that the colocation of the Grand Junction and Rifle tailings at the Lucas Mesa site was not a reasonable alternative due to unacceptably high environmental impacts and costs. Codisposal was therefore eliminated from further consideration.

Following initial engineering, the State of Colorado nominated the Two Road site to replace the 6 & 50 Reservoir site because the Two Road site had less relief and was less susceptible to erosion than the 6 & 50 Reservoir site. The Two Road site is very near the 6 & 50 Reservoir site and received the highest rating by the Colorado Candidate Site Review Committee (Section C.2). The DOE approved this nomination and replaced the 6 & 50 Reservoir site with the Two Road site.

In the fall of 1985, DOE conducted a further site screening process to identify an alternate site in the Grand Junction area that was both technically suitable and less costly than the other alternatives. Sites within a 10-mile radius of Grand Junction were identified and rated against a 30 point environmental and engineering evaluation criteria. Two sites were selected for further analysis--Leach Creek and 32 Road. The Leach Creek site is located one mile north of the Grand Junction airport on land administered by the BLM and the 32 Road site is located one mile southeast of Grand Junction on privately owned land. The 32 Road site received the highest rating and was selected for more detailed consideration. Following the collection of site-specific environmental data, preparation of initial cost estimates, and discussions with local officials, DOE determined, and the State of Colorado concurred, that relocation of the tailings to a site only one mile from Grand Junction was not appropriate. This alternative was therefore eliminated from further consideration.

Therefore, the alternate disposal sites addressed in the EIS are the Cheney Reservoir and Two Road sites.

C.4 TRANSPORTATION METHODS

Railroad lines run from the Grand Junction site south to within approximately 10 miles of the Cheney Reservoir site and west to within approximately 10 miles of the Two Road site. Although trucks would be required to transport the tailings from an appropriate point on the rail line (load-out point) to the disposal site, the transport of the tailings by rail from the Grand Junction site to the load-out points was determined to be a reasonable alternative. Therefore rail transport of the tailings to both the Cheney Reservoir and the Two Road site are included as alternatives in this EIS.

C.5 REPROCESSING THE TAILINGS PRIOR TO DISPOSAL

The DOE is required by the Uranium Mill Tailings Radiation Control Act to determine the practicality of reprocessing the Grand Junction uranium mill tailings for the recovery of their residual mineral content. A detailed economic evaluation of the possibility was conducted for the DOE (DOE, 1982). The evaluation concluded that the cost of recovering these minerals would be about \$34 million and would yield only about \$22 million worth of uranium and vanadium under present market conditions; the net reprocessing cost would therefore be about \$12 million. The report further concludes that the market value of uranium and vanadium would have to increase by almost 60 percent for reprocessing to reach the break-even point. Since the preparation of this report, the market value of uranium has dropped even lower.

In addition, reprocessing the tailings would not reduce the radium content of the tailings. Since the radioactive decay of radium is the source of radon (the principal health hazard from the tailings) there would be no reduction of the hazard from radon daughters. Therefore the reprocessed tailings would still require remedial action to meet EPA standards. Reprocessing the tailings was therefore rejected as unreasonable.

C.6 RETURNING THE TAILINGS TO THE MINES

The uranium ore processed at the Grand Junction site was mined from a large number of surface and underground mines in the western Colorado and eastern Utah area. These mines have been abandoned for many years and many have collapsed and are not accessible.

The possibility of returning the Grand Junction tailings to these mines was considered but was rejected as infeasible and unreasonable because many of the mines are inaccessible and the environmental conditions (such as the presence of ground water) are not conducive to tailings disposal.

REFERENCES FOR APPENDIX C

- CGS (Colorado Geological Survey), 1982. "Potential Sites Suitable for Reclamation and/or Reprocessing of the Grand Junction and Rifle Uranium Mill Tailings Piles," Open-File Report 82-2, Denver, Colorado, September, 1982.
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APPENDIX D
WEATHER, AIR QUALITY, AND NOISE



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D.1 INTRODUCTION

This appendix contains environmental information and data compiled from the literature and collected during investigations of Grand Junction and the alternate sites. The materials in this appendix are referred to in the weather, air quality, and noise sections of the DEIS text.

D.2 WEATHER

D.2.1 REGIONAL TEMPERATURES AND PRECIPITATION

A summary of data on temperatures in the region of Grand Junction and the alternate sites is presented in Table D.2.1. These data were collected at weather stations at Altenbern, Colorado National Monument, Fruita, Grand Valley, Grand Junction, Palisade, and Rifle. Precipitation data for the region are summarized in Table D.2.2.

D.2.2 WINDS

The National Weather Service station at the Grand Junction airport is the only source of long-term data on wind speed and wind direction. However, for the Two Road site, data collected by the Colorado-Ute Electric Association from its meteorological tower three miles east of the site were obtained. To provide the information needed for this EIS about the winds at the Cheney Reservoir site, a meteorological tower was installed at the site, with temperature, wind-speed, and wind-direction sensors at a height of 35 feet above the surface of the ground. The data collection at the Cheney Reservoir site began in September, 1982, and continued through August, 1983.

The wind rose for Grand Junction shown in Figure D.2.1, based on data for 1960 to 1964, shows the apparent topographic effects of the Grand Valley. The dominant wind directions are from the east-southeast, southeast, and northwest. This distribution of wind direction is quite constant throughout the year because of the dominance of valley-induced upslope and downslope flows.

For the period 1941 to 1970, the wind speed at the Grand Junction airport averaged 8.7 miles per hour (mph). The prevailing wind direction was east-southeast. The highest sustained wind speed on record was 66 mph, recorded in June, 1951.

It is evident from the wind rose for the Cheney Reservoir site that the winds tend to conform to the orientation of the Gunnison River valley. The average annual wind speed was measured at the site for the period September, 1982, through August, 1983.

The wind rose for the Two Road site, derived from data obtained from the nearby Colorado-Ute tower for the period February 1, 1981, through January 1, 1982, shows a prevalence of winds from the west-northwest and northwest. The high frequencies of northwesterly winds can be attributed to drainage flows that originate in the high terrain northwest of the tower during stable atmospheric conditions.

The average annual wind speed measured at the Colorado-Ute tower was 5.8 mph. This wind speed is lower than that measured at the Grand Junction airport during the same period (8.7 mph), probably because the terrain in the area of the Two Road site is more sheltered than that at the airport.

Table D.2.1 Summary of regional temperature data

Station	Elevation	Temperature (°F)			No. of days per year with maximum 90° or above	No. of days per year with minimum 0° or below
		Average maximum	Average minimum	Annual average		
Altenbern ^a	5690	62.6	30.1	46.4	34	15
Colorado National Monument ^b	5780	63.6	40.1	51.9	47	2
Fruita ^b	4510	66.7	34.0	50.4	66	9
Grand Valley ^c	5090	66.0	33.1	49.6	67	13
Grand Junction ^d	4843	65.1	40.2	52.7	66	6
Palisade ^b	4800	67.6	41.1	54.4	72	2
Rifle ^b	5320	63.6	30.1	46.9	37	17

^aBased on the period 1959-1981.

^bBased on the period 1951-1981.

^cBased on the period 1965-1981.

^dBased on the period 1941-1970.

Ref. Colorado Climatological Office, 1982.

Table D.2.2 Summary of regional precipitation data

Station	Annual precipitation (inches)	Annual snowfall (inches)	Mean no. of days per year with precipitation >0.1 inch
Altenbern ^a	15.42	62.9	49
Colorado National Monument ^a	10.60	41.6	39
Fruita ^a	8.23	18.0	30
Grand Valley ^b	12.25	35.7	41
Grand Junction	8.41 ^c	26.5 ^d	(e)
Palisade ^a	9.15	17.9	34
Rifle ^a	11.47	50.9	42

^aBased on the period 1951-1981.

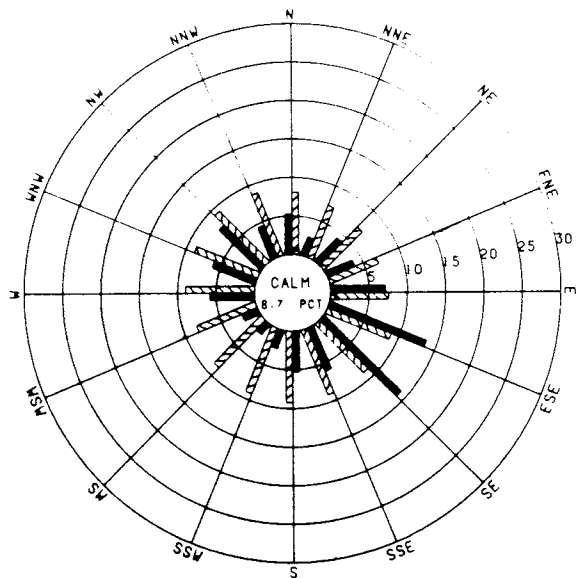
^bBased on the period 1965-1981.

^cBased on the period 1941-1970.

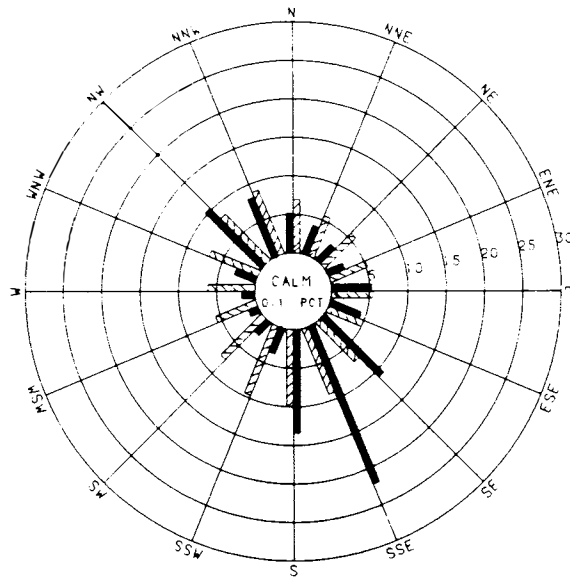
^dBased on the period 1942-1981.

^eThis record not reported in Local Climatological Data (LCD) for Grand Junction.

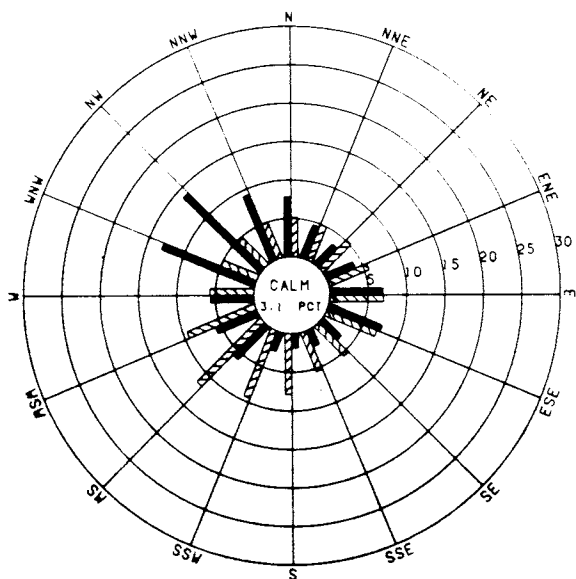
Ref. Colorado Climatological Office, 1982.



GRAND JUNCTION



CHENEY RESERVOIR



TWO ROAD

 Wind-direction frequency (%)
 Mean wind speed (mph)

FIGURE D.2.1
WIND ROSE FOR GRAND JUNCTION (1960-1964),
THE CHENEY RESERVOIR SITE (SEPTEMBER 1982-AUGUST 1983),
AND THE TWO ROAD SITE (COLORADO-UTE ELECTRIC
ASSOCIATION TOWER NEAR THE SITE, FEBRUARY 1981-JANUARY 1982).

D.3 EXISTING AIR QUALITY

Grand Junction and the alternate sites are in the Grand Mesa Air Quality Control Region (AQCR). Established by the EPA, the Grand Mesa AQCR consists of the Colorado counties of Delta, Eagle, Garfield, Gunnison, Hinsdale, Mesa, Montrose, Ouray, Pitkin, San Miguel, and Summit. Except for the concentrations of TSP, the results of air-quality monitoring show that the region has acceptable (i.e., attainment) air quality.

Besides total suspended particulates, the "criteria pollutants" are sulfur dioxide, ozone, nitrogen dioxide, carbon monoxide, and lead. For any criteria pollutant, an area can be classified as attainment, unclassified, or nonattainment. Attainment or unclassified implies that the air quality is generally acceptable; nonattainment means that air-quality standards are being exceeded. The attainment status for the criteria pollutants in Mesa County is as follows:

- o Total suspended particulates: the urbanized area around Grand Junction is classified as nonattainment. This area extends from Fruita east to Palisade. The Grand Junction tailings site is within the nonattainment area; however, the alternate sites are not.
- o Sulfur dioxide: the concentrations in Mesa County are lower than the national and state standards.
- o Ozone: the concentrations in Mesa County are lower than the national and state standards.
- o Nitrogen dioxide: the concentrations in Mesa County are lower than the national and state standards.
- o Carbon monoxide: the concentrations in Mesa County are lower than the national and state standards.
- o Lead: the concentrations in Mesa County are lower than the national and state standards.

Table D.3.1 presents an annual summary of the measured concentrations of total suspended particulates in Mesa County.

The national and Colorado air-quality standards are summarized in Table D.3.2. The major sources of emissions in the Grand Junction region are listed in Table D.3.3.

A major source is defined as emitting more than 50 tons per year of a particular pollutant. As shown in Table D.3.3, the two largest sources are the Gary Refining Company and the Public Service Company of Colorado. These sources are more than 10 miles from the tailings pile in Grand Junction. The Gary Refining Company is approximately 12 miles southeast of the Two Road site. No major sources of air pollution are known to exist near the Cheney Reservoir site.

The air-quality regulations of the State of Colorado require that strict control measures be used for any construction or transportation activities in nonattainment areas for TSP. These control measures apply to the following:

Table D.3.1 Annual summary of available data on total suspended particulate concentrations in Mesa County^a

Address of monitoring station	Station type	Number of obs. (days)	Annual geometric mean (microg/m ³)	24-hour concentration (microg/m ³)		Number of excursions ^b	
				Highest	Second highest	Primary standard	Secondary standard
5th and Rood Sts. Grand Junction	City center-commercial	84	77 ^c	243	232	0	2
		14	64 ^d	194	113	0	1
		57	45 ^e	144	137	0	0
12th and North Ave. Grand Junction	City center-commercial	78	79 ^c	225	186	0	6
100 W. Pabor St. Fruita	City center-residential	80	87 ^c	192	178	0	5
		14	57 ^d	124	121	0	0
		66	48 ^e	129	121	0	0
Island Lakes Park U.S. Highway 6 and I-70 Palisade	Suburban-residential	78	48 ^c	130	113	0	0

^aAll data collected in 1981.

^bNumber of times the 24-hour concentration exceeded primary or secondary standards for total suspended particulates.

^cSamples collected at EPA SLAMS station (gravimetric).

^dSSI sampler operated by the Mesa County Department of Health.

^eSSI sampler colocated with the TSP SLAMS station.

Ref. DOE, 1983.

Table D.3.2 National and Colorado standards for ambient air quality^a

Pollutant	Averaging time	Primary standard	Secondary standard
Sulfur dioxide, national	Annual arithmetic mean 24-hour ^b 3-hour ^b	80 365 ---	--- --- 1300
		Category I (incremental)	Category II (incremental)
state	Annual arithmetic mean 24-hour maximum ^b 3-hour maximum ^b	2 5 25	10 50 300
		Category III (incremental)	
		Primary standard	Secondary standard
Total suspended particulates ^{c,d}	Annual geometric mean 24-hour ^b	75 260	60 ^e 150
Carbon monoxide ^{c,d}	8-hour ^b 1-hour ^b	10,000 40,000	10,000 40,000
Ozone	1-hour ^c 1-hour ^d	235 160	235 ---
Nitrogen dioxide ^{c,d}	Annual arithmetic mean	100	100
Lead ^c	Calendar quarter average	1.5	1.5

^aAll concentrations are in micrograms per cubic meter.^bNot to be exceeded more than once per year.^cNational Ambient Air Quality Standard.^dColorado Ambient Air Quality Standard.^eAn 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.^fAveraging time 6 a.m. to 9 a.m.

Table D.3.3 Major sources of air pollutants in the Grand Junction region^a

Source	Distance and direction from the Grand Junction tailings site	Pollutant	Estimated rate of emission (tons per year)
Gary Refining Company	16 miles northwest	Total suspended particulates	2647
		Sulfur dioxide	2929
		Hydrocarbons	424
		Carbon monoxide	492
Public Service Company of Colorado	13 miles east-northeast	Sulfur dioxide	1805
		Hydrocarbons	55
		Carbon monoxide	145
Louisiana-Pacific Corporation	14 miles northwest	Total suspended particulates	155
Corn Construction Company	7 miles east-northeast	Total suspended particulates	89
Elam Construction Company	14 miles northwest	Total suspended particulates	61

^aData from the Colorado Department of Health (1983).

- o Unpaved roadways. These are roadways used by more than 15 vehicles per day. Controls can include watering, chemical stabilization, and speed limits.
- o Paved roadways. Controls can include covering haul vehicles, washing exteriors, limiting loads, limiting vehicular speed, treating the loads, and keeping the roadway free of debris.
- o Haul roads. These are roads used by more than 40 haul vehicles per day or more than 200 total vehicles per day. Controls can include speed limits, watering, chemical stabilization, and road carpeting.
- o Haul trucks. Controls can include covering, washing the exterior, limiting loads, reducing speeds, and wetting the load.
- o Construction activities. Controls are applied when more than one acre is cleared or leveled; they can include vegetation, synthetic covers, watering, chemical stabilization, furrows, compacting, minimization of the disturbed area, and wind breaks.
- o Storage and handling of materials. Controls can include enclosures, covers, stabilization, compaction, watering, and limiting of fine particulates.
- o Tailings piles and ponds. Controls can include watering and/or chemical stabilization, covers, wind breaks, minimization of the disturbed area, and speed limits.
- o Demolition activities. Controls can include wetting down surfaces; removing dirt from streets; and wetting, washing, and covering haulage equipment. Special regulations apply if asbestos exists in the building.

D.4 ASSESSMENT OF AIR QUALITY IMPACTS

This section describes the methods used for calculating air pollution resulting from wind erosion and the operation of trucks and other equipment for each tailings disposal alternative.

Wind erosion of tailings and other material for each alternative was estimated by using a version of the universal soil-loss equation recommended by the Colorado Department of Health (1981). The following factors were used in the equation:

- o Portion of total wind-erosion losses suspended: 2.5 percent.
- o Soil erodibility: 220 tons per acre per year for tailings; 160 tons per acre per year for soil.
- o Climatic factor: 69.
- o Unsheltered field width: 1. (This is the field-width factor for a field with a width greater than 2000 feet.)
- o Vegetative cover: 1. (This figure denotes no vegetative cover.)
- o Surface roughness: 1. (This figure stands for a smooth surface.)

The amount of dust generated by wind depends on the type of material on the ground. For each of the alternate disposal sites, it was assumed that 50 percent of the area exposed to wind erosion was tailings and 50 percent soil.

Fugitive-dust emissions of all equipment and haul trucks (Table D.4.1) were calculated by using emission factors developed by the Colorado Department of Health (1981).

Control of fugitive-dust emissions during construction was assumed. The specific assumptions concerning the control of dust generated by equipment and haul trucks were that water would be applied twice a day to all haul roads and to areas being continuously disturbed by scrapers and other construction equipment, and that the control efficiency would be 50 percent.

Exhaust emissions from construction equipment, off-road trucks, and locomotives were calculated with emission factors recommended by the EPA (1982). Exhaust emission rates of on-road haul trucks (15- and 25-ton), were calculated by using emission factors developed by the EPA (1978). The emission factors used are presented in Table D.4.1.

The construction schedules established for the remedial action were used to define when and where each piece of equipment and truck is operated. Emission totals were calculated by adding up the total pounds emitted for each piece of equipment and each activity.

The controlled (50 percent) short-term fugitive particulate emission rates used in the modeling analysis represented those occurring in the peak month of activity. It was conservatively assumed that all equipment during the peak month would be operating concurrently. Wind erosion emissions along with truck

Table D.4.1 Air pollutant emission factors^a

Equipment	Dust-emission factor	Exhaust-emission factors ^b				
		Nitrogen oxides	Sulfur dioxide	Carbon monoxide	Hydrocarbons	Particulates
Scraper	16.0 lb/hr	6.62	0.49	1.55	0.68	0.43
Front-end loader						
3.5-cy bucket	0.034 lb/cy	1.88	0.14	0.44	0.15	0.13
4.5-cy bucket	0.033 lb/cy	2.53	0.19	0.59	0.20	0.18
6.0-cy bucket	0.033 lb/cy	3.47	0.27	0.81	0.27	0.25
7.0-cy bucket	0.033 lb/cy	5.39	0.41	1.26	0.43	0.39
Grader	32.0 lb/hr	2.09	0.17	0.44	0.10	0.12
Dozer	32.0 lb/hr	3.59	0.34	0.95	0.27	0.27
Compactor	32.0 lb/hr	4.68	0.44	1.23	0.35	0.36
Grizzly (separator)	0.2 lb/ton	--	--	--	--	--
Conveyor	0.2 lb/ton	--	--	--	--	--
Conveyor transfer	0.023 lb/ton	--	--	--	--	--
15-ton haul truck						
On-site haul	7.34 lb/mile	14.32	2.8	17.9	2.7	1.3
Gravel-road haul	15.10 lb/mile	--	--	--	--	--
Paved-road haul	1.99 lb/mile	--	--	--	--	--
Dumping	0.034 lb/cy	--	--	--	--	--
25-ton truck						
On-site haul	13.21 lb/mile	14.32	2.8	17.9	2.7	1.3
Gravel-road haul	27.18 lb/mile	--	--	--	--	--
Paved-road haul	2.85 lb/dump	--	--	--	--	--
Dumping	0.037 lb/cy	--	--	--	--	--
35-ton truck						
On-site haul	4.40 lb/hr	3.41	0.20	0.60	0.20	0.12
Dumping	0.041 lb/cy	--	--	--	--	--
Water truck (on-site)	2.94 lb/hr	6.62	0.49	1.55	0.68	0.43
Locomotive						
Idle	---	1.85	0.29	0.65	0.47	0.13
Running	---	14.4	2.21	5.04	3.64	0.97

^aRef. EPA, 1978, 1982; Colorado Department of Health, 1981.^bExhaust emission factors are in pounds per hour except for those for the 15- and 25-ton trucks, which are in grams per mile.

hauling and dumping emissions were assumed to be constant throughout the period of activity. Tables D.4.2 and D.4.3 show the breakdown of fugitive particulate emissions for each alternative.

Air quality impacts were determined by using the EPA Industrial Source Complex Short Term (ISCST) dispersion model (EPA, 1983). Given information concerning emission rates, source locations, and meteorology, the model predicts concentrations of chemically inert pollutants downwind from the source. The model will also take into account the effects of the gravitational settling of larger particulates.

For modeling purposes, emissions were assumed to be emitted from a single area source. The specific inputs used in the model and the area over which emissions were distributed are presented in Table D.4.4.

Receptors were placed downwind of the sources at 250-meter intervals out to a distance of 1500 meters. Receptors were located downwind of truck haul roads at 100, 300, 500, and 700 meters.

Assumed worst-case meteorological conditions were used to estimate peak 24-hour averages of particulate concentrations. Light winds (2.5 meters per second) were assumed to blow persistently from a single direction under stable meteorological conditions. These conditions were allowed to persist for only the first six hours of the 24-hour modeling period. The remaining hours were assumed to have no impact. This approach is conservative and is consistent with other screening methodologies.

A site-specific particle size distribution was not available. A size distribution derived from measurements made at surface mining operations throughout the Rocky Mountain region was substituted. The particle size distribution and deposition parameters used in the analysis are presented in Table D.4.5.

In order to assess the impacts of pollutants on air quality, the Industrial Source Complex Short Term (ISCST) dispersion model was used to estimate particulate concentrations because it has EPA approval for the required purpose (EPA, 1983). This model allows for the modeling of multiple sources, multiple meteorological conditions, gravitational settling, and dry disposition. The ISCST model requires input data on emission rates, source locations, and meteorology.

The ISCST model output consists of a table listing the 24-hour average concentration at each of the receptors. The maximum 24-hour average concentration occurring over the grid for each alternative is summarized in Table D.4.6.

The particulate emissions and concentrations from remedial action at vicinity properties were not modeled. Particulate emissions from the vicinity properties are expected to be very low because most of the activity would be performed with hand held tools and small earth-moving equipment and because the average amount of material to be removed from each vicinity property (105 cubic yards) is very small. There would be very little cumulative effect between the various vicinity property sites that would be cleaned up at the same time, since the vicinity properties are widely scattered throughout the area.

Table D.4.2 Summary of worst-month hourly fugitive particulate emissions at the Grand Junction site

	No action	Grand Junction	Disposal alternative			
			Cheney Reservoir		Two Road	
			By truck	By train	By truck	By train
Worst-case month	--	9	3/4	3/4	3/4	3/4
Emissions (lb/hr)						
Scrapers	--	288	112	112	96	96
Bulldozers	--	416	320	320	128	128
Graders	--	32	32	32	32	32
Compactors	--	160	--	--	--	--
Water trucks	--	9	6	6	6	6
Truck dumping, total ^a (tons)	--	51	6.2	6.2	6.2	6.2
(lb/hr)	--	28	2	2	2	2
Truck loading, total ^a (tons)	--	--	50.5	5	50.5	5
(lb/hr)	--	--	16	2	16	2
Train loading, total ^a (tons)	--	--	--	574	--	575
(lb/hr)	--	--	--	177	--	177
Wind erosion, total ^a (tons)	320 ^b	850	944	944	944	944
(lb/hr)	73	86	86	86	86	86
Total, uncontrolled (lb/hr)	73	1019	573	736	582	745
Total, controlled (lb/hr)	--	510	287	368	291	373
Total, controlled (grams/sec)	--	64.2	36.1	46.4	36.7	46.9

^aTotal emissions are for the life of the project.^bTons per year.

Table D.4.3 Summary of worst-month hourly fugitive particulate emissions at the alternate disposal sites

	Disposal alternative	
	Cheney Reservoir	Two Road
Worst-case month	3/4	3/4
Emissions (lb/hr)		
Scrapers	112	96
Bulldozers	320	128
Graders	32	32
Compactors	64	64
Water trucks	6	6
Truck dumping, total emissions ^a (tons)	65.3	65.3
(lb/hr)	20	20
Truck hauling, total emissions ^a (tons)	686.9	686.9
(lb/hr)	211	211
Wind erosion, total emissions ^a (tons)	504	504
(lb/hr)	46	46
Total, uncontrolled (lb/hr)	811	603
Total, controlled (lb/hr)	406	302
Total, controlled (grams/sec)	51.1	38.0

^aTotal emissions are for the life of the project.

Table D.4.4 ISCST model TSP emission inputs

Alternative	Location	Emission rate ^a (grams/sec)	Area of Activity (square meters)
No action	Grand Junction	9.2	469,000
Stabilization On site	Grand Junction	64.2	469,000
Cheney Reservoir ^b truck, Two Road truck ^b	Grand Junction	36.1	469,000
Cheney Reservoir train and truck ^b , Two Road train and truck ^b	Grand Junction	46.4	469,000
Cheney Reservoir (both options)	Cheney Reservoir disposal site	51.1	324,000
Two Road (both options)	Two Road disposal site	38.0	324,000

^aControlled.^bResults for the Two Road alternatives at Grand Junction were proportioned based on emissions relative to model results for the Cheney alternatives; this is why the emission rates for the Cheney alternatives are given in this table for the Grand Junction site for the Cheney and Two Road alternatives.

Table D.4.5 Particle size distribution and deposition parameters used in the air quality impact analysis

Particle size class	Diameter range (microns)	Mass distribution (%)	Characteristic diameter (microns)	Gravitational settling velocity ^a (meters/second)	Surface reflection coefficient
1	0 - 2.5	3	1.1	7.20×10^{-5}	1.0
2	2.5 - 5	4	3.3	6.48×10^{-4}	1.0
3	5 - 10	9	7.0	2.92×10^{-3}	0.9
4	10 - 15	5	12.0	8.57×10^{-3}	0.78
5	>15	79	25.0	3.72×10^{-2}	0.65

^aBased on a particle density of 2 grams per cubic meter.

Table D.4.6 Maximum 24-hour concentrations of particulates during construction (in micrograms per cubic meter)

	Disposal alternative					
	No action	Grand Junction	Cheney Reservoir		Two Road	
			By truck	By train	By truck	By train
Grand Junction site	60	425	239	307	243	310
Disposal site	--	--	445	445	331	331
Truck transportation route	--	171	344	---	353	---

D.5 NOISE

D.5.1 REGULATIONS

Colorado noise regulations (Colorado General Assembly, 1973) specify the maximum permissible noise level for each zoning classification and for the time of day. Construction activities and rail transport are restricted to a maximum of 80 decibels during the day at a distance of 25 feet beyond the construction property or right-of-way. An additional 10 decibels is permitted for no more than 15 minutes in any one hour.

The EPA (1974) has issued a guideline exposure level, based on average sound energy, that can be used for assessing noise impacts. In a residential environment, the time-weighted day-night outdoor average sound level below which no effects on public health and welfare are expected to occur is 55 decibels.

The EPA (1976a,b) and the State of Colorado (Colorado General Assembly, 1973) have also issued noise-emission standards for construction equipment and trucks; however, these regulations apply only to individual items of equipment. They do not limit the combined noise intensity from several pieces of equipment operating simultaneously.

D.5.2 SOUND-LEVEL SURVEY IN GRAND JUNCTION

A background sound-level survey was conducted on September 12 through 14, 1982, to establish current sound levels around the Grand Junction site. The survey was designed to provide a representative sample of noise levels and sources near the site. Two sets of daytime and nighttime measurements were taken at each sampling location--the first for the weekend period and the second for the weekday period. Daytime measurements were made between 7 a.m. and 10 p.m.; nighttime measurements were made between 10 p.m. and 7 a.m.

The instruments used during the sound-level survey included a Bruel and Kjaer (B&K) type 2209 precision sound-level meter, a B&K type 4145 one-inch condenser microphone, a B&K type 4166 0.5-inch condenser microphone, a B&K type 4420 pistonphone, and accessory equipment. This equipment conforms to the standards of the American National Standards Institute (ANSI) for precision sound-level meters (ANSI, 1976). The one-inch diameter condenser microphone was used for most samples to ensure accurate measurements of low ambient sound levels. An open-celled polyurethane-foam wind screen was used in all measurements to minimize wind-generated microphone noise.

The survey was conducted in accordance with guidelines established by the American National Standards Institute (ANSI, 1969, 1971). Sound-level measurements were made with the precision sound-level meter operating in the A-weighted slow-response mode. The data were collected by observing and recording the meter readings approximately every five seconds over a 10-minute period at each sampling location. The measure-

ment approach of taking a sample every five seconds results in a statistically independent sample because the interval is considerably greater than the meter averaging time. Measurements were not taken when the wind speed exceeded 12 mph. Headphones were used to determine whether distortion, amplifier overloading, or intermittent electrical connections existed and to eliminate these from the sample. The microphone was mounted on a tripod and located a sufficient distance from vertical surfaces to minimize reflection effects. The sound-level meter was acoustically calibrated with the B&K pistonphone periodically throughout the survey to ensure accuracy of measurement.

To provide correlations with measurements, information on other parameters was also recorded during the survey. Atmospheric conditions--wind speed, wind direction, temperature, and relative humidity--were recorded at each sampling location. These measurements were made with hand-held instruments that included a Dwyer wind meter and a Bendix Model 556 battery-powered psychrometer. Measurements obtained near roadways were accompanied by a traffic count over a 10-minute period. Sound-source observations were recorded during each sample; a notation of the predominant sound sources was included. Barometric-pressure readings were obtained from the National Weather Service Station at the Grand Junction airport.

Sound levels were measured at four sampling points around the Grand Junction site. The approximate sampling points are shown in Figure D.5.1 and described in Table D.5.1.

Sound levels around the Grand Junction site are characteristic of a town setting. The residual background sound levels (L_{90}) exceed 35 decibels at night and 45 decibels during the day. Traffic noise predominates throughout the site area. Table D.5.2 presents the observations of noise sources and atmospheric conditions for each sampling period, and Table D.5.3 presents the summarized data in A-weighted L_{10} , L_{50} , and L_{90} sound levels--that is, the sound levels that are exceeded 10, 50, and 90 percent of the time, respectively. Also given in Table D.5.3 are the energy-equivalent sound levels (L_{eq}) and the time-weighted day-night L_{eq} levels (L_{dn}). The L_{10} sound levels indicate that the present sound levels are below the maximum levels allowed by the Colorado noise regulations (Section D.5.1). The L_{dn} sound levels measured during this brief survey indicate that the residential areas around sampling points 1 and 3 may approach, or possibly exceed, the EPA-recommended L_{dn} exposure limit of 55 decibels. In addition, residences near sampling point 2 are probably exposed to L_{dn} sound levels greater than 55 decibels because of the heavy traffic on U.S. Highway 50.

D.5.3 ALTERNATE DISPOSAL SITES

No measurements of ambient sound levels have been made at the alternate disposal sites. However, ambient sound levels at the sites can be estimated by considering the rural, undeveloped nature of the sites. Sound levels in rural locations removed from human activity are primarily a function of the wind speed which varies seasonally and daily. Wind

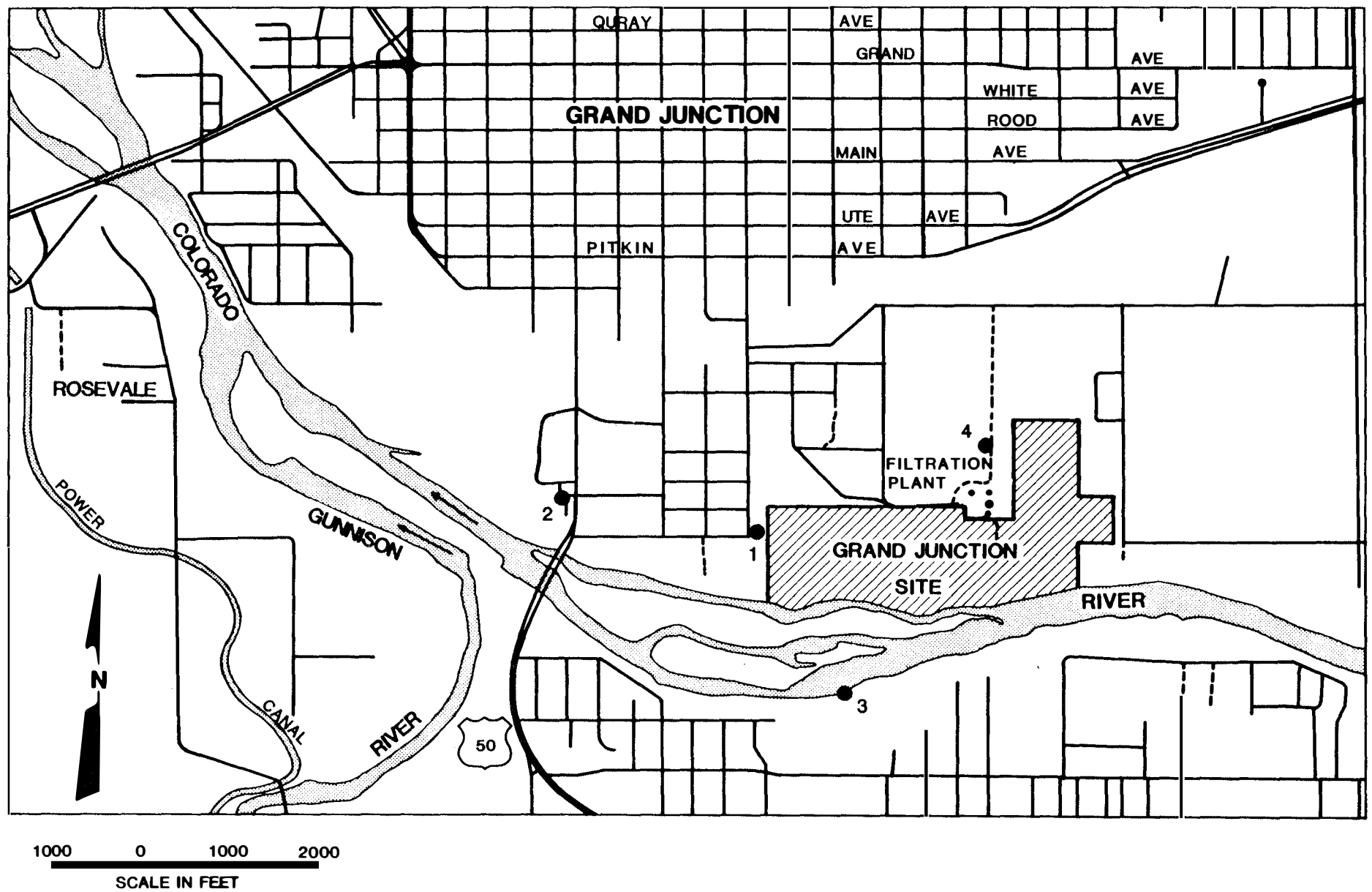


FIGURE D.5.1
SOUND-LEVEL SURVEY SAMPLING POINTS
GRAND JUNCTION SITE

Table D.5.1 Description of sampling points for background sound levels near the Grand Junction site

Location ^a	Description
1	At the western entrance to the tailings area at the end of Struthers Avenue, just east of South 9th Street.
2	On the south side of Noland Avenue, 150 feet west of the centerline of U.S. Highway 50, adjacent to a junkyard.
3	In a new residential area at the dead end of Santa Clara Avenue, at the edge of the bluff overlooking the Colorado River.
4	In the industrial area to the north of the tailings area and the abandoned filtration plant, on the south side of Winters Avenue at its intersection with South 15th Street.

^aSee Figure D.5.1 for locations.

Table D.5.2 Noise sources and atmospheric conditions recorded at the Grand Junction site during survey of background sound levels

Location ^a	Date	Time	Period ^b	Observations ^c
1	9/12/82	1734-1744	3	WS, less than 2 mph; WD, north; RH, 54%; BP, 634 mm Hg Traffic: 6 cars Sources: traffic on highway, jet, dogs, birds, insects, music concert
1	9/12/82	2352-0007	4	WS, less than 2 mph; WD, south; RH, 72%; BP, 636 mm Hg Sources: insects and distant traffic
1	9/13/82	0130-0140	2	WS, less than 2 mph; WD, south; RH, 61%; BP, 637 mm Hg Sources: insects, wind in trees, possible locomotive, dog, distant traffic, bats
1	9/13/82	1154-1204	1	WS, 4-6 mph; WD, south to southeast; RH, 62%; BP, 635 mm Hg Traffic: 1 car, 5 light trucks, 2 heavy trucks, 1 jet Sources: wind in trees, children, insects, powersaw
2	9/12/82	1843-1854	3	WS, less than 2 mph; WD, west; RH, 39%; BP, 634 mm Hg Traffic: 154 cars, 78 light trucks, 2 heavy trucks, 11 motorcycles, 1 jet plane Sources: traffic on U.S. Hwy 50, dog, insects

Table D.5.2 Noise sources and atmospheric conditions recorded
at the Grand Junction site during survey of
background sound levels (Continued)

Location ^a	Date	Time	Period ^b	Observations ^c
2	9/12/82	2257-2309	4	WS, less than 2 mph; WD, south; RH, 71%; BP, 636 mm Hg Traffic: 40 cars, 19 light trucks, 2 motorcycles Sources: traffic on U.S. Hwy 50, bats, and insects
2	9/13/82	0102-0112	2	WS, less than 2 mph; WD, variable; RH, 62%; BP, 637 mm Hg Traffic: 9 cars Sources: insects, traffic, street sweeper on U.S. Hwy 50
2	9/13/82	1211-1222	1	WS, 4-6 mph; WD, south to southeast; RH, 62%; BP, 635 mm Hg Traffic: 185 cars, 125 light trucks, 3 heavy trucks, 2 motorcycles Sources: traffic
3	9/12/82	1714-1724	3	WS, 6-10 mph; WD, north; RH, 41%; BP, 634 mm Hg Traffic: 1 jet plane, 1 helicopter Sources: traffic on U.S. Hwy 50, aircraft, concert, dog, children

Table D.5.2 Noise sources and atmospheric conditions recorded at the Grand Junction site during survey of background sound levels (Continued)

Location ^a	Date	Time	Period ^b	Observations ^c
3	9/12/82	2320-2329	4	WS, less than 2 mph; WD, south; RH, 67%; BP, 636 mm Hg Traffic: 1 airplane Sources: wind, river, insects, distant traffic, bats, dog
3	9/13/82	1252-1302	1	WS, 6 mph; WD, south to south-east; RH, 66%; BP, 635 mm Hg Traffic: 2 light trucks, 1 jet plane Sources: wind, distant traffic, dogs
3	9/14/82	0347-0354	2	WS, less than 2 mph; WD, southwest; RH, 88%; BP, 640 mm Hg Sources: traffic on U.S. Hwy 50, geese, river, dogs
4	9/12/82	1805-1815	3	WS, 2-5 mph; WD, north; RH, 35%; BP, 634 mm Hg Traffic: 1 helicopter Sources: traffic on neighborhood streets, band, wind, and insects
4	9/13/82	0156-0205	2	WS, 3-6 mph; WD, southeast; RH, 69%; BP, 637 mm Hg Sources: insects, distant traffic, and wind

Table D.5.2 Noise sources and atmospheric conditions recorded at the Grand Junction site during survey of background sound levels (Concluded)

Location ^a	Date	Time	Period ^b	Observations ^c
4	9/13/82	1130-1140	1	WS, 6-8 mph; WD, south; RH, 66%; BP, 636 mm Hg Traffic: 1 car, 4 light trucks Sources: wind, industrial noise nearby, dog, construction, horn

^aSee Figure D.5.1 for locations of sampling points.

^bKey to periods: 1 = weekday daytime (0700-2200 hr); 2 = weekday nighttime (2200-0700 hr); 3 = weekend daytime (0700-2200 hr); 4 = weekend nighttime (2200-0700 hr).

^cAbbreviations: WS = wind speed; WD = wind direction; RH = relative humidity; BP = barometric pressure.

Table D.5.3 Grand Junction A-weighted sound levels,
September 12-14, 1982^a

Location ^b	Date	Time	Period ^c	Sound level				
				L ₁₀	L ₅₀	L ₉₀	L _{eq}	L _{dn}
1	9/12/82	1734-1744	3	52.0	48.7	46.1	49.5	48.9
1	9/12/82	2352-0007	4	40.2	36.6	35.2	37.6	
1	9/13/82	0130-0140	2	44.8	41.4	38.7	44.2	59.0
1	9/13/82	1154-1204	1	78.4	48.4	44.8	60.5	
2	9/12/82	1843-1854	3	68.8	63.2	57.5	65.7	67.3
2	9/12/82	2257-2309	4	61.0	53.9	46.6	59.1	
2	9/13/82	0102-0112	2	68.8	51.2	40.1	65.0	71.7
2	9/13/82	1211-1222	1	70.0	65.1	60.0	66.8	
3	9/12/82	1714-1724	3	49.8	46.6	45.1	47.7	51.2
3	9/12/82	2320-2329	4	48.3	40.6	39.0	44.1	
3	9/13/82	1252-1302	1	56.1	51.4	49.3	56.8	55.5
3	9/14/82	0347-0354	2	43.6	40.8	39.4	41.5	
4	9/12/82	1805-1815	3	54.5	48.5	45.1	53.3	
4	9/13/82	0156-0205	2	40.0	37.5	35.5	38.0	51.6
4	9/13/82	1130-1140	1	55.1	50.7	49.1	52.9	

^aReference sound pressure is 2×10^{-5} newtons per square meter.

^bSee Figure D.5.1 for locations of sampling points.

^cKey to periods: 1 = weekday daytime (0700-2200 hours); 2 = weekday nighttime (2200-0700 hours); 3 = weekend daytime (0700-2200 hours); 4 = weekend nighttime (2200-0700 hours).

speeds above 12 miles per hour normally produce enough local turbulence in trees and bushes to dominate other natural sounds. In periods of calm, the noises made by birds and insects predominate. Distant traffic may also be heard at the Cheney Reservoir and Two Road sites. The perceptibility of noise from traffic is governed by distance from the road, road conditions, the speed at which vehicles are traveling, and weather conditions. Day-night sound levels at both sites are expected to be approximately equivalent to the level listed for "rural, undeveloped" in Table D.5.4.

D.5.4 VICINITY PROPERTIES

The 3465 properties in Grand Junction expected to be candidates for cleanup will include mainly residential and commercial properties, as well as some open lands. No measures of ambient sound levels have been made at any vicinity properties. Ambient sound levels at these properties undoubtedly vary greatly depending on associated land uses. Day-night sound levels would be expected to range from approximately 40 decibels in rural, partially developed areas to 60 decibels or more in the most urbanized portions of Grand Junction.

D.5.5 BORROW SITES

The borrow sites that are not located at the alternate disposal sites include the 32 and C $\frac{1}{2}$ site, the Unawep site, and the Fruita site. No sound measurements have been taken at any of these borrow sites. The 32 and C $\frac{1}{2}$ site and Fruita site are both located in rural, partially developed areas that would probably be characterized by day-night sound levels of 40 to 45 decibels. The Unawep site is in a rural, undeveloped area that would probably have a day-night sound level under 40 decibels. None of the borrow sites have residences within 0.25 mile.

D.5.6 NOISE IMPACTS ANALYSIS

Noise impacts were estimated for the proposed remedial action alternatives. For the action alternatives, the major noise-producing sources would be the heavy-duty construction equipment used at the tailings, disposal, and borrow sites, and the trucks used to haul tailings and borrow materials. Typical sound levels and assumed usage rates for the type of equipment used in the action alternatives are presented in Table D.5.5.

A noise prediction model (Kessler et al., 1978) was used to estimate the maximum A-weighted sound level emitted from the tailings, disposal, and borrow sites during the remedial action for each project alternative. The model is based on the numbers and types of equipment operating on the site, usage factors for operation in the noisiest modes, and the distance from the activity to the nearest noise-sensitive receptors. The model tends to overpredict noise levels since it assumes a clustering of equipment. In reality, the equipment would be located over a number of acres. The model is based on actual field measurements of construction equipment and is derived from the equation:

Table D.5.4 Typical values of day-night sound levels, L_{dn} ^a

Land use description	Population density (people/sq mi)	L_{dn} (dBA)
Rural, undeveloped	20	35
Rural, partially developed	60	40
Quiet suburban	200	45
Normal suburban	600	50
Urban	2,000	55
Noisy urban	6,000	60
Very noisy urban	20,000	65

^aDay-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.

Ref. National Academy of Sciences, 1977.

Table D.5.5 Sound levels for equipment that would be used at the tailings, disposal, and borrow sites

Equipment	Maximum sound level at 50 feet (decibels)	Use factor
D-8 bulldozer	88	0.5
Front-end loader	85	0.5
Scraper	87	0.6
Water truck	89	0.5
Haul truck	86	0.5
Compactor	87	0.6
Grader	83	0.4

Ref. Kessler et al., 1978.

$$L_{eq} = 10 * \log \sum_i^n (UF_i)(n_i)(10^{LP_i/10})$$

where

L_{eq} = average noise level of all equipment

UF_i = usage factor of equipment type i

n_i = number of units of equipment type i

LP_i = maximum sound level of equipment type i

D.5.6.1 Stabilization at the Grand Junction site

All alternatives except no action would involve excavation at the Grand Junction site. The maximum potential equivalent sound level at the Grand Junction site for the stabilization on site alternative would be approximately 95 decibels at a location 100 feet from the center of activity. This would result in maximum outdoor noise levels of approximately 74 and 73 decibels in the closest residential areas to the west and southeast of the site, respectively. (These residential areas are at distances of approximately 1400 and 1500 feet, respectively.) These potential noise levels would occur only during daytime hours and represent a worst-case situation in equipment utilization; average daytime noise levels through the duration of the project would probably be up to three decibels less. The alternatives involving tailings disposal at either the Cheney Reservoir or Two Road sites would result in noise levels about three to four decibels lower at the Grand Junction site. However, under any of the alternatives except the no action alternative, daytime noise levels for nearby residents would be elevated over 10 decibels above existing noise levels.

D.5.6.2 Alternate disposal sites

The noise levels associated with tailings disposal at the Cheney Reservoir and Two Road sites would be almost as great as for excavation and disposal at the Grand Junction site. The nearest residences that could be affected by noise emissions at these sites are about 1.5 miles away at the Cheney Reservoir site and three miles away at the Two Road site. Noise levels from the disposal sites would probably be in the 50 to 55 decibel range at these nearest residences, even under worst-case conditions. As at the Grand Junction site, impacts would occur only during daylight hours. Daytime noise levels for the nearest residences would be elevated about 15 to 20 decibels for these alternatives.

The rail transport alternatives would result in much lower noise emissions in Grand Junction and in the affected corridors since the trains would only travel these corridors twice a day. However, unloading operations in Whitewater or Mack and increased truck activities would result in substantially increased noise levels in Whitewater and the corridor southeast of Whitewater for the Cheney train and truck alternative, and in Mack and the corridor northwest of Mack for the Two Road train and truck alternative.

D.5.6.3 Vicinity properties

Most remedial action activities for vicinity properties would involve hand held tools and the occasional use of small front-end loaders, backhoes, and dump trucks. The noise levels associated with these activities would be similar to small-scale street repair work that is common in residential areas. Typical daytime equivalent noise levels associated with these activities are expected to be in the 79 to 81 decibel range at a distance of 100 feet. Remedial action at some of the larger and more complex vicinity properties may involve larger equipment such as dozers, scrapers, and large front-end loaders and trucks. The noise levels associated with these activities are expected to be in the 87 to 89 decibel range at 100 feet. All vicinity property remedial action would occur during normal working hours and would last an average of one month per property. Therefore, the noise from remedial action at vicinity properties is expected to usually result in short-term and minor annoyances to neighbors.

D.5.6.4 Borrow sites

The maximum equivalent noise levels associated with equipment activities at the 32 and C $\frac{1}{2}$ borrow site and at the Unaweep Canyon borrow site (for the stabilization on site alternative), and at the Fruita borrow site (for both of the Two Road disposal alternatives) would be approximately 92, 89, and 87 decibels, respectively, 100 feet away from the centers of activity. The nearest residence to the 32 and C $\frac{1}{2}$ borrow site would be subjected to daytime noise levels up to 63 decibels. The nearest residence to the Fruita borrow site would be subjected to daytime noise levels up to approximately 66 decibels. Daytime noise levels at the residences near these borrow sites would be elevated by about 20 decibels. Noise impacts at the Unaweep site and at other potential borrow sites would be minor because of the isolation of the sites from sensitive receptors or because of relatively limited requirements for equipment activity.

D.5.6.5 Transportation routes

All of the proposed alternatives would involve substantial truck use on public roads and highways. Table D.5.6 presents data on existing noise levels and projected truck usage for route segments receiving substantial use for extended periods of time (as discussed in the transportation impacts section of this document). Trucks can be expected to produce noise levels of approximately 79 decibels at a distance of 100 feet and up to 73 decibels at 200 feet. For the stabilization on site alternative, high levels of truck activity on D Road may cause substantial annoyance to some residential areas. For the Cheney Reservoir truck alternative, D Road would get substantially lower use; however, some areas along U.S. Highway 50 southeast of Grand Junction may be adversely affected. The Two Road truck alternative would involve high levels of truck activity and disturbance in the downtown area of Grand Junction and along some parts of U.S. Highway 50 northwest of Grand Junction.

The rail transport alternatives would result in much lower noise emissions in Grand Junction and in the affected corridors since the trains would only travel these corridors twice a day. However, unloading operations in Whitewater or Mack and increased truck activities would result in substantially increased noise levels in Whitewater and the corridor southeast of Whitewater for the Cheney Reservoir train and truck alternative, and in Mack and the corridor northwest of Mack for the Two Road train and truck alternative.

Table D.5.6 Existing noise levels and project-truck pass-byes for selected route segments

Alternative/segment	Existing daily traffic (vehicles)	Existing noise levels ^a	Truck pass-byes, with noise up to 79 dB at 100 feet ^b
Stabilization on site D Road (15th St. to 32 Rd.)	3700-6900	55-60	74 per/hour
Cheney-truck D Road (15th St. to 32 Rd.)	3700- 6900	55-60	26 per/hour
U.S. Highway 50 (N of 32 Rd.)	4600-21500	60-70	26 per/hour
U.S. Highway 50 (S of 32 Rd.)	3800- 4600	55-60	52 per/hour
Cheney-train and truck U.S. Highway 50 (S of Whitewater)	3800	50-60	52 per/hour
D-36 Two Road-truck Ute/Pitkin (1st St. to 9th St.) ^c	17300-24800	60-65	42 per/hour
I-70 and U.S. Highway 50 (Fruita to Two Road)	1100- 3400	50-60	49 per/hour
Two Road-train and truck U.S. Highway 50 (Mack to Two Road)	1110	50-55	60 per/hour

^aEstimated day-night equivalent levels L_{dn} in decibels at a distance of 100 feet, based on traffic levels; Ref. Swing, 1975.

^bBased on maximum daily projected truck trips and noise emissions of 85 decibels (dB) at 50 feet for passing trucks.

^cBecause Ute and Pitkin Avenues are one-way streets in close proximity to each other, figures for daily traffic and truck trips are combined.

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APPENDIX E
SOILS, GEOLOGIC, AND SEISMIC INFORMATION

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E.1 SOILS INFORMATION

Soil conditions at the Grand Junction, Cheney Reservoir, and Two Road sites were investigated using various standard techniques. Field procedures, which consisted of drilling and test pitting, were supplemented by laboratory analysis to determine the physical characteristics of the soils.

Lab tests were performed in accordance with the standard methods and specifications of the American Society for Testing and Materials (ASTM) or accepted practice. Additional information on soils of the site can be found in Appendix B, Engineering Designs. The regional geological conditions are shown on Figure E.1.1.

E.1.1 GRAND JUNCTION SITE

At the Grand Junction site, 130 borings and five test pits were located in a grid pattern on approximately 100-foot centers across the present pile. Most of the borings were used to characterize the tailings themselves. All but 14 borings were advanced until refusal. An additional 23 borings were located around the perimeter of the site.

The soils beneath the tailings consists of a thin layer of brown sandy silt from zero to five feet in thickness. This soil layer overlies three to eight feet of river alluvium, which consists of gravel, cobbles, and boulders. Beneath the alluvium is Mancos Shale.

The gravels and sands under the pile were very moist to saturated in most of the borings. In isolated instances there appeared to be zones of clays and silts immediately below the tailings which exhibited low blow counts.

E.1.2 CHENEY RESERVOIR SITE

Eight borings were drilled and four test pits were excavated at the Cheney Reservoir site to determine the soil characteristics. Depth of the soil at the site ranged from 16 to 39 feet. The soil on the site consists of light grayish-tan to brown sandy silt and clay with gravel, cobble, and boulder-sized rounded basalt fragments. The percentage of coarse materials varies greatly, with some zones relatively free and others containing from 25 to 50 percent. The soils at the site are derived from pediment materials from Grand Mesa and are underlain by Mancos Shale. These soils are of the Utaline-Nelman-Lazear Association which are warm, well drained stoney soils (SCS, 1978). Table E.1.1 is a summary of laboratory test results of the soils at Cheney Reservoir, and Figure E.1.2 indicates the location of the boreholes.

E.1.3 TWO ROAD SITE

Seventeen borings and six test pits were used to determine the soil characteristics of the Two Road site. The soil, which ranged in depth from 20 to 33 feet, consists of three to eight feet of tan, sandy, clayey silt and silty clay. Underlying the silt and clay are up to 25 feet

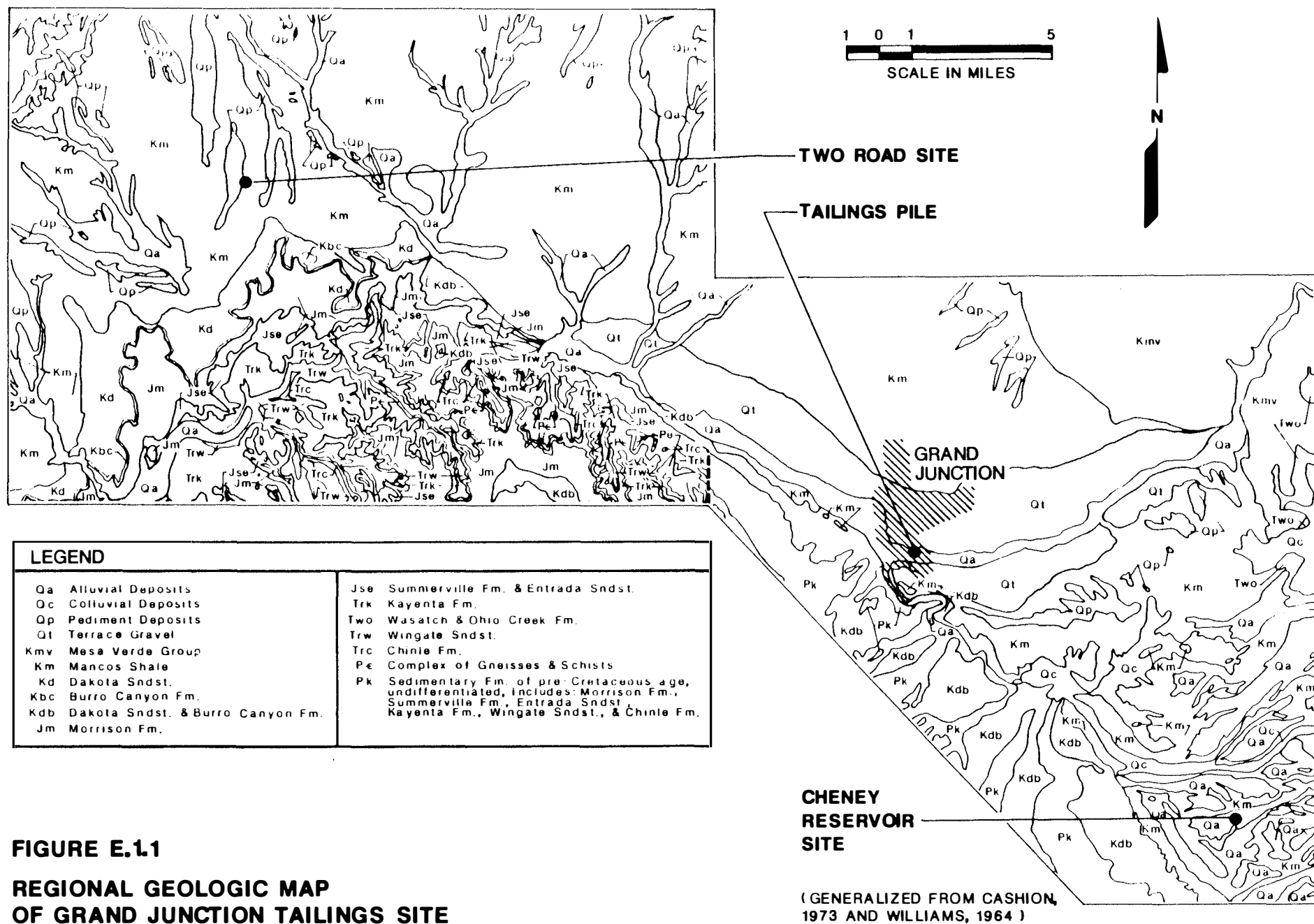


Table E.1.1 Summary of laboratory results for undisturbed soil samples from the Cheney Reservoir site

Borehole ^a	Sample depth (feet)	Description	USCS classification ^b	Moisture content (%)	Wet unit weight (lb/ft ³)	Percent passing through No. 200 sieve	Atterberg limits ^c (%)		
							LL	PL	PI
GCH-1	0.2-2.8	Silty clay	CL	10.2	86.3	78	41	22	19
GCH-1	33-34	Silty clay	CL	10.3	--	--	32	15	17
GCH-2	0.2-1.5	Sandy silt	CL-ML	14.5	97.7	61	37	23	14
GCH-2	8.5-10	Sandy silt	CL-ML	5.3	--	--	22	14	8
GCH-4	0.5-2.5	Silty clay	CL	9.6	93.0	49	40	22	18
GCH-4	13-15	Sandy silt	CL-ML	6.0	--	--	22	18	4
GCH-4	43-44	Clay shale	CL	10.4	--	--	34	18	16
GCH-6	0-1.8	Sandy silt	CL-ML	14.5	97.4	67	24	16	8
GCH-6	23-24	Sandy silt	CL-ML	5.0	--	--	23	18	5

^aSee Figure E.1.1 for location.

^bClass in the Unified Soil Classification System. Key: SM, silty sands, sand-silt mixtures; CL, inorganic clays of low to medium plasticity, and gravelly, sandy, silty, and lean clays; ML, inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity.

^cAtterberg limits: LL = liquid limit; PL = plastic limit; PI = plastic index.

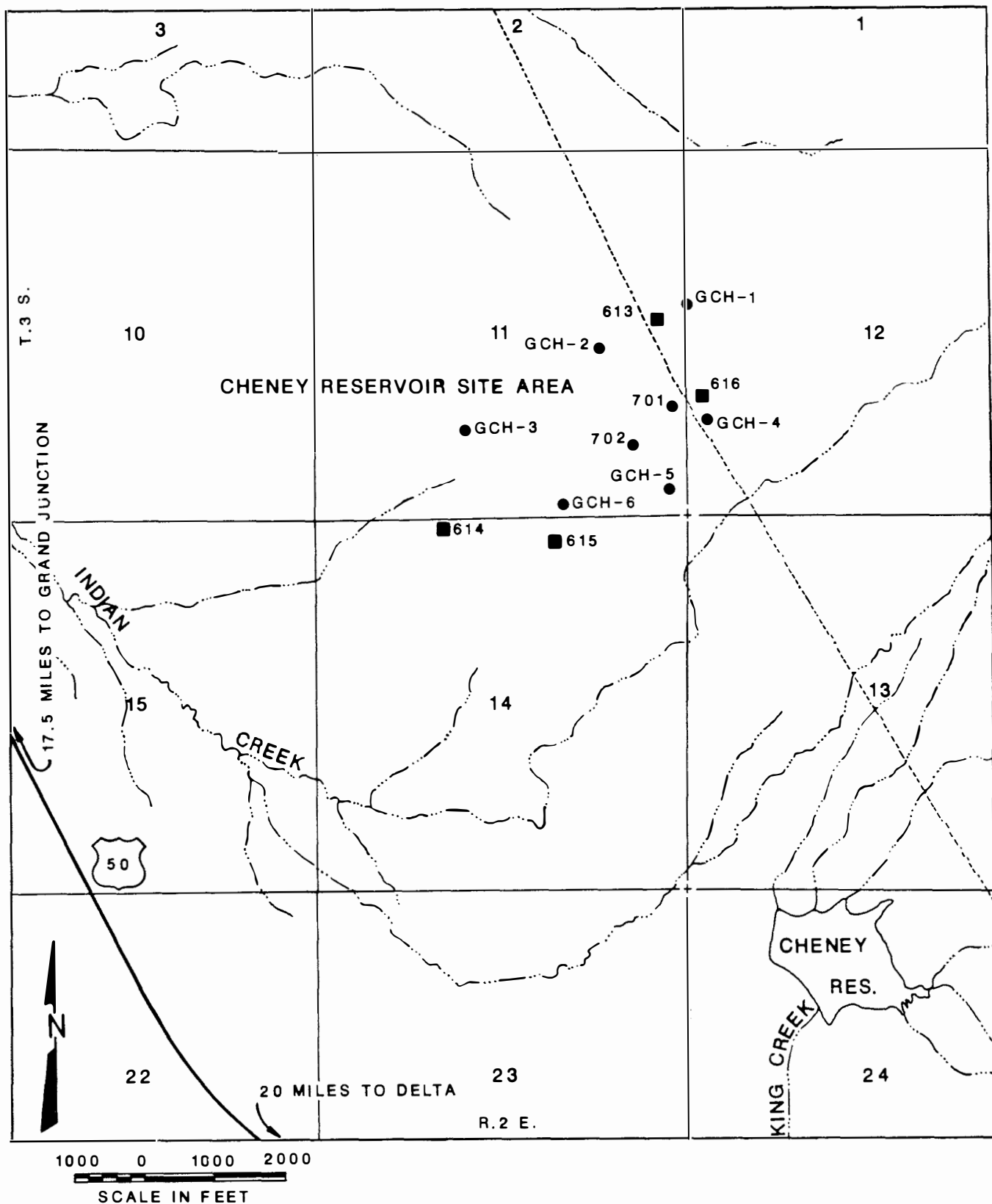


FIGURE E.12
LOCATION OF GEOTECHNICAL DRILLING AND TEST PITTING
AT CHENEY RESERVOIR

of graded sand. The top five to 10 feet is a dense silty fine sand, which grades into a dense fine to medium gravelly sand. The soils are warm, well drained stoney soils of the Haplargids-Camborthids Association (SCS, 1978). The first bedrock unit at the site is moderate to highly weathered Mancos Shale. Table E.1.2 indicates data from lab analyses of the Two Road site soils. Figure E.1.3 shows locations of the soil samples.

Table E.1.2 Summary of laboratory results for undisturbed soil samples from the Two Road site

Borehole ^a	Sample depth (feet)	Description	USCS classification ^b	Moisture content (%)	Wet unit weight (lb/ft ³)	Percent passing through No. 200 sieve	Atterberg limits ^c (%)		
							LL	PL	PI
C-4	7-22	Silty clay	CL-ML	--	--	55	20	13	7
C-13	4-6	Sandy silt and clay	CL-ML	5.7	82.4	64	26	19	7
C-17	3.5-5	Silty clay	CL	8.1	89.4	79	27	15	12
EP-1	1-10	Sand	SC-SM	4.4	--	41	21	16	5
EP-2	8.5	Clay	CL	8.6	--	67	30	22	8

^aSee Figure E.1.2 for locations.

^bClass in the Unified Soil Classification System. Key: SM, silty sands, sand-silt mixtures; CL, inorganic clays of low to medium plasticity, and gravelly, sandy, silty, and lean clays; ML, inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity; SC clayey sands, sand-clay mixtures.

^cAtterberg limits: LL = liquid limit; PL = plastic limit; PI = plastic index.

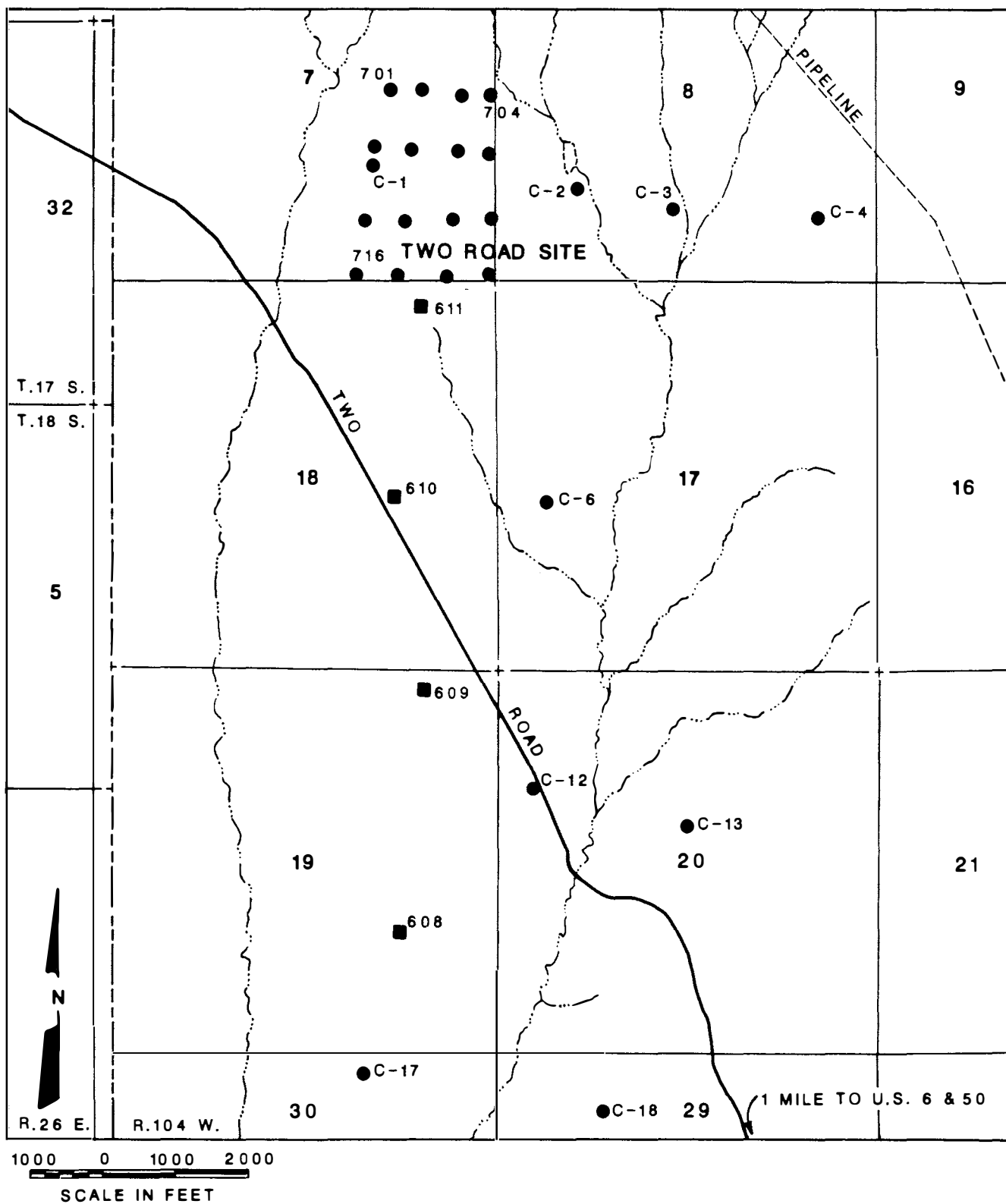


FIGURE E.1.3
LOCATIONS OF GEOTECHNICAL DRILLING AND TEST PITTING
AT TWO ROAD

E.2 GEOLOGICAL AND SEISMIC INFORMATION

E.2.1 GEOLOGY

E.2.1.1 Physiography and topography

All the disposal sites are located in the Colorado Plateau Physiographic Province. This province is characterized by deeply incised river channels primarily flowing through sedimentary rocks, exposing large cliffs and flat mesas. The Grand Junction area is in the Grand Valley between the Uncompahgre Uplift to the southwest and the Piceance Basin to the north. The Book Cliffs form the northern boundary of Grand Valley with Grand Mesa to the east.

The topography and structure in the Grand Junction area are dominated by the Uncompahgre Arch, which is a northwest-trending asymmetrical block, located 12 miles southwest of Grand Junction. Elevations in the vicinity range from about 4600 feet at Grand Junction to more than 10,000 feet on Grand Mesa. The area is drained by the Gunnison and Colorado Rivers.

The Grand Junction site is located adjacent to the north side of the Colorado River and is on a young alluvial terrace about three to six feet higher than the current river. It is about a mile upstream from the junction of the Gunnison and Colorado Rivers. The site elevation is about 4560 feet above sea level.

The Cheney Reservoir site is dominated by Grand Mesa and is located on a pediment surface on the western flank of the mesa. The drainage from the site is to the southwest toward a ridge of resistant Burro Canyon Formation and Dakota Sandstone, then toward the northwest to the Gunnison River. Southwest of the site, the Gunnison cuts through an 800-foot-deep canyon. Elevation of the Cheney Reservoir site ranges from 5320 feet on the east side of the site to 5200 on the west side.

The Two Road site is located on two broad, relatively flat pediment deposits dissected by several intermittent streams which primarily run north to south. The eastern pediments appear older than those to the west. Distinct bluffs over 100 feet high border the eastern pediment on the north, east, and west. The Book Cliffs are to the north of the site with up to 2000 feet of relief. The site elevation ranges from 4960 feet to about 4900 feet.

Topography of the vicinity properties is characteristic of locations within the Grand Valley.

The borrow sites, with the exception of the Unaweep Canyon site, are located in the Colorado River alluvium. Unaweep Canyon, a spectacular U-shaped valley exhibiting 2500 feet of relief, is thought to be an ancestral Gunnison River channel.

E.2.1.2 Stratigraphy

The following discussion is from Lohman (1965). Aside from the Quaternary deposits, the exposed strata in the Grand Junction area range in age from Precambrian to Upper Cretaceous. The general stratigraphy of the disposal locations is shown in Figure E.2.1.

The Precambrian basement complex is composed of metamorphic intrusive rocks. The overlying sedimentary rocks are all of Mesozoic age. There is a large unconformity between the Precambrian and the Upper Cretaceous, representing a loss of more than one billion years from the geologic record. In addition, there is an erosional unconformity at the base of the Entrada Sandstone. Here, most to all of the Kayenta Formation, all the Navajo Sandstone and Carmel Formation, and part of the Entrada Sandstone are absent.

The Precambrian rocks in the Grand Junction area are of two general types: schist and gneiss, and younger intrusive rocks and dikes. There are many local variations in composition and texture. Most of the largest outcrops of Precambrian rocks occur southwest of the Redlands Fault. Some exposures occur in the southeast of Grand Junction in canyons such as Unaweep.

The Triassic sequence in the area begins with the Chinle Formation which lies unconformably on the Precambrian complex. The Chinle is a soft red siltstone with some lines and beds of red siltstone, limestone, and conglomerate and thin layers of greenish siltstone. This formation forms gentle to steep slopes between nearly vertical cliffs of the Wingate Sandstone above and the relatively smooth erosional surface on the underlying Precambrian. The Chinle is exposed in many of the deeper canyons in the area.

The Wingate Sandstone is one of the most striking formations in the Grand Junction area. It is a very fine grained sand with lesser amounts of sand and silt, smaller amounts of clay, and sand in various locations. In the western and central parts of the region, the Wingate is buff to reddish buff with some salmon colored beds. In and east of Unaweep Canyon, it is more silty and red. Many shear cliff faces are coated with desert varnish which distinguishes the Wingate from other sandstones in the region.

SYSTEM	SERIES	FORMATION	MEMBER	THICKNESS	CHARACTER
CRETACEOUS	UPPER CRETACEOUS	MANCOS SHALE		TOP NOT EXPOSED	GRAY MARINE SHALE: FEW THIN BEDS OF LIMESTONE. UNDERLIES GRAND VALLEY & FORMS BOOK CLIFFS
		DAKOTA SANDSTONE		150 ±	COARSE WHITE BASAL CONGLOMERATE, LIGNITIC SHALE, BUFF SANDSTONE & THIN BEDS OF LIGNITE. SANDSTONE FORMS EDGES & CLIFFS
	LOWER CRET.	BURRO CANYON FORMATION		50-120	EROSIONAL UNCONFORMITY BUFF SANDSTONE, GENERALLY IRON STAINED, & GREEN-HUED SILTSTONE & MUDSTONE: SANDSTONE LOCALLY CONGLOMERATIC. FORMS CLIFFS WHERE LARGELY SANDSTONE
JURASSIC	UPPER JURASSIC	MORRISON FORMATION	BRUSHY BASIN MEMBER	260-340	MAINLY RED, GREEN, BROWN , PURPLE, & GRAY-WHITE SILT STONE & MUDSTONE: CONTAINS SOME BENTONITIC BEDS & A FEW THIN BEDS OR LENSES OF WHITE TO BROWN & LIMESTONE
			SALT WASH MEMBER	190-312	SIMILAR TO BRUSHY BASIN MEMBER, BUT CONTAINS THICK LENTICULAR SANDSTONE BEDS & IN LOWER PART, THIN BEDS OF DOVE GRAY LIMESTONE
		SUMMERVILLE FORMATION		40-60	RED, GREEN, GRAY, PURPLE, & BROWN MUD-STONE & SILTSTONE & PERSISTENT THIN BEDS OF HARD SANDSTONE, SOME RIPPLE MARKED
		ENTRADA SANDSTONE	MOAB MEMBER	60-200	WHITE TO GRAY EVENLY BEDDED FINE-GRAINED SANDSTONE, SOME RIPPLE MARKED
			SLICK ROCK MEMBER		SALMON-COLORED TO PINK FINE-GRAINED GENERALLY CROSSBEDDED SANDSTONE, CONTAINING SCATTERED GRAINS OF MEDIUM TO COARSE-GRAINED SAND. FORMS CLIFFS
TRIASSIC (?)	UPPER TRIASSIC	KAYENTA FORMATION		0-127	EROSIONAL UNCONFORMITY MEDIUM TO COARSE GRAINED HIGHLY LENTICULAR HARD SANDSTONE: SOME LENSES OF RED & PURPLE SILTSTONE & MUDSTONE: & SOME LENSES OF CONGLOMERATE & CONGLOMERATIC SANDSTONE. FORMS BENCHES
TRIASSIC	UPPER TRIASSIC	WINGATE SANDSTONE		215-370	THICK BEDS OF SALMON-COLORED TO BUFF FINE-GRAINED GRAINED GENERALLY CROSS BEDDED SANDSTONE. FORMS CLIFFS: MANY CLIFF FACES COATED WITH DESERT VARNISH.
		CHINLE FORMATION		80-120	RED SILTSTONE CONTAINING A FEW THIN LENSES OF GREEN HUED LIMESTONE OR CONGLOMERATE, FORMS SLOPES
PRECAMBRIAN COMPLEX				BASE NOT EXPOSED	GREAT UNCONFORMITY SCHIST, GNEISS, GRANITE, & PEGMATITE DIKS

AFTER LOHMAN, 1965

FIGURE E.2.1
GENERALIZED SECTION OF ROCK FORMATIONS IN THE
GRAND JUNCTION AREA, COLORADO, EXCLUDING
QUATERNARY DEPOSITS

The Kayenta is a fine to medium grained sandstone with irregular lenses of siltstone and shale and conglomerate or conglomeratic sandstone. This formation is harder and coarser grained than the Wingate. It is buff, white, or gray with some lavender, gray, or red. The siltstone and shale are red and locally purple or green. The Kayenta is typically a bench former between cliffs of Wingate and Entrada Sandstones. The Kayenta is absent in some locations within the Grand Junction area.

The upper Jurassic is first represented by the Entrada Sandstone which forms a colorful series of cliffs slightly smaller in stature than the Wingate. The Slick Rock Member of the Entrada, which is salmon to pink in color, forms generally unjointed smooth cliff faces. The Moab Member overlies the thicker Slick Rock Member. This member is evenly bedded white to light buff sandstone, with small amounts of low angle cross-bedding. The Entrada is the main artesian aquifer in the area.

Generally, the Summerville Formation is thin bedded, with alternating beds of siltstone and sandstone. The formation also contains some shale and mudstone and near the top contains some limestone. The siltstone and mudstone are various shades of gray and brown with some red. The gray and reddish gray sandstone interbeds are fine to medium grained and very hard. The Summerville is the least exposed unit in the Grand Junction area. This is because it forms slopes that are covered by slumping of the Summerville and the overlying Morrison Formation.

The Morrison Formation is a varied and colorful assemblage of siltstone, mudstone, sandstone, and some conglomerate and limestone. This unit is less resistant to erosion, as there are many landslides in the Morrison. The Salt Wash Member comprises the lower one-third to one-half of the Morrison. The Salt Wash consists of alternating beds or lenses of siltstone or mudstone and some lenses of sandstone and limestone. The sandstone is fine to coarse grained and is locally conglomeratic. The well known vanadium and uranium ore deposits of the Salt Wash Member are absent in the Grand Junction area. The Brushy Basin Member is primarily siltstone and mudstone with a few beds of sandstone, limestone, and bentonitic mudstone.

The Lower Cretaceous Burro Canyon Formation is mainly a green shale, but contains a medium grained massive cross bedded basal sandstone. The sandstone is generally iron stained. In the western half of the area, the formation is primarily shale. The Burro Canyon and overlying Dakota form caps on some of the mesas in the area.

In the Grand Junction area, there is an erosional unconformity at the base of the Upper Cretaceous Dakota Sandstone. This formation is only completely exposed in Gunnison Canyon. The Dakota consists of a white basal conglomerate or conglomeratic sandstone overlain by carbonaceous or lignitic shale, lignite, and a medium grained buff colored sandstone. The formation becomes sandier in the eastern part of the vicinity. Lignite coal was formerly mined in the Dakota in the Gunnison River Valley. Due to its high ash content, the coal has not been mined for many years. Most of the coal beds are six inches or less in thickness with some beds up to 20 inches.

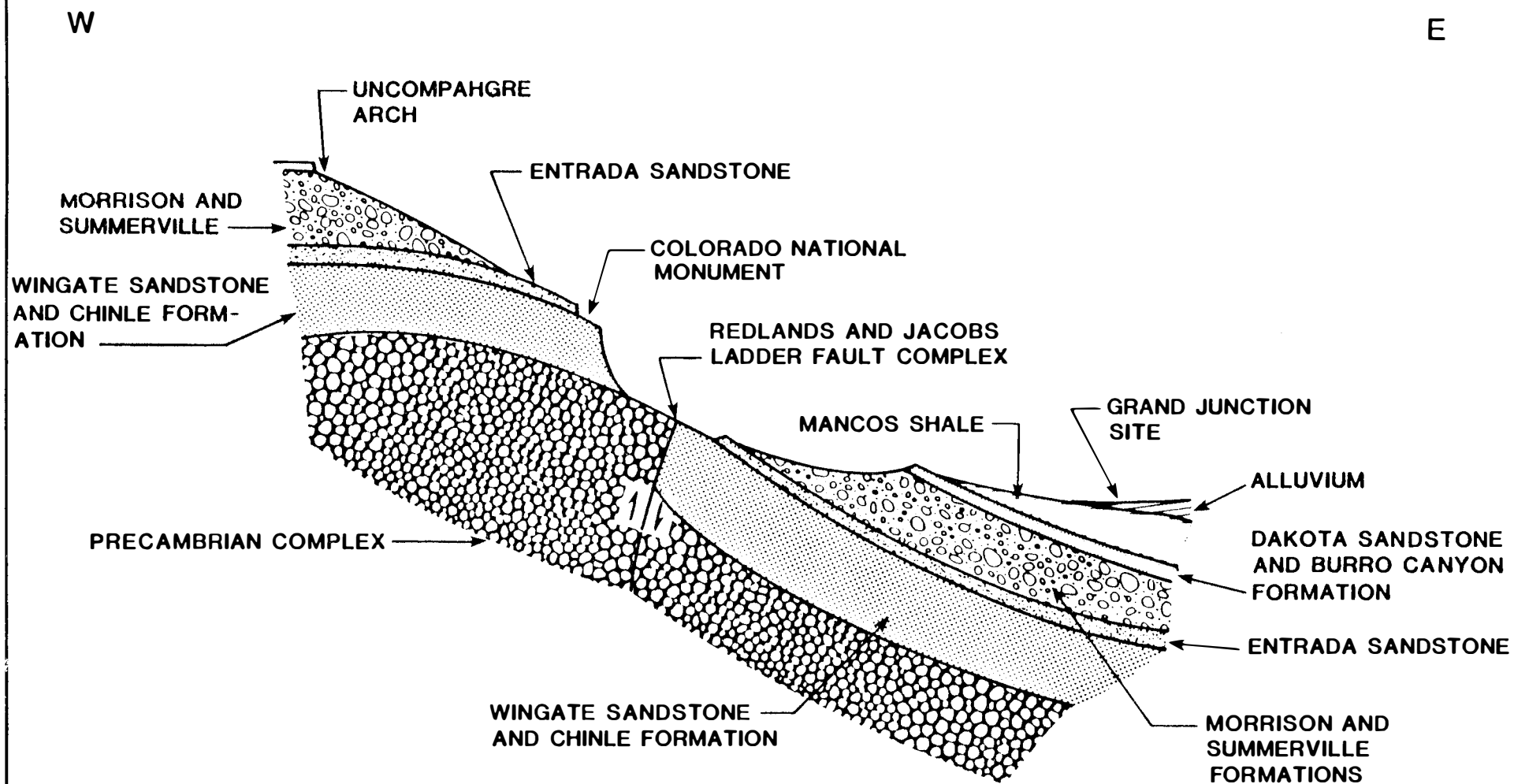
The Mancos Shale underlies the entire Grand Valley and forms the Book Cliffs and the base of Grand Mesa. This formation lies conformably on the Dakota and consists of a thick gray sequence of mostly fissile shale with a few sandy sandstone beds.

Overlying the Mancos in the area are various types of Quaternary deposits such as alluvial and pediment deposits. The nature, origin, and extent of these deposits vary by locality.

At the Grand Junction site, alluvium is present beneath the tailings and varies in thickness from five to 15 feet. Beneath this Quaternary alluvial material is Mancos Shale, which is about 150 feet thick on the east side of the site and 50 feet thick on the west. Figure E.2.2 is a generalized cross-section of the geologic structure in the Grand Junction area. South of the site, on the south side of the Colorado River, the Mancos is exposed. In this area, the Mancos dips three degrees to the northeast. Beneath the Mancos is the Dakota Sandstone which contains beds six inches or less in thickness of coal, approximately 110 feet beneath the tailings pile. There was also a very small amount of oil in one of the test borings.

There is no bedrock exposed at the Cheney Reservoir site. The thickness of the alluvial deposits on the site ranges from 23 to 42 feet thick. The uppermost bedrock unit at the site is the Mancos Shale. The thickness of the shale increases from southwest to northeast and ranges from 300 to 700 feet. The shale is reported to dip northeast at about 200 feet per mile. Information from boreholes indicates that the first five feet of Mancos are extremely weathered. Beneath this zone, the Mancos becomes fractured. With increasing depth, the fractures diminish and the shale becomes relatively impermeable.

At the Two Road site, shallow pediment deposits from two to 31 feet thick overlie the Mancos Shale. The Mancos dips two to five degrees north to northwest at the disposal site. The thickness of the shale ranges from less than 500 feet in the southern area to 1400 feet in the northern part. Based on drilling, the zone of weathering of the shale appears to be between 20 and 60 feet in depth (URS, 1983).



SOURCE: LOHMAN (1981)

FIGURE E.2.2
GENERALIZED CROSS-SECTION OF THE GEOLOGIC STRUCTURE
IN THE GRAND JUNCTION AREA.

Site specific geology of the vicinity properties is not known. The geology of the various properties is expected to be similar to that discussed for the Grand Junction site.

The borrow sites, with the exception of Unaweep Canyon, are located in Colorado River alluvium. At these locations, various thicknesses of sands, gravels, and clays are underlain by various thicknesses of Mancos Shale.

The Unaweep Canyon site is located in Precambrian granite which forms the prominent lower bench that arises 240 to 360 feet above the alluvial covered valley floor. The base of the second bench in the canyon consists of the Triassic Chinle.

E.2.1.3 Structure

Regionally, the Colorado Plateau consists of a seismically stable interior portion that is bounded on three sides by more active border zones (Figure E.2.3). These border zones are transitional to major structural zones that have experienced high levels of seismicity.

The structure of the Grand Junction area which lies in the northwestern part of the plateau is controlled by the Uncompahgre Arch, which is a northwest plunging anticline southwest of Grand Junction, and the Piceance Basin, a broad deep syncline north and northeast of Grand Junction. Evidence indicates the uplift is as recent as three million years ago (Lohman, 1981).

The uplift is one of the few features lying within the stable interior portion of the Colorado Plateau that is identified as potentially active. The major faults in the area include the Redlands Fault and the Jacobs Ladder Fault complex. Figure E.2.4 shows potentially active faults in the region.

The Grand Junction site is located on a low alluvial terrace of the Colorado River. The site is within 12 miles of the Uncompahgre Uplift, which dominates the structure in the area.

The Cheney Reservoir vicinity is a broad homocline which separates the Uncompahgre Uplift from the Book Cliffs monocline. The site is on a gently sloping alluvial terrace between Grand Mesa to the northeast and the Gunnison River canyon to the southwest.

The axis of a large regional anticline runs through the Two Road site. The site is located on pediment deposits formed from the Book Cliffs several miles to the north.

Additional structural geologic information can be found in the seismicity section of this appendix and in Attachment E4, Seismic Risk Evaluation.

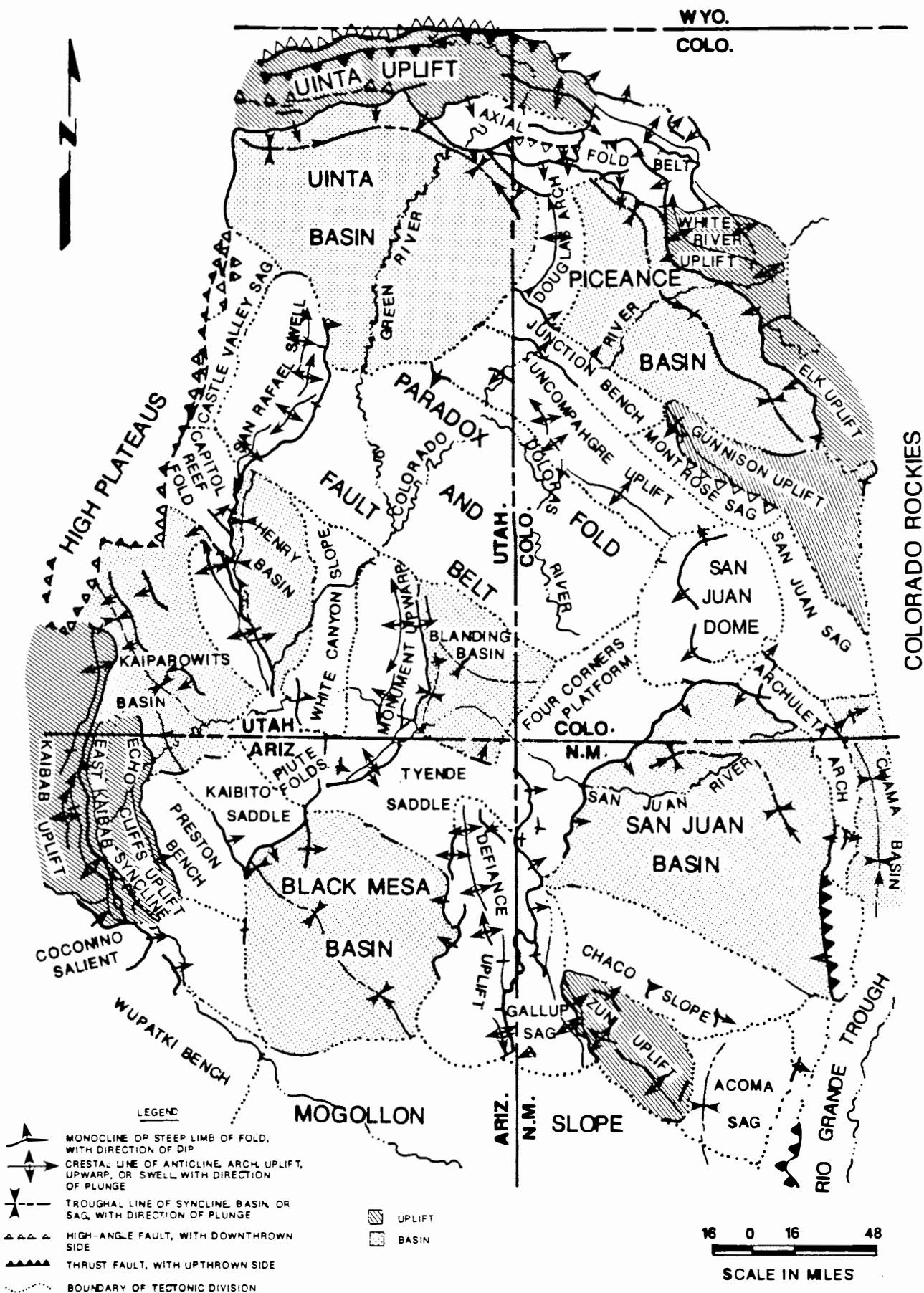


FIGURE E.2.3
LOCATION AND TECTONIC SETTING OF THE GRAND JUNCTION AREA

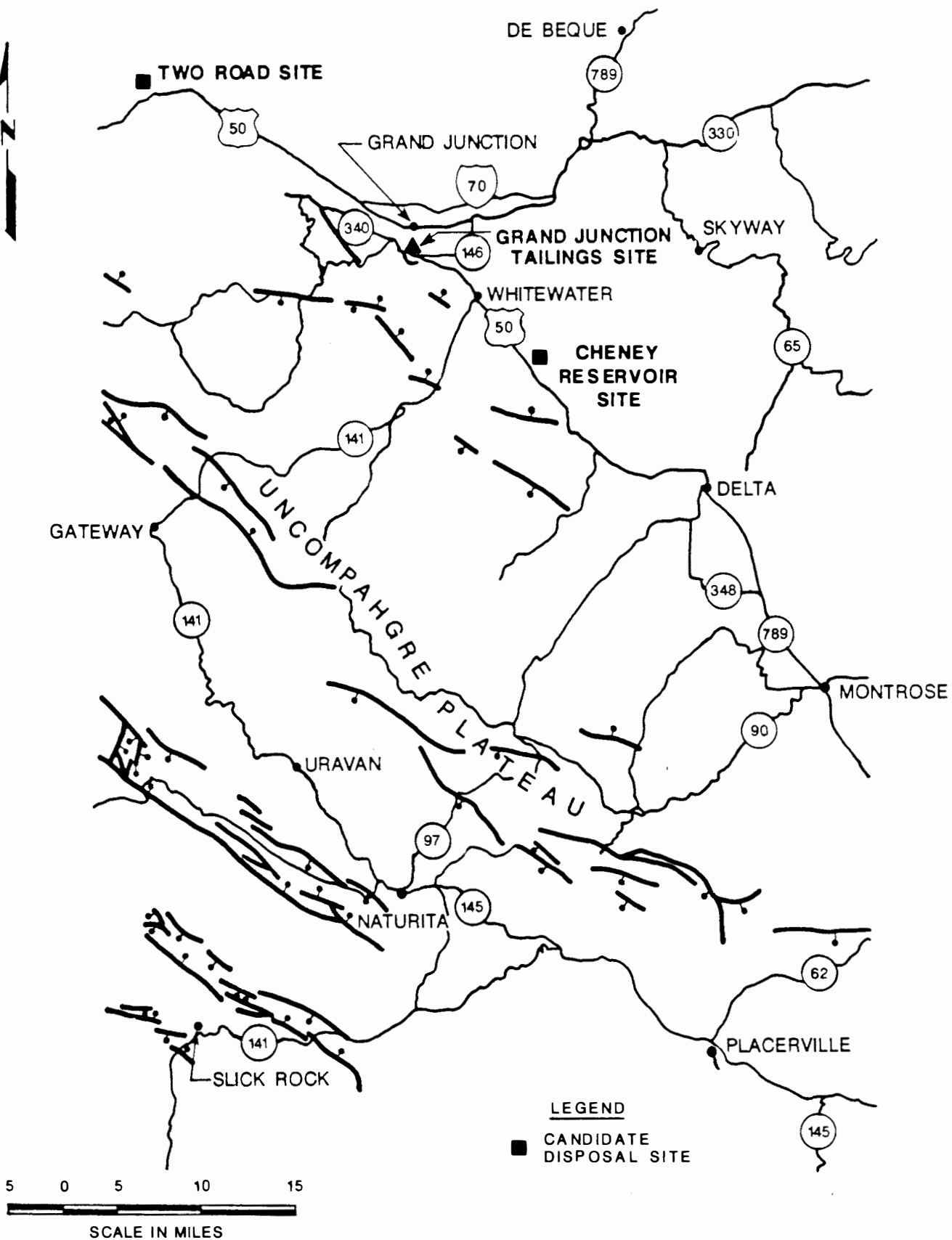


FIGURE E.2.4
POTENTIALLY ACTIVE FAULTS ASSOCIATED
WITH THE UNCOMPAHGRE UPLIFT

E.2.2 MINERAL RESOURCES

E.2.2.1 Grand Junction site

Two-thirds of the producing gas fields in Mesa County are in the Mesa Verde group. The remainder of the gas fields are located in the Mancos, Dakota, Morrison, and Entrada Formations which lie beneath all the disposal sites. In recent years, oil has been produced in very small quantities from nearby gas fields.

Coal occurs beneath the site in the Dakota Sandstone. The thickness of the coal is less than six inches and is a highly volatile D type bituminous coal. Depth to the coal at the site is about 110 feet. There is an outcrop of Dakota coal about one mile southwest of the site.

In addition, three to eight feet of gravel and sand exist at the site beneath the tailings. Since this deposit is thin, and larger, more suitable deposits occur elsewhere, it is not of commercial interest.

E.2.2.2 Cheney Reservoir site

The Cheney Reservoir site has similar potentials for mineral resource development as those discussed for the Grand Junction site. There is an additional potential for oil and gas development. The nearest gas field is 20 miles to the north and northeast. The nearest producing gas well is approximately four miles east of the disposal site. The area has one active oil and gas lease which includes the disposal site. The area is not in a Known Geologic Structure (KGS), therefore the potential for the presence of gas or oil at the site is not great.

Borrow materials for disposal at Cheney Reservoir would be obtained from the site itself. Approximately 801,000 cy of sand and gravel would be consumed for the remedial action. Since this site is not near any planned developments, and more adequate supplies occur elsewhere, these deposits are not of commercial interest.

E.2.2.3 Two Road site

The Two Road site has similar potential for mineral development as that discussed for Cheney Reservoir. There are several active oil and gas leases in and near the Two Road site. There is a producing gas well about four miles north of the site. The vicinity is not in a KGS. The potential for sand and gravel development is questionable due to the distance from developments and the uncertain quality (URS, 1983). The disposal of tailings at the Two Road site would consume 564,700 cy of sandy silt from the site itself.

E.2.2.4 Vicinity properties

The vicinity properties have no mineral resources.

E.2.2.5 Borrow sites

The borrow sites, except the Unaweep site, are located at existing commercial sand and gravel operations. These are the only known mineral resources at these sites and the volume of these materials is unknown.

The Unaweep Canyon site, a source of quarry rock, is near the inactive Unaweep copper district. The copper deposits are reported to be thin and not continuous as described by Schwochow (1978). There are some ongoing commercial quarry operations in the vicinity which use Precambrian granite. Production quantities are not known.

E.2.3 SEISMICITY

This seismicity discussion is a summary of the seismic risk evaluation contained in Attachment E4.

Recurrence intervals of seismic activity in the Grand Junction vicinity are not known due to the lack of historic data. The probability that active or potentially active faults will move during the disposal site design life cannot be estimated with a high degree of confidence. The magnitude of the Maximum Credible Earthquake (MCE) potential at each of the disposal sites is based on currently available literature and data.

The tectonic setting of the Colorado Plateau is composed of a seismically stable interior bounded by transitional zones to major seismic and structural zones. These major zones are the Intermountain Seismic Belt west of the area, the Rio Grande Rift which borders the eastern edge of the plateau in Colorado and New Mexico, and the Colorado Plateau/Basin and Range transition zone in north-central Arizona.

The disposal sites are near the Uncompahgre Uplift which contains potentially active faults. In addition, the study area is located 120 to 160 miles east of the Intermountain Seismic Belt and 100 to 140 miles west of the Rio Grande Rift. These are all possible sources of large earthquakes which could impact the Grand Junction area.

The historical seismicity of the province has been classified as very low and the largest instrumentally recorded earthquakes ranged in magnitude from 4.5 to 5.5. Magnitudes and accelerations could be greater in the study area due to the presence of the Uncompahgre Uplift.

The Uplift experienced considerable movement during the Pleistocene and the Quaternary along bounding faults and monoclines. It is possible that movement has continued through the Pleistocene to the present time. There are numerous possibly active Cenozoic faults, five to 25

miles in length, that flank the Uplift on both the northeast and southwest. Those on the northeast are within five to 20 miles from the Grand Junction and Cheney Reservoir sites and from 15 to 45 miles from the Two Road site. Movements associated with the Uplift, in the Grand Junction area, would produce ground accelerations larger than those accelerations from movements from other seismic zones in the region.

The MCE on known faults within the area could produce accelerations as high as 0.34g at the Cheney Reservoir and Grand Junction sites and up to approximately 0.18g at the Two Road site. Higher accelerations could result from the occurrence of earthquakes with magnitudes as high as 6.6 on previously undetected faults within less than five miles of the site.

For the Two Road and Cheney Reservoir sites, the potential for seismically-induced soil liquefaction is very remote. This is due to the composition of materials present at each site and the lack of saturated zones near the surface. The Grand Junction site has a relatively low potential for soil liquefaction. This is due to the possibility of undetected faults near the site and probable variations in the water table. There is also a possibility of landslide failure of the riverbanks at and near the pile.

There is no direct evidence of any potential for on-site rupture at any of the sites. However, the possibility cannot be ruled out completely, primarily at the Grand Junction site.

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ATTACHMENT E1

GEOMORPHIC EVALUATION

GRAND JUNCTION TAILINGS SITE
GRAND JUNCTION COLORADO
URANIUM MILL TAILINGS REMEDIAL ACTION PROJECT

AUGUST, 1985

PREFACE

The Uranium Mill Tailings Radiation Control Act of 1978, Public Law 95-604, 42 USC 7901, authorizes the U.S. Department of Energy (DOE) to undertake remedial actions at 24 DOE-designated processing sites. The Uranium Mill Tailings Remedial Action (UMTRA) Project Office of the DOE issued a Plan for Implementing EPA Standards for UMTRA Sites in January, 1984. In this report, under a section on long-term stability, the DOE stated that a design objective of 1000 years was established to be satisfied whenever reasonably achievable, but in any case with a minimum performance period of 200 years.

For the subject processing site, a remedial action plan is being developed to ensure the long-term stability of the proposed reclamation. This geomorphic evaluation report represents a portion of the site characterization efforts being completed. The major objective of this evaluation is to fully recognize which geomorphic processes may cause long-term changes at the existing disposal site or at alternate disposal areas. This report is provided as a reference document for use during the site selection process and/or design development of the remedial action plan.

This report was prepared by the Phoenix office staff of Sergent, Hauskins & Beckwith Geotechnical Engineers, Inc., a part of the Jacobs-Weston Team, the UMTRA Project Technical Assistance Contractor to the DOE.

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E1.1 EXECUTIVE SUMMARY

Geomorphic studies were performed to characterize the long-term stability of existing uranium mill tailings piles located on the north bank of the Colorado River in Grand Junction, Colorado.

The site is on a young alluvial terrace five to six feet above the low flow level of the river. It is protected from flood flows by a concrete block berm placed on the alluvial terrace materials.

Calculated 100- and 500-year flood levels would cause significant erosion of the site area. The principal threat is at the southeast corner of the site where erosion of the bank and undercutting of the berm are occurring. Avulsion or channel migration in the area upstream from the site could also increase the erosion potential at the site by directing the flow of the river against the eastern boundary.

The development of a large sinkhole of unknown cause is the most significant aspect of site erosion hazard.

E1.2 INTRODUCTION

E1.2.1 PURPOSE AND SCOPE OF INVESTIGATION

This report presents the findings of geomorphic studies performed in the area of existing uranium mill tailings piles in Grand Junction, Colorado. The purpose of the investigation was to characterize the geomorphic conditions currently acting on the site area and to evaluate the potential for long-term stability of disposal facilities at the site.

The existing piles are located at the site of the former Climax Uranium Company mill site on the northern bank of the Colorado River (Figure E1.2.1).

The evaluation is restricted to the assessment of natural processes, particularly fluvial erosion, which could compromise the integrity of disposal facilities during the specified design life. The U.S. Environmental Protection Agency's (EPA) design life standard which regulates the design of disposal facilities involved in the Uranium Mill Tailings Remedial Action (UMTRA) Project states that engineered design and site selection processes developed during the project should result in containment structures which are capable of resisting natural intrusion for a period of at least 1000 years whenever reasonably achievable (DOE, 1984a). A minimum longevity standard of 200 years is imposed whenever the 1000-year design life is found to be impractical.

E1.2.2 FIELD INVESTIGATION AND RESEARCH

This investigation involved field work and research into the pertinent aspects of the geologic history of the site region, geomorphic conditions at the site area, and estimations of the potential impact of geomorphic processes on the planned facility during the EPA-specified design life. The program of field work and research carried out for this study included the following:

- o Acquisition and review of aerial photography, published geologic mapping, and pertinent literature and data, including geotechnical data and previous reports developed during the UMTRA Project investigation.
- o Geologic and geomorphic field reconnaissance in the site region.

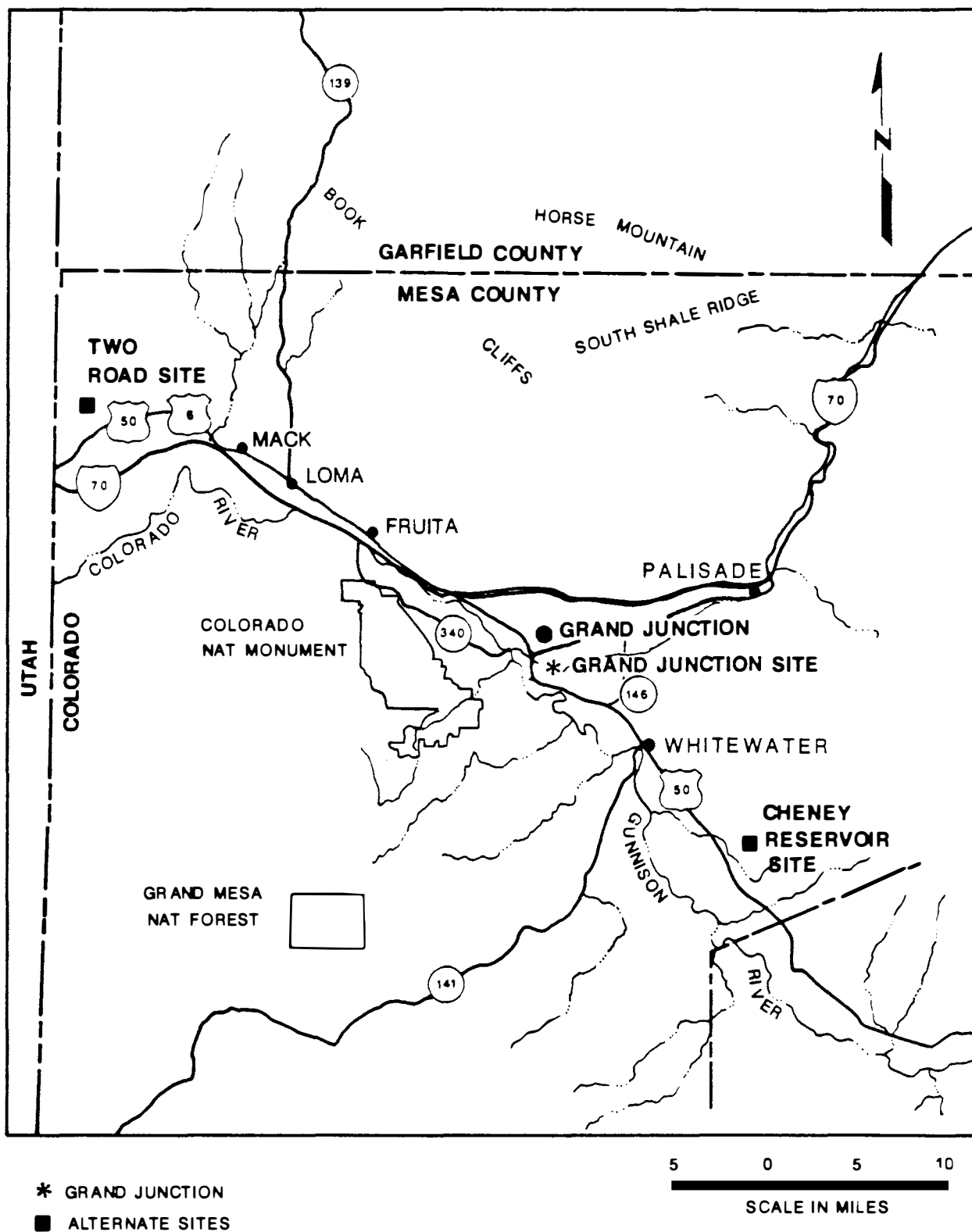


FIGURE E1.2.1
LOCATION OF DISPOSAL SITES

E1.3 REGIONAL SETTING

E1.3.1 PHYSICAL SETTING

The site study area is in western Colorado, in the Canyon Lands section of the Colorado Plateau physiographic province (Hunt, 1967) (Figure E1.3.1). Structurally, the region is characterized by large upwarps and intervening basins formed mostly in upper Paleozoic and lower Mesozoic sandstones and shales. The most prominent landforms are broad mesas and pediment surfaces, narrow rock-walled gullies, and deeply incised canyons of the Colorado River and its tributaries. The site is in the Grand Valley near the confluence of the Colorado and Gunnison Rivers.

Elevation at the site is about 4575 feet. To the southwest, the Uncompahgre Uplift, a large northwest-trending structural upwarp, reaches elevations of 9000 to 10,000 feet. To the northeast, the Colorado River flows through DeBeque Canyon, flanked by the Book Cliffs on the west and Grand Mesa on the east. Elevations in this area reach a maximum of about 11,000 feet.

Annual precipitation at Grand Junction is eight to nine inches (NOAA, 1982) and is generally evenly distributed throughout the year. Precipitation in the higher elevations which form the headwaters of the Colorado River system is somewhat higher, ranging from 10 to 25 inches per year. Climatological data for western Colorado are summarized in Table E1.3.1.

The lower valley areas, such as the Grand Valley, are protected by surrounding higher terrain. They experience higher summer and winter temperatures than the higher terrain. A spring flood potential results from the melting of the snowpack at higher elevations.

Natural vegetation in the lower elevations consists of cottonwood, willow, desert shrub, and grass. Juniper, sagebrush, pine, oak, and Douglas fir are prominent at elevations of 5000 to 8000 feet. From 8000 feet to the timberline, vegetation consists of aspen, spruce, sub-alpine fir, lodgepole pine, grasses, and shrubs. Alpine willow, grasses, and sedges are found above the timberline.

E1.3.2 BEDROCK GEOLOGY

The Grand Junction region is in the northeastern portion of the Colorado Plateau, a major tectonic block composed of Precambrian rock overlain by Paleozoic, Mesozoic, and Tertiary sedimentary rocks. The Paleozoic section is absent in the Grand Junction area due to uplift of the Uncompahgre Arch in Middle Pennsylvanian time, and Mesozoic units rest directly on the Precambrian. The total thickness of the Mesozoic section in the Grand Junction area is about 8000 feet (Lohman, 1965; Yeend, 1969). Thick Tertiary sections lie to the northwest and northeast in the Uinta and Piceance Basins, and basalt flows of Pliocene age cap Grand Mesa. Sedimentary units in the Grand Junction area dip to the northeast at about 250 feet per mile (Cashion, 1973).

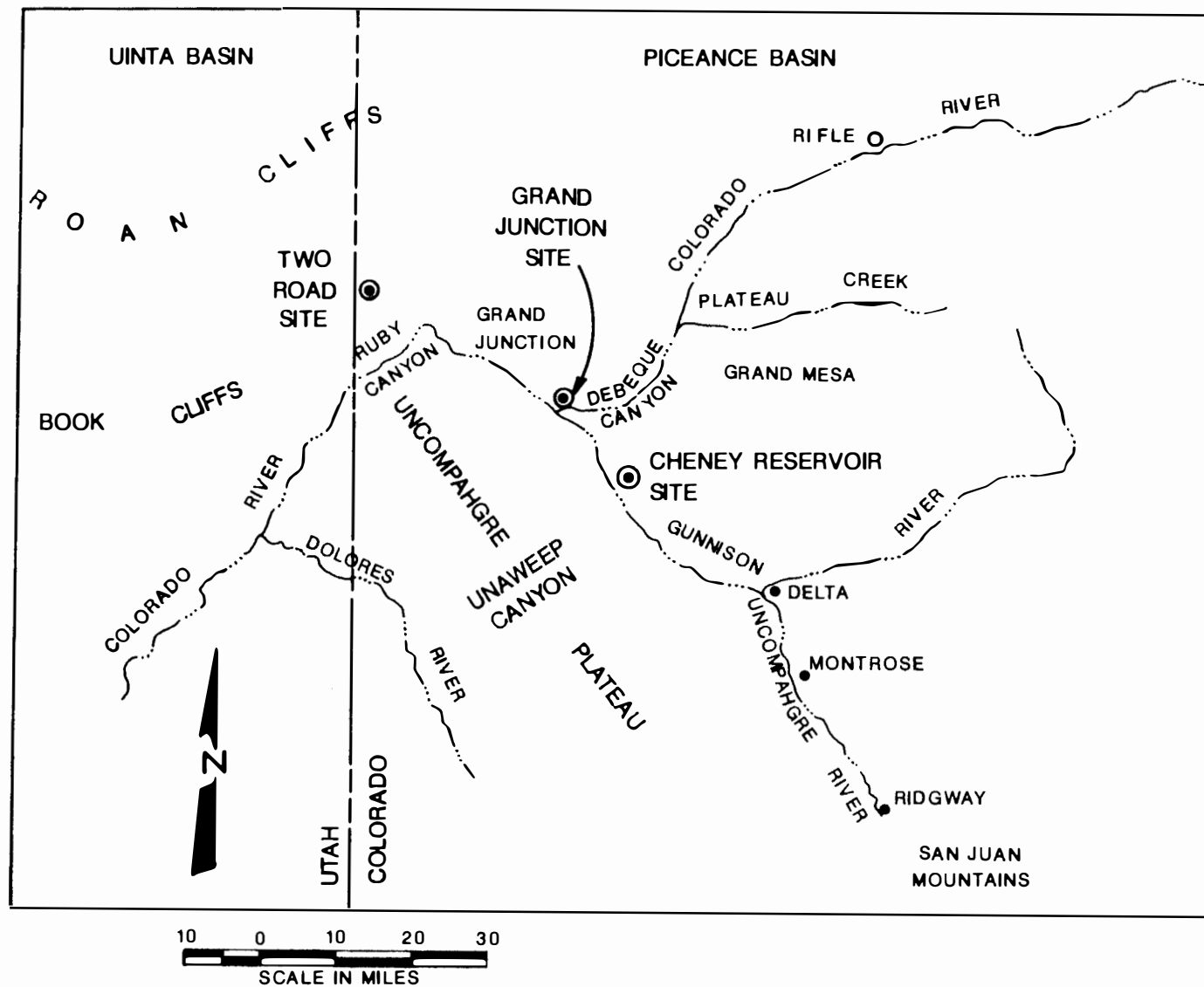


FIGURE E1.3.1
PHYSIOGRAPHIC SKETCH MAP OF GRAND JUNCTION REGION, SHOWING
LOCATIONS OF UMTRA SITES AND FEATURES DISCUSSED IN TEXT

Table E1.3.1 Climatological data for western Colorado

	Month	Mean temp. °F	Precipitation (inches)
Station: Grand Junction Elevation: 4843 Period: 1975	January	26.6	0.64
	February	33.6	0.61
	March	41.2	0.75
	April	51.7	0.79
	May	62.2	0.63
	June	71.3	0.55
	July	78.7	0.46
	August	75.4	1.05
	September	67.2	0.84
	October	54.9	0.93
	November	39.8	0.61
	December	29.5	0.55
	Annual	52.7	8.41
Station: Cedaredge Elevation: 6180 Period: 1951-1973	January	27.5	0.81
	February	32.3	0.77
	March	38.5	0.86
	April	47.1	0.90
	May	57.0	0.96
	June	65.6	0.81
	July	71.9	0.89
	August	69.5	1.36
	September	61.6	1.20
	October	50.9	1.40
	November	37.5	0.94
	December	28.5	1.02
	Annual	49.0	11.92
Station: Cortez Elevation: 6177 Period: 1951-1973	January	27.7	0.97
	February	32.4	0.73
	March	38.3	0.93
	April	46.7	0.97
	May	56.2	0.94
	June	65.2	0.45
	July	72.1	1.13
	August	69.8	1.66
	September	62.0	1.14
	October	51.1	1.54
	November	38.1	0.89
	December	28.5	1.23
	Annual	49.0	12.58

Table E1.3.1 Climatological data for western Colorado (Concluded)

	Month	Mean temp. °F	Precipitation (inches)
Station: Gunnison Elevation: 7664 Period: 1951-1973	January	10.3	0.99
	February	15.1	0.88
	March	25.5	0.81
	April	37.9	0.71
	May	47.6	0.61
	June	56.0	0.54
	July	61.9	1.56
	August	59.7	1.57
	September	51.9	1.11
	October	42.2	0.90
	November	27.8	0.75
	December	13.8	0.97
	Annual	37.5	11.40
Station: Telluride Elevation: 8800 Period: 1951-1973	January	21.9	1.37
	February	23.6	1.47
	March	27.8	1.62
	April	36.7	1.95
	May	46.1	1.66
	June	54.1	1.08
	July	59.5	2.54
	August	57.7	2.85
	September	51.4	2.06
	October	43.0	2.07
	November	30.7	1.46
	December	22.8	1.66
	Annual	39.6	21.79

Ref. NOAA, 1982.

The major structural feature of the region is the Uncompahgre Uplift, which extends from the San Juan Mountains northwestward into Utah. The uplift is a northeast-tilted block bounded on the southwest and on the northeastern flank near Grand Junction by abrupt, locally faulted monoclines (Lohman, 1965; Cater, 1966, 1970).

To the north of the Grand Junction area, the uplift is flanked by the Uinta and Piceance Basins which contain Paleocene and Eocene shale, sandstone, siltstone, and limestone, reaching thicknesses of about 10,000 feet. These rocks are primarily lacustrine in origin and were formed from the erosion of surrounding uplifts of Laramide age. Permanent fresh water or near fresh water lakes formed in the region during the Eocene. Deposition of sediments apparently ended at the end of Eocene time and erosion has been the dominant process since then with the exception of the extrusion of basalt flows during Pliocene time (Cashion, 1973).

The existing tailings site is on the modern floodplain of the Colorado River on a low terrace about five to six feet above the river. Geologic units underlying the site are floodplain deposits of the Colorado River, Mancos Shale of Cretaceous age, and older sedimentary units. The dip of the Mancos and older rocks is to the northeast.

E1.3.3 SURFICIAL GEOLOGY AND GEOMORPHOLOGY

E1.3.3.1 Regional geomorphic history

A number of geologists have investigated the development of drainage patterns, terraces, sediments, and glacial moraines in the Grand Valley region. The following discussion is excerpted from articles by Hunt (1956), Lohman (1965, 1981), Yeend (1969), and Sinnock (1981a, b).

Until perhaps Pliocene time, the Grand Junction area and adjacent parts of the Colorado Plateau were undergoing erosion by drainage of the ancestral Colorado River. The course of the Colorado River may have been established by the end of the Miocene. Differential uplift of the Uncompahgre Arch was renewed during the Pliocene, causing major changes in the drainage patterns of the Colorado and Gunnison Rivers.

Some disagreement exists between various investigators on the question of whether tectonic activity essentially stopped before or shortly after the end of the Tertiary, or has continued up to the present time. The evolution of the modern drainage systems is also controversial. For example, Lohman (1965, 1981) presented evidence that the ancestral Colorado and Gunnison Rivers once flowed through Unaweep Canyon and that the present pattern evolved from successive stages of stream piracy by tributary streams cutting Mancos Shale north and west of the Uncompahgre Arch. The more rapid rate of stream downcutting in the Mancos than in the Precambrian granitic terrain of the Uncompahgre Uplift was the determining

factor. Sinnock (1981b), on the other hand, believes that Unaweep Canyon was formerly occupied by the Gunnison alone, and that the Colorado River has been in essentially the same position relative to the Uncompahgre Uplift since the Miocene. He attributes the diversion of the Gunnison away from Unaweep Canyon to successive stages of uplift of the Uncompahgre Arch.

The development of the present landforms of the river valleys was strongly influenced by Pleistocene glaciations. Sinnock (1981a) identified four sets of glacial moraines of Bull Lake (?) and Pinedale (?) age in the Ridgway area. He correlated these with glacial episodes in the San Juan Mountains to the south. Evidence for successive periods of Pleistocene glaciation was also recognized on Grand Mesa and Battlement Mesa by Yeend (1969). The glacial stages can be correlated with alluvial terraces along the Uncompahgre, Gunnison, and Colorado Rivers. Episodes of significant erosion and incision of the rivers occurred during major readvances of the ice. During interglacial periods, a general equilibrium exists. Hence, it appears that the level of the Colorado River near Grand Junction may have been fairly constant since the end of the Pleistocene.

Potassium-argon dating of the basalt flows capping Grand Mesa, about 5000 feet above the Colorado River, gives a Pliocene age of 9.7 plus or minus 0.485 million years (Yeend, 1969). Assuming that the basalt formerly covered the area now occupied by the river, an average rate of downcutting by the Colorado River of six inches per thousand years is obtained. This average rate includes downcutting during both glacial and interglacial stages, and the greater part of the downcutting probably occurred during the glacial intervals. There is some uncertainty related to the present rate of uplift of the Uncompahgre Arch, which may also affect rates of downcutting or cause aggradation. However, it is reasonable to assume that this value will not be greatly exceeded in the Grand Junction area during the design life of the proposed facility.

E1.3.3.2 Surficial geology of the Grand Valley area

A surficial geologic map of the Grand Valley area was prepared by Whitney (1981). A portion of that map is presented as Figure E1.3.2. Surficial deposits in the region range from Late Pliocene to Holocene in age.

Glacial tills of Bull Lake (?) and Pinedale (?) age (Late Pleistocene) cover the surface of Grand Mesa (Yeend, 1969). These are composed of unsorted material ranging from clay to boulders deposited by at least four episodes of Pleistocene glaciation. The thicknesses of these materials range from about five feet to 75 feet.

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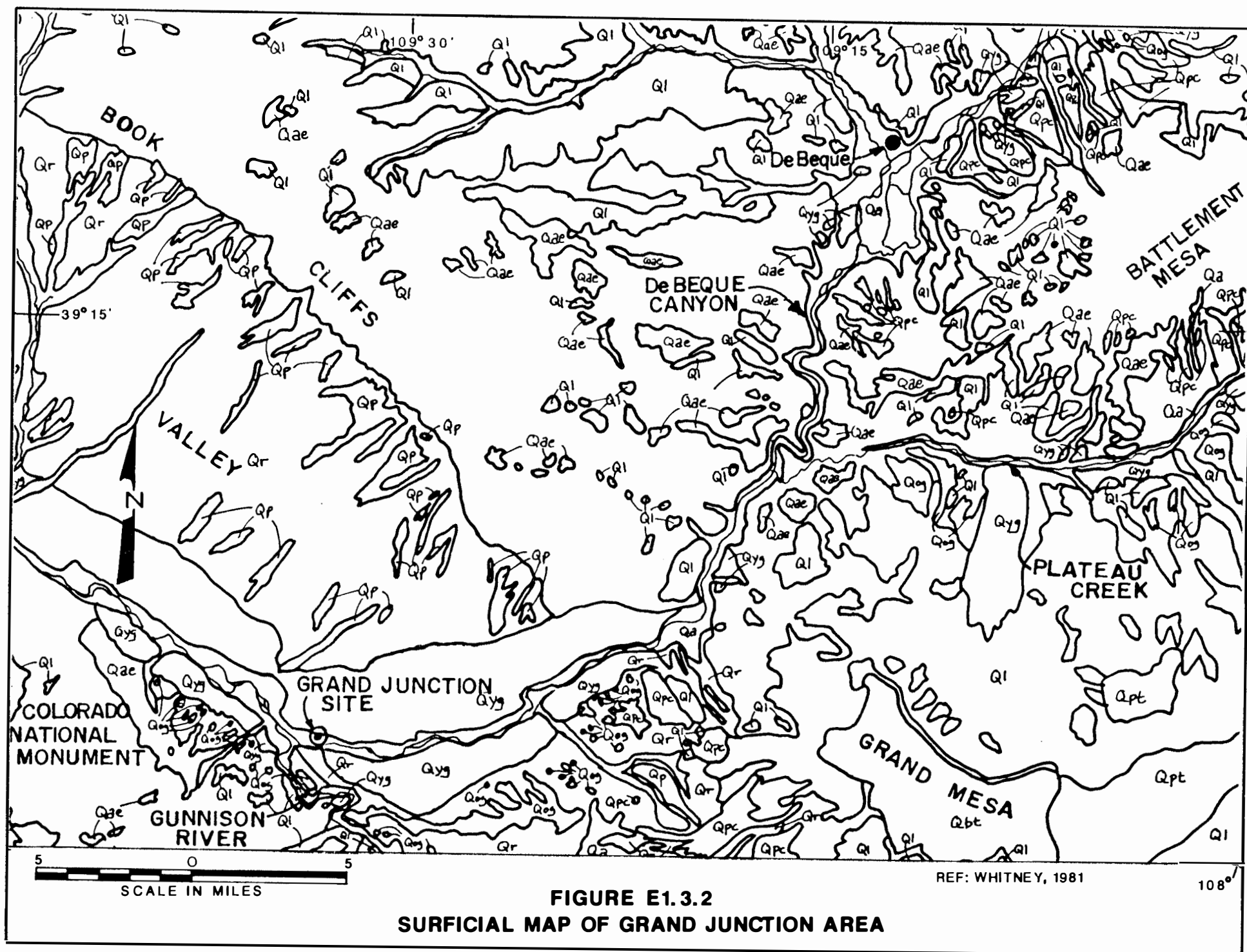


FIGURE E1.3.2
SURFICIAL MAP OF GRAND JUNCTION AREA

Figure E1.3.2 Surficial map of Grand Junction area
(Concluded)

LEGEND

Qa	Alluvium (Holocene). Clay, silt, sand, and gravel deposits underlying modern floodplains.
Qae	Locally deposited sand and silt (Holocene to Late Pleistocene). Locally derived and reworked by eolian and fluvial processes.
Qrg	Reworked gravel (Holocene to Late Pleistocene).
Qyg	Young gravel (Late Pleistocene). Terrace gravels of Pinedale (?) and Bull Lake (?) age.
Qg	Older gravel (Middle to Early Pleistocene). Terraces and terrace remnants of pre-Bull Lake age.
Qp	Pediment deposits (Holocene to Pleistocene).
Qpc	Colluvial deposits on pediments (Pleistocene to Late Pliocene).
Qr	Weathered shale (Holocene to Late Pleistocene). Residual soil formed on Mancos Shale.
Ql	Landslide deposits (Holocene and Pleistocene).
Qpt	Till of Pinedale (?) age (Late Pleistocene).
Qbt	Till of Bull Lake (?) age (Late Pleistocene).

Extensive landslide deposits of Pleistocene and Holocene age occur on the flanks of Grand and Battlement Mesas and in the area west of DeBeque. These deposits are the result of slumping, rock and debris falls, rockslides, and solifluction movements. These movements occurred throughout the Pleistocene and are continuing today.

Residual deposits (weathered shale) of Late Pleistocene to Holocene age, developed from in-place weathering of the Mancos Shale, floor much of the Grand Valley. The thickness of the clayey residuum generally ranges from one to six feet. This material underlies much of the town of Grand Junction.

Surfaces adjacent to Grand and Battlement Mesas are mantled by deposits of Late Pliocene to Pleistocene age. These are coarse deposits of poorly sorted pebbles, cobbles, and boulders, commonly 15 to 30 feet thick. The gravel is composed largely of basalt. These deposits are mainly formed by colluvial processes and debris flows associated with Pleistocene glaciation. Pediment deposits that are distinct from those described above are thin, discontinuous deposits of clayey silt, sand, and gravel, which resulted from local flooding and slope wash. They range in age from Pleistocene to Holocene and are most common in areas underlain by Mancos Shale. These surfaces are frequently mantled by a thin (three to six feet) cover of eolian silt and fine sand and may be strongly cemented by caliche. Caliche crusts on gravel and boulders are common.

Terrace remnants occur at various elevations above the Colorado and Gunnison Rivers and Plateau Creek. They are underlain by gravels which range in age from Early to Late Pleistocene. The oldest gravels are from 30 to 450 meters above modern stream levels, and may be of pre-Bull Lake age. The surfaces of these deposits are often covered by eolian or alluvial sand up to 15 feet thick, and they may contain caliche deposits as much as four feet thick. The thickness of these gravels ranges from six to 45 feet. Terrace remnants of small areal extent exist about 300 feet above the Colorado River in the Redlands and Orchard Mesa areas south of Grand Junction (Hart, 1976; Whitney, 1981).

Younger terraces correlated with Pinedale (?) and Bull Lake (?) glaciations (Yeend, 1969; Whitney, 1981; Sinnock, 1981a) generally occur between 15 and 65 feet above the modern channels. Gravels underlying these terraces range from 10 to 45 feet in thickness. Gravels of this age are widely distributed in the Redlands and Orchard Mesa areas. They may be overlain by as much as 10 to 15 feet of alluvial or eolian sand.

The modern floodplains are underlain by unconsolidated clay, silt, sand, and gravel deposits. These may reach thicknesses of 20 feet or more along the Colorado River.

E1.4 GEOMORPHIC EVALUATION OF GRAND JUNCTION SITE

E1.4.1 GEOLOGICAL DESCRIPTION

The site is on a young alluvial terrace a few feet above the present level of the Colorado River. Bedrock beneath the site consists of the Cretaceous Mancos Shale, Dakota Sandstone, and Burro Canyon Formation, which dip to the northeast under the site at a gradient of about 250 feet per mile (Cashion, 1973).

The surficial materials underlying this terrace occur at several locations along the floodplain in gravel pits, banks, bars, and islands. They are similar to modern floodplain materials, and consist of unconsolidated clay, silt, sand, and gravel. A generalized profile consists of two to six feet of clay, silt, and fine sand overlying coarse sand and gravel with numerous well-rounded cobbles and boulders. Thickness of the gravels may range from about five to 15 feet. Exploratory borings advanced for this study (DOE, 1983a) reported that the tailings piles are underlain by zero to five feet of sandy silt underlain by five to fifteen feet of sandy gravel, cobbles, and occasional boulders. This alluvial terrace is apparently of Late Holocene age. Soil profiles of terraces which apparently correspond to the terrace underlying the site exhibit a very weakly developed soil profile consistent with very recent deposition, probably less than 1000 years. The growth of vegetation on the terraces and islands at the same elevation is consistent with an age at least older than 50 to 100 years. The terrace underlying the site is probably 100 to 1000 years old.

E1.4.2 GEOMORPHOLOGY OF SITE AREA

A sketch map (Figure E1.4.1) showing the existing channels of the Colorado and Gunnison Rivers and evidence for recent channel shifts was prepared from topographic maps. In the site area, the river flows along the south bank against steep bluffs cut into the Mancos Shale. On the north bank, the river is bounded by slip-off slopes cut into the Mancos.

The channel morphology is fairly straight to island braided over about a three-mile reach extending from the junction of the Colorado and Gunnison Rivers to a point about one mile upstream of the site. Elsewhere it displays a meandering pattern. The change in channel morphology near the site does not appear to result from any significant change in channel gradients. Gradients are fairly uniform, ranging from six to eight feet per mile in the Grand Junction area. The impact of human activities, such as diking and filling along the bank, may be one cause. Backwater effects from the Gunnison River may be the cause of the island braided pattern evident near the confluence of the two rivers.

The fairly straight channel morphology directly opposite the site is characteristic of a relatively stable channel. A comparison of the 1882 General Land Office Survey map and 1980 aerial photographs (DOE, 1983b) indicates that the river has been very stable at this location and apparently there has been no major shift in the position of the

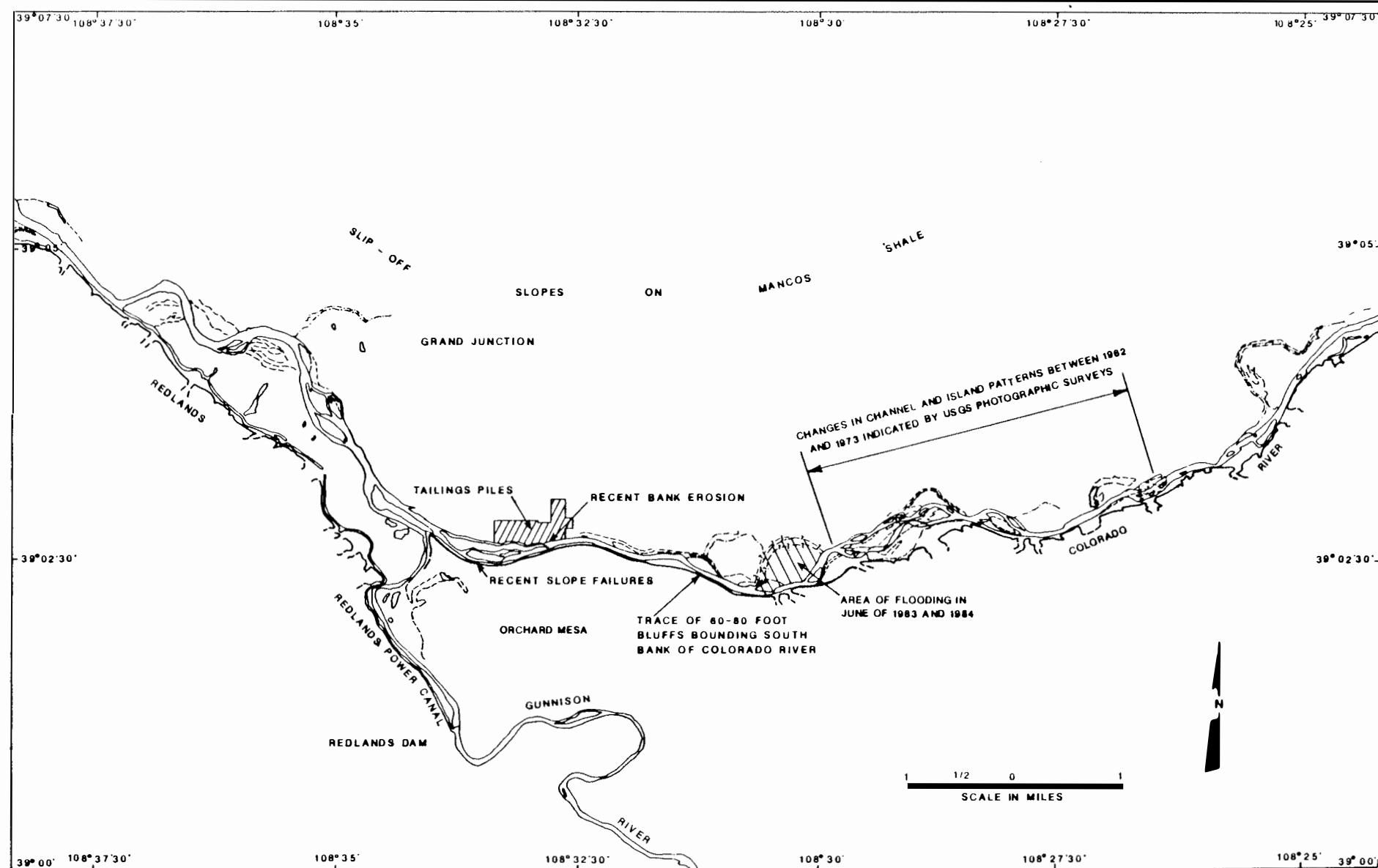


FIGURE E1.4.1
SKETCH MAP OF COLORADO & GUNNISON RIVER NEAR GRAND JUNCTION,
SHOWING EVIDENCE FOR RECENT CHANNEL SHIFTS

channel for the past 100 years. However, the meandering patterns displayed both upstream and downstream of the site are characteristic of less stable rivers. A classification of channel types by Schumm and Chorley (1983) indicates that the meandering channel morphology is characteristic of low stability. Channels of this type have a tendency for meander shift, chute cutoff, thalweg shift, and avulsion. There is evidence that significant shifts have recently occurred in the reach upstream of the site (Figure E1.4.1). Changes in channels and islands that occurred between 1962 and 1973 as recorded by USGS aerial topographic surveys are on the revised 1973 Clifton 7.5 minute quadrangle. Cutoff meander loops, abandoned channels, and oxbow lakes are evident on topographic maps and aerial photographs. Similar features are evident in the reach south of the confluence of the Colorado and Gunnison Rivers. Such features are not evident in the immediate site area. However, the much greater density of construction, placement of the tailings piles, and other human activities in this area may have obliterated natural contours.

E1.4.2.1 Evidence for erosion of site area by the Colorado River

A single meander loop with low curvature flows against the southeast corner of the site (Figure E1.4.1). This loop is directing the flow of the river toward the site area and is causing some undercutting of the bank at the present time. The gravel bar near the site is also apparently being eroded. At the present time, the tailings pile is protected by a 30-foot berm composed of concrete blocks and other debris. This material was placed on the alluvial terrace materials and could be undercut by erosion of the terrace. A narrow width of the original riverbank ranging from zero to 15 or 20 feet presently separates the base of the berm from the river. This bank shows evidence of recent erosion, such as the development of transverse cracks near the water's edge and slumping of the bank. Removal of the remaining width of riverbank will result in erosional undercutting of the berm and tailings pile.

Mining of gravel is occurring at the present time in a large area of the north bank, east of the site. These operations could increase the possibility of avulsion or meander shift immediately upstream of the site. The tailings pile is bounded on the east by an extension of the low terrace upon which the site sits. This surface will not offer any significant erosion protection to the site area.

Aerial photographs obtained for this study from Nichols Engineering Associates of Grand Junction were taken during flooding of the Colorado River in June of 1983 and 1984. These photographs show that an area of the north bank from two to 2.5 miles upstream of the site was flooded both years. They also clearly show flood flows directed against the bank underneath the southeast corner of the site.

Tailings are presently being dumped in an area at the eastern end of the site which is separated from the older

tailings pile by a 30- to 40-foot-deep drainage ditch that is not armored against erosion. Flash flooding in the area drained by this ditch could cause erosion of the site area.

The new tailings area is set back further from the river (50 to 60 feet) and protected by a 15- to 20-foot berm. The east end of the new pile is bounded by a 20-foot-deep ditch. A low gravel berm extends some distance to the east along the bank. This area is not well protected from bank erosion or overbank flooding at the present time.

It is apparent from the above discussion that the potential for erosion of the Grand Junction site by the Colorado River is significant during the next 1000 years. The principal threat occurs at the southeast corner of the site where erosion is occurring at the present time. Constant maintenance and repair of the existing berm are necessary to protect the tailings pile from undercutting and erosion during normal flows, and may not be sufficient to control erosion during future floods. Avulsions or major channel migration in the area upstream of the site could also increase the erosion potential at the site by directing the river against the east boundary.

E1.4.2.2 Flood potential

Flood flows for the Grand Junction area have been calculated by the U.S. Army Corps of Engineers (COE, 1976) and as a part of the UMTRA Project study (DOE, 1984b). These studies indicate that a major portion of the area surrounding the site will be inundated during the 100-year flood. Sheet flows in overbank areas would have velocities ranging from one to three or four fps, and channel flows would range from seven to nine fps. Levels of the 500-year flood would inundate the base of the pile. The pile would be completely inundated and subject to channel flows on all sides during a Probable Maximum Flood (PMF) event.

These results indicate that severe erosion (associated with 100- and 500-year flood levels) may affect the banks of the river and the terrace deposits underlying the pile during the 1000-year design life.

Erosion which is presently occurring at the southeast corner of the pile would be accelerated during major flood flows. The area to the east of the site is unprotected, except by the floodplain. There is significant evidence that channel shifts have recently occurred in this area, as discussed above. High channel and overbank flows could result in significant erosion of the surficial materials in this area and result in northward channel shifts. This would redirect the flow of the river against the east boundary of the pile.

E1.4.2.3 Erosion by other processes

The surface of the tailings pile is gently rolling and relatively smooth. Portions of the surface are vegetated with grasses and shrubs; however, large bare spots are common and may be subject to erosion by wind and rain. Elevation relief of about 20 feet occurs across the site surface.

The most significant on-site erosional feature is a large sinkhole, about 25 feet wide by 35 feet long and four to five feet deep, which has evidently developed within the last few years near the north edge of the pile. The sinkhole occurs near the site of two former settling ponds shown on the 1962 topographic map.

The cause of this feature is apparently not known; however, an underground cavity may exist due to previous construction. Metal tanks or machinery from the former mill may have been buried at the site of the former settling ponds during construction or grading of the pile (Rush, 1984). The sinkhole showed evidence of recent expansion during on-site reconnaissance in October and November of 1984. Fresh grass on hummocky piles lying within the sinkhole appeared to have fallen in very recently. Several smaller sinks, with diameters of three to five feet and three feet or more in depth, occur within 50 feet to the east of the larger feature. Rainwater appears to drain into a cavity at the bottom of the hole, probably into terrace materials beneath the tailings. The process of collapse of this feature, and erosion by water draining into it, will result in serious erosion of the pile until corrective measures are taken.

Gullying is occurring along the access road at the northwest corner of the site and at several spots along the northern perimeter. Depths of these gullies range from six inches to two to three feet. Numerous rills and gullies are present along the southwest edge of the pile.

Burrowing by prairie dog colonies is widespread, especially near the northwest corner of the site. This causes disruption and dispersion of the clay cap and contributes to erosion of the area. Wind gusts were observed dispersing materials brought to the surface in burrows during the on-site investigation.

Large-scale slump features are present at points along the steep bluffs on the south side of the river. A large slump area lies directly across the river from the site. Slumping of large volumes of material into the river could be a hazard to the site as it may result in redirecting flows toward the north.

Frost heave and solifluction are processes which pose a hazard to the long-term performance of any structure constructed to isolate the tailings at the site. Climatic conditions

at the site favor the occurrence of these processes in winter. Frost heave is the vertical displacement of matter in response to freezing. The process requires that adequate moisture be present to form ice lenses within a fine-grained soil. Growth of the ice lenses causes upward expansion, displacing the surface. In the tailings impoundment, ice lenses could form in the upper part of the radon attenuation layer. This process can be mitigated by using a radon attenuation layer that is sufficiently impermeable to prevent significant water penetration and an aggregate cover that is sufficiently porous to restrict water buildup over the clay. Solifluction is the slow flowage of saturated soils above frozen subsoils. The saturation prerequisite for this process can also be mitigated by using permeable aggregate and impermeable radon attenuation materials.

The average wind speed of about eight mph (NOAA, 1982) in the Grand Junction area would not pose a hazard to the site; however, gusting winds at speeds of 45 to 70 mph occur throughout the year. Proper selection of aggregate cover to mitigate gullyng and solifluction hazards will also mitigate this problem.

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ATTACHMENT E2

GEOMORPHIC EVALUATION

CHENEY RESERVOIR ALTERNATE SITE FOR DISPOSAL OF
GRAND JUNCTION URANIUM MILL TAILINGS

URANIUM MILL TAILINGS REMEDIAL ACTION PROJECT

AUGUST, 1985

PREFACE

The Uranium Mill Tailings Radiation Control Act of 1978, Public Law 95-604, 42 USC 7901, authorizes the U.S. Department of Energy (DOE) to undertake remedial actions at 24 DOE-designated processing sites. The Uranium Mill Tailings Remedial Action (UMTRA) Project Office of the DOE issued a Plan for Implementing EPA Standards for UMTRA Sites in January, 1984. In this report, under a section on long-term stability, the DOE stated that a design objective of 1000 years was established to be satisfied whenever reasonably achievable, but in any case with a minimum performance period of 200 years.

For the subject processing site, a remedial action plan is being developed to ensure the long-term stability of the proposed reclamation. This geomorphic evaluation report represents a portion of the site characterization efforts being completed. The major objective of this evaluation is to fully recognize which geomorphic processes may cause long-term changes at the existing disposal site or at alternate disposal areas. This report is provided as a reference document for use during the site selection process and/or design development of the remedial action plan.

This report was prepared by the Phoenix office of Sergeant, Hauskins & Beckwith Geotechnical Engineers, Inc., a part of the Jacobs-Weston Team, the UMTRA Project Technical Assistance Contractor to the DOE.

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E2.1 EXECUTIVE SUMMARY

Geomorphic studies were performed to characterize the long-term stability of a proposed alternate site for the stabilization of uranium mill tailings presently located in Grand Junction, Colorado. The proposed alternate site is near Cheney Reservoir, about 16 miles southeast of Grand Junction.

The site is on surficial deposits that rest on a pediment eroded into Cretaceous Mancos Shale on the west flank of Grand Mesa. These deposits consist of mixed alluvial and eolian sediments.

The site area appears to be relatively stable in geomorphic terms. Structures placed on the site should be set back a minimum of 0.1 to 0.2 mile from actively eroding gully systems to avoid problems of erosion.

Potential erosion or disturbance by frost heave, solifluction, wind, and sheet flow will be mitigated by proper design and selection of proper materials.

There is no evidence of mudflow or landslide activity in the site area.

E2.2 INTRODUCTION

E2.2.1 PURPOSE AND SCOPE OF INVESTIGATION

This report presents the findings of geomorphic studies performed in an area proposed as an alternate site for stabilization of uranium mill tailings presently located in Grand Junction, Colorado. The purpose of the investigation was to characterize the geomorphic conditions currently acting on the site area and to evaluate the potential for long-term stability of disposal facilities at the site. The site area is in T3S, R2E, Sections 11, 12, 13, and 14, about 16 miles southeast of Grand Junction (Figure E2.2.1).

The evaluation is restricted to the assessment of natural processes, such as eolian and fluvial erosion, and the potential for mudslides and landslides which could compromise the integrity of disposal facilities during the specified design life. The U.S. Environmental Protection Agency's (EPA) design life standard which regulates the design of disposal facilities involved in the Uranium Mill Tailings Remedial Action (UMTRA) Project states that engineered design and site selection processes developed during the program should result in containment structures which are capable of resisting natural intrusion for a period of at least 1000 years whenever reasonably achievable (DOE, 1984). A minimum longevity standard of 200 years is imposed whenever the 1000-year design life is found to be impractical.

E2.2.2 FIELD INVESTIGATION AND RESEARCH

This investigation involved field work and research into the pertinent aspects of the geologic history of the site region, geomorphic conditions at the site area, and estimations of the potential impact of geomorphic processes on the planned facility during the design life. The program of field work and research carried out for this study included the following:

- o Acquisition and review of aerial photography, published geologic mapping, and pertinent literature and data, including geotechnical data and previous reports developed during the UMTRA Project investigations.
- o Geologic and geomorphic field reconnaissance in the site region.

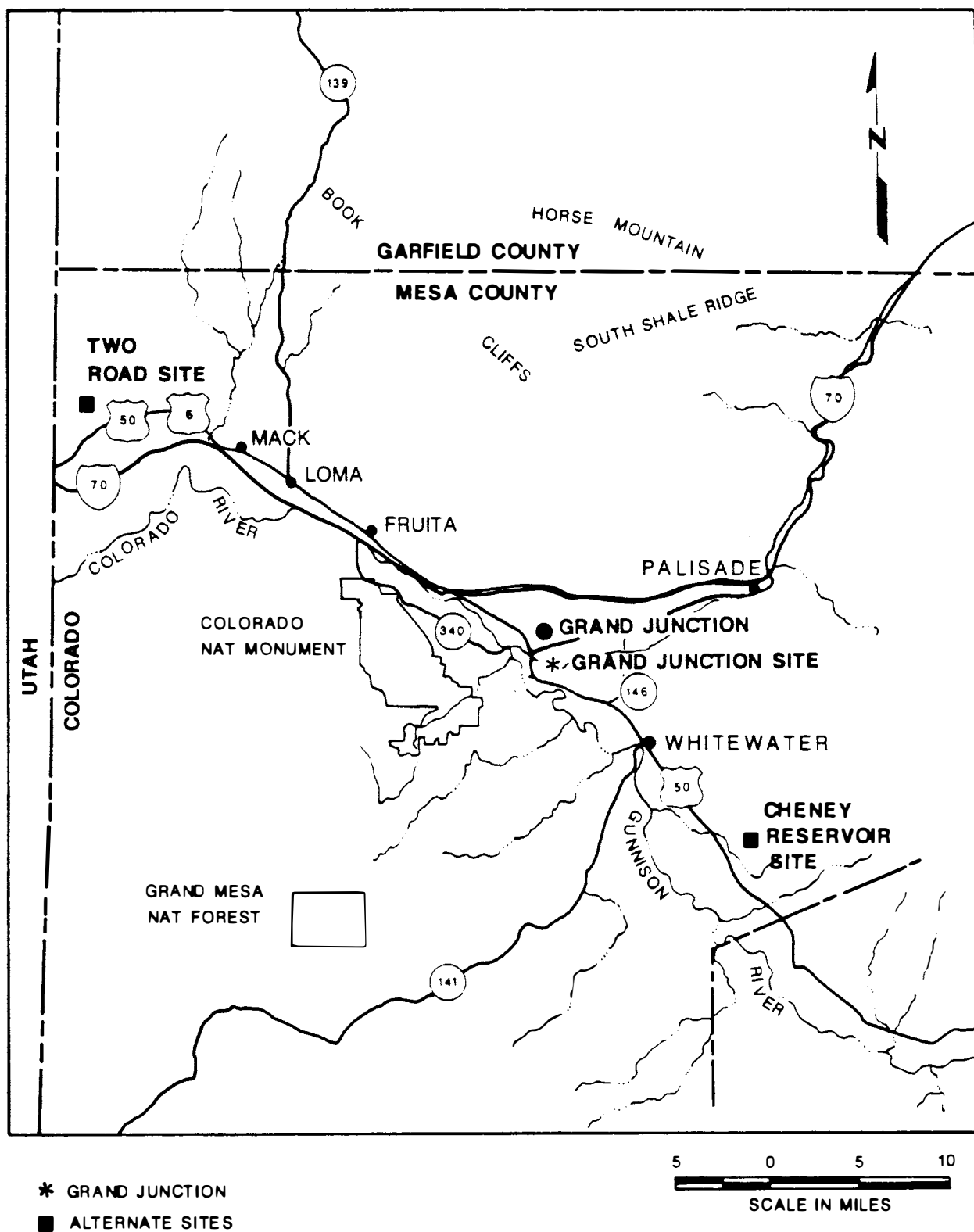


FIGURE E2.2.1
LOCATION OF DISPOSAL SITES

E2.3 REGIONAL SETTING

E2.3.1 PHYSICAL SETTING

The study area is in western Colorado, in the Canyon Lands section of the Colorado Plateau physiographic province (Hunt, 1967) (Figure E2.3.1). Structurally, the region is characterized by large upwarps and intervening basins affecting upper Paleozoic and lower Mesozoic sandstones and shales. The most prominent landforms are broad mesas and pediment surfaces, narrow rock-walled gullies, and deeply incised canyons of the Colorado River and its tributaries. The site is situated on the western slope of Grand Mesa, about five miles north of the Gunnison River.

Elevation in the site area ranges from about 5200 to 5400 feet. Northeast of the site, the elevation of Grand Mesa reaches a maximum of more than 11,000 feet. To the southwest, across the Gunnison River, the Uncompahgre Uplift, a large northwest-trending structural upwarp, reaches elevations of 9000 to 10,000 feet.

Annual precipitation at Grand Junction is eight to nine inches (NOAA, 1982) and is evenly distributed throughout the year. Precipitation in the higher elevations which form the headwaters of the Colorado River system is somewhat higher, ranging from 10 to 25 inches per year. Climatological data for western Colorado are summarized in Table E2.3.1.

The lower valley areas, such as the Grand Valley, are protected by surrounding higher terrain. They experience higher summer and winter temperatures than the higher terrain. A spring flood potential results from the melting of the snowpack at higher elevations.

Natural vegetation in the lower elevations consists of cottonwood, willow, desert shrub, and grass. Juniper, sagebrush, pine, oak, and Douglas fir are prominent at elevations of 5000 to 8000 feet. From 8000 feet to the timberline, vegetation consists of aspen, spruce, sub-alpine fir, lodgepole pine, grasses, and shrubs. Alpine willow, grasses, and sedges are found above the timberline.

E2.3.2 BEDROCK GEOLOGY

The Grand Junction region is in the northeastern portion of the Colorado Plateau, a major tectonic block composed of a core of Precambrian rock overlain by Paleozoic, Mesozoic, and Tertiary sedimentary rocks. The Paleozoic section is absent in the Grand Junction area due to uplift of the Uncompahgre Arch in Middle Pennsylvanian time, and Mesozoic units rest directly on the Precambrian. The total thickness of the Mesozoic section in the Grand Junction area is about 8000 feet (Lohman, 1965; Yeend, 1969). Thick Tertiary sections lie to the northwest and northeast in the Uinta and Piceance Basins, and basalt flows of Pliocene age cap Grand Mesa. Sedimentary units in the Grand Junction area dip to the northeast at about 250 feet per mile (Cashion, 1973).

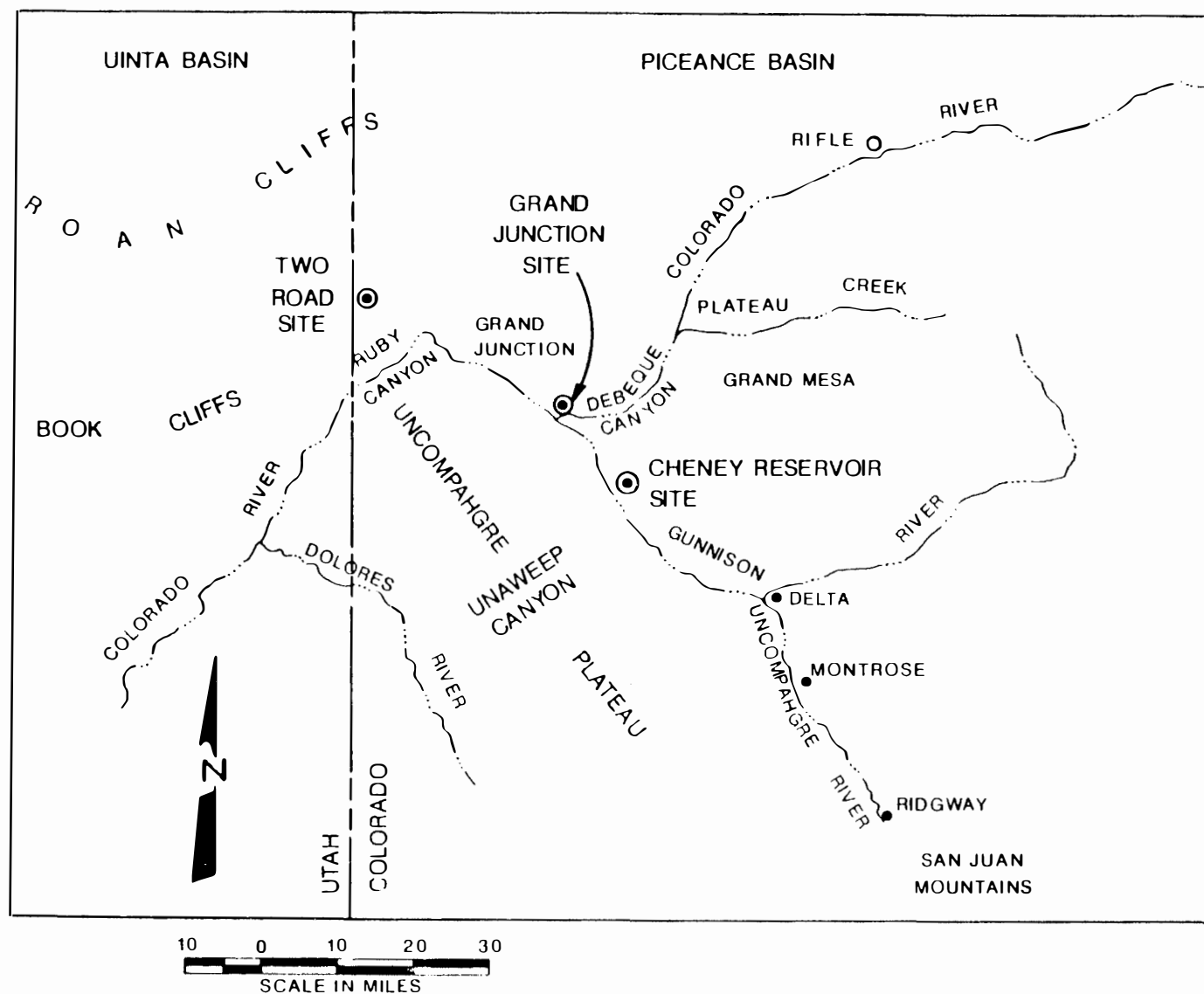


FIGURE E2.3.1
PHYSIOGRAPHIC SKETCH MAP OF GRAND JUNCTION REGION, SHOWING
LOCATIONS OF UETRA SITES AND FEATURES DISCUSSED IN TEXT

Table E2.3.1 Climatological data for western Colorado

	Month	Mean temp. °F	Precipitation (inches)
Station: Grand Junction Elevation: 4843 Period: 1975	January	26.6	0.64
	February	33.6	0.61
	March	41.2	0.75
	April	51.7	0.79
	May	62.2	0.63
	June	71.3	0.55
	July	78.7	0.46
	August	75.4	1.05
	September	67.2	0.84
	October	54.9	0.93
	November	39.8	0.61
	December	29.5	0.55
	Annual	52.7	8.41
Station: Cedaredge Elevation: 6180 Period: 1951-1973	January	27.5	0.81
	February	32.3	0.77
	March	38.5	0.86
	April	47.1	0.90
	May	57.0	0.96
	June	65.6	0.81
	July	71.9	0.89
	August	69.5	1.36
	September	61.6	1.20
	October	50.9	1.40
	November	37.5	0.94
	December	28.5	1.02
	Annual	49.0	11.92
Station: Cortez Elevation: 6177 Period: 1951-1973	January	27.7	0.97
	February	32.4	0.73
	March	38.3	0.93
	April	46.7	0.97
	May	56.2	0.94
	June	65.2	0.45
	July	72.1	1.13
	August	69.8	1.66
	September	62.0	1.14
	October	51.1	1.54
	November	38.1	0.89
	December	28.5	1.23
	Annual	49.0	12.58

Table E2.3.1 Climatological data for western Colorado (Concluded)

	Month	Mean temp. °F	Precipitation (inches)
Station: Gunnison Elevation: 7664 Period: 1951-1973	January	10.3	0.99
	February	15.1	0.88
	March	25.5	0.81
	April	37.9	0.71
	May	47.6	0.61
	June	56.0	0.54
	July	61.9	1.56
	August	59.7	1.57
	September	51.9	1.11
	October	42.2	0.90
	November	27.8	0.75
	December	13.8	0.97
	Annual	37.5	11.40
Station: Telluride Elevation: 8800 Period: 1951-1973	January	21.9	1.37
	February	23.6	1.47
	March	27.8	1.62
	April	36.7	1.95
	May	46.1	1.66
	June	54.1	1.08
	July	59.5	2.54
	August	57.7	2.85
	September	51.4	2.06
	October	43.0	2.07
	November	30.7	1.46
	December	22.8	1.66
	Annual	39.6	21.79

Ref. NOAA, 1982.

The major structural feature of the region is the Uncompahgre Uplift, a northeast-tilted block bounded on the southwest and on the northeastern flank near Grand Junction by abrupt, locally faulted monoclines (Lohman, 1965; Cater, 1966, 1970).

Grand Mesa and Battlement Mesa, which lie further to the north, are erosional remnants of a large Pliocene basalt plain (Yeend, 1969). This feature formerly extended over a much broader area. Uplift in the Late Tertiary caused streams to cut down through the basalt plain into underlying, less resistant sedimentary rocks of Early Tertiary to Late Cretaceous age. More than 5000 feet of downcutting has occurred since the uplift began, producing long, steep slopes, oversteepened cliffs, and narrow canyons.

The Cheney Reservoir site is underlain by sediments that rest on a pediment slope produced by erosion of the Cretaceous Mancos Shale on the lower slope of Grand Mesa.

E2.3.3 SURFICIAL GEOLOGY AND GEOMORPHOLOGY

E2.3.3.1 Regional geomorphic history

A number of geologists have investigated the development of drainage patterns, terraces, sediments, and glacial moraines in the Grand Valley region. The following discussion is excerpted from articles by Hunt (1956), Lohman (1965, 1981), Yeend (1969), and Sinnock (1981a,b).

Until perhaps Pliocene time, the Grand Junction area and adjacent parts of the Colorado Plateau were undergoing erosion by the ancestral Colorado River. The course of the Colorado River may have been established by the end of the Miocene. Differential uplift of the Uncompahgre Arch was renewed during the Pliocene, causing major changes in the drainage patterns of the Colorado and Gunnison Rivers.

Some disagreement exists between various investigators on the question of whether tectonic activity essentially stopped before or shortly after the end of the Tertiary, or has continued up to the present time. The evolution of the modern drainage systems is also controversial. For example, Lohman (1965, 1981) presented evidence that the ancestral Colorado and Gunnison Rivers once flowed through Unaweep Canyon and that the present pattern evolved from successive stages of stream piracy by tributary streams cutting Mancos Shale north and west of the Uncompahgre Arch. The more rapid rate of stream downcutting in the Mancos than in the Precambrian granitic terrain of the Uncompahgre Uplift was the determining factor. Sinnock (1981b), on the other hand, believes that Unaweep Canyon was formerly occupied by the Gunnison alone, and that the Colorado River has been in essentially the same position relative to the Uncompahgre Uplift since the Miocene. The diversion of the Gunnison away from Unaweep Canyon is attributed to successive stages of uplift of the Uncompahgre Arch.

The development of the present landforms of the river valleys was strongly influenced by Pleistocene glaciations. Sinnock (1981a) identified four sets of glacial moraines of Bull Lake (?) and Pinedale (?) age in the Ridgeway area. He correlated these with glacial episodes in the San Juan Mountains to the south. Evidence for successive periods of Pleistocene glaciation was also recognized on Grand and Battlement Mesas by Yeend (1969). The glacial stages can be correlated with alluvial terraces along the Uncompahgre, Gunnison, and Colorado Rivers. Episodes of significant erosion and incision of the rivers occurred during major readvances of the ice. A general equilibrium exists during interglacial periods. Hence, it appears that the level of the Colorado River near Grand Junction may have been fairly constant since the end of the Pleistocene.

Potassium-argon dating of the basalt flows capping Grand Mesa, about 5000 feet above the Colorado River, gives a Pliocene age of 9.7 plus or minus 0.485 million years (Yeend, 1969). Assuming that the basalt formerly covered the area now occupied by the river, an average rate of downcutting by the Colorado River of six inches per thousand years is obtained. This average rate includes downcutting during both glacial and interglacial stages, and the greater part of the downcutting will have occurred during the glacial intervals. There is some uncertainty related to the present rate of uplift of the Uncompahgre Arch, which may also affect rates of downcutting or cause aggradation. However, it is reasonable to assume that this value will not be greatly exceeded in the Grand Junction area during the design life of the proposed facility.

Landslides, slumps, and mudflows have greatly influenced the topography in the area flanking Grand Mesa. The presence of rapidly eroding sedimentary units beneath the durable basalts has been responsible for widespread mass wasting, particularly slumping. Extensive slumping of large blocks of basalt has greatly reduced the aerial extent of Grand Mesa throughout the Quaternary. Breakup of the basalt flows facilitated rapid removal of the high, originally more extensive surface of Grand Mesa by glacial and colluvial processes. Solifluction, slumping, frost breakup of basalt, landslides, and mudslides moved debris from the high parts of the mesa onto the surrounding slopes and stream valleys (Yeend, 1969).

Stream downcutting has been the dominant process since the disappearance of the last glacier at the close of the Pinedale (?) time.

E2.3.3.2 Surficial geology of the Grand Valley area

A surficial geologic map of the Grand Mesa area after Whitney (1981) and Williams (1964) is presented as Figure E2.3.2. Surficial deposits in the region range from Late Pliocene to Holocene in age.

Glacial tills of Bull Lake (?) and Pinedale (?) age (Late Pleistocene) cover the surface of Grand Mesa (Yeend, 1969). These are composed of unsorted material ranging from clay to boulders deposited by at least four episodes of Pleistocene glaciation. The thickness of these materials ranges from five to six feet to 75 feet.

Extensive landslide deposits of Pleistocene and Holocene age occur on the flanks of Grand and Battlement mesas and in the area west of DeBeque. These deposits are the result of slumping, rock and debris falls, rockslides, and solifluction movements. These movements occurred throughout the Pleistocene and are continuing today. A dominant factor in the formation of the landslides around Grand and Battlement Mesas is the presence of rapidly eroding claystones stratigraphically underlying durable basalt flows. The extreme jointing, abundant water, and common freezing temperatures are other important factors. Elsewhere, the presence of rapidly eroding early Tertiary sandstones, siltstones, and shales are major factors.

Residual deposits, developed from Late Pleistocene to Holocene weathering of the Mancos Shale, floor much of the Grand Valley. This material underlies younger alluvial, colluvial, and eolian deposits of the site area.

Surficial deposits of Late Pliocene to Pleistocene age occur adjacent to Grand and Battlement Mesas. These are coarse deposits of poorly sorted pebbles, cobbles, and boulders, commonly 15 to 30 feet thick (locally thicker). The gravel is composed largely of basalt. These deposits are probably debris flows associated with Pleistocene glaciation. Pediment deposits distinct from those described above are thin, discontinuous deposits of clayey silts, sand, and gravel, resulting from local flooding and slopewash. They range in age from Pleistocene to Holocene and are most common in areas underlain by Mancos Shale. These deposits are frequently mantled by a thin (three to six feet) cover of eolian silt and fine sand which may be strongly cemented by caliche. Caliche crusts on gravel and boulders are common.

Terraces occur at various elevations above the Colorado and Gunnison Rivers and Plateau Creek. They are underlain by gravels which range in age from Early to Late Pleistocene. The oldest gravels are from 30 to 450 feet above modern stream levels, and may be of pre-Bull Lake age.

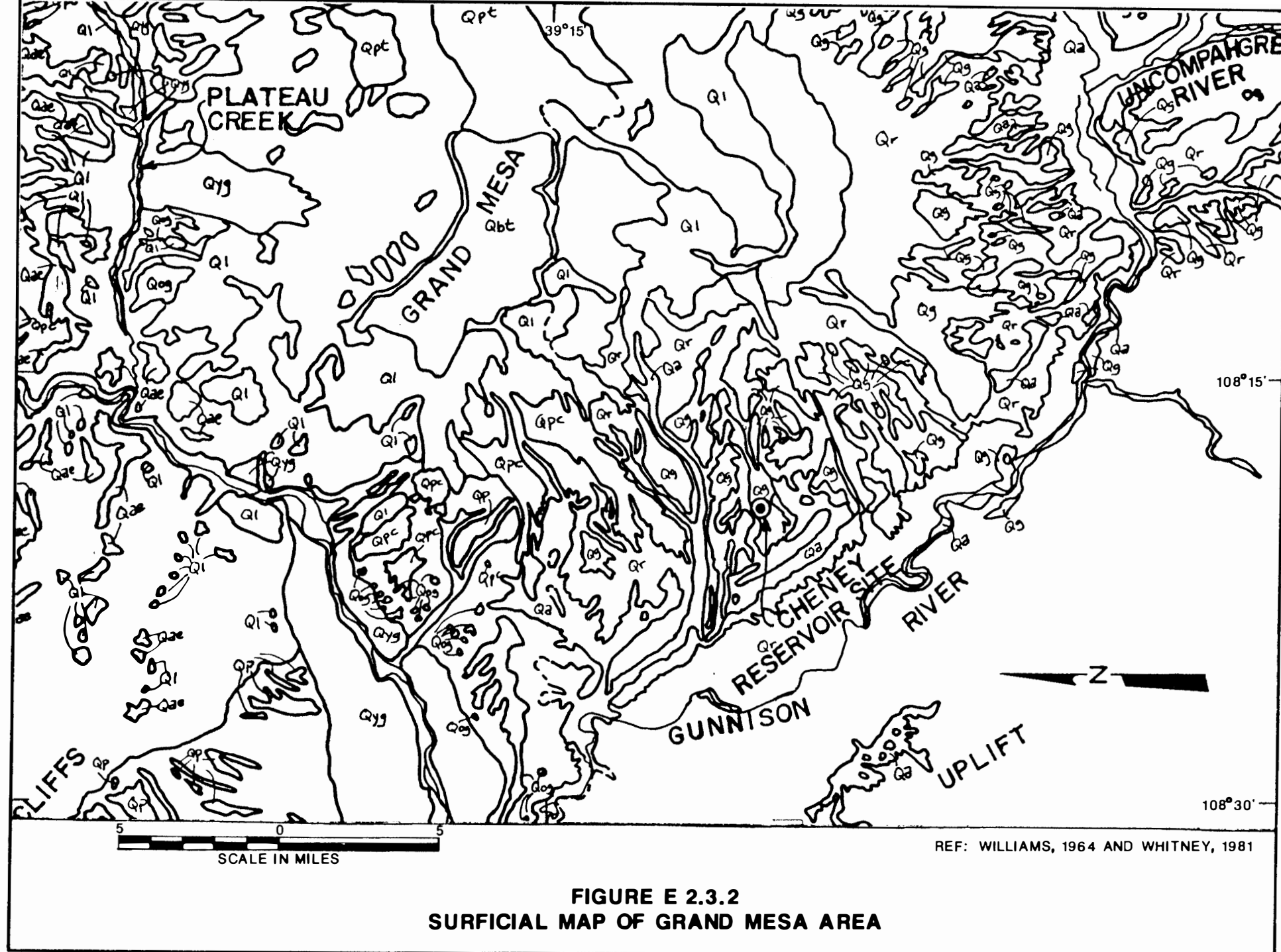


FIGURE E 2.3.2
SURFICIAL MAP OF GRAND MESA AREA

Figure E2.3.2 Surficial map of the Grand Mesa area (Concluded)

LEGEND

- Qa Alluvium (Holocene). Clay, silt, sand, and gravel deposits underlying modern floodplains.
- Qae Locally deposited sand and silt (Holocene to Late Pleistocene). Locally derived and reworked by eolian and fluvial processes.
- Qrg Reworked gravel (Holocene to Late Pleistocene).
- Qyg Young gravel (Late Pleistocene). Terrace gravels of Pinedale (?) and Bull Lake (?) age.
- Qog Older gravel (Middle to Early Pleistocene). Terraces and terrace remnants of pre-Bull Lake age.
- Qg Gravel (undifferentiated; Late Pleistocene to Early Pleistocene). Terraces and terrace remnants.
- Qp Pediment deposits (Holocene to Pleistocene).
- Qpc Colluvial deposits on pediments (Pleistocene to Late Pliocene).
- Qr Weathered shale (Holocene to Late Pleistocene). Residual soil formed on Mancos Shale.
- Ql Landslide deposits (Holocene and Pleistocene).
- Qpt Till of Pinedale (?) age (Late Pleistocene).
- Qbt Till of Bull Lake (?) age (Late Pleistocene).

Younger terraces correlated with Pinedale (?) and Bull Lake (?) glaciations (Yeend, 1969; Whitney, 1981; Sinnock, 1981) generally occur between 15 and 70 feet above the modern channels.

The modern floodplains are underlain by unconsolidated clay, silt, sand, and gravel deposits. These may reach thicknesses of 20 feet or more along the Colorado River.

E2.4 GEOMORPHIC EVALUATION OF CHENEY RESERVOIR SITE

E2.4.1 GEOLOGICAL DESCRIPTION

The Cheney Reservoir site is on an alluvial surface on the western flank of Grand Mesa. The area is characterized by gently-dipping, smooth slopes developed on Mancos Shale or bouldery debris flows and capped by eolian and fluvial deposits.

Exploratory boreholes advanced on the site as part of the UMTRA Project study (DOE, 1983) can be used to develop a generalized subsurface profile of the study area. The thickness of surficial deposits, composed of alluvial and eolian deposits and based on the logs of nine borings, ranges from 23.5 to 42 feet. A brown to reddish brown eolian silt, with some clay and sand and occasional gravel to boulder sized fragments of basalt, varies from zero to two to three feet at the surface. This material is underlain by interlayered clay, silt, sand, and gravel, with occasional layers of cobbles and boulders of basalt. This layer apparently represents mixed alluvial and debris-flow deposits. Surficial materials are underlain by the Mancos Shale, a gray shaly claystone with occasional thin beds of sandstone and limestone, which is greater than 400 feet thick. The Mancos and older units underlying it dip to the northeast at gradients of about 250 feet per mile (Williams, 1964; Cashion, 1973).

E2.4.2 GEOMORPHOLOGY OF SITE AREA

The site area is a gently rolling, sparsely vegetated surface underlain by alluvial and eolian deposits. Vegetation consists mainly of sagebrush and grass. The site area is presently used for grazing.

Basalt cobbles and boulders are common on the surface at the higher elevations above the site (above 5400 feet). The cobbles and boulders are in a finer-grained matrix of clay, silty sand, and gravel. The depth and extent of these deposits is unclear. They apparently were derived from mass wasting, colluvial processes, or possibly from ancient mudflows during erosion of Grand Mesa.

Proceeding downslope to the site area, the relative percentage of fine-grained material at the surface increases while gravels and cobbles are less common, though they may be present at depth. Soils at the surface are composed of strongly caliche-cemented sandy, clayey silt, which may be derived from eolian deposition and transport downslope by sheet wash. A thin veneer of basaltic lag gravels is common at the ground surface. Caliche coatings on basaltic gravel and cobbles are often overturned, indicating that some reworking of older gravels is occurring on the site at the present time. Bare soil patches and a thin veneer of basaltic lag gravels are common, indicating that erosion by wind and sheet wash are on-going processes.

Several ephemeral washes draining from the higher elevations are present on and near the site. Large boulders (eight to 10 feet in diameter) are present in some of the larger washes. The boulders probably

were deposited on or near the site by glacial streams or debris-flow processes, and evidently are not being transported at the present time. The washes on the site are occasionally incised to depths of five feet or more and some show steep banks indicative of rapid erosion. Structures placed on the site should be set back a minimum distance of 0.1 to 0.2 mile from steeper gullies to avoid problems of erosion or flooding during periods of heavy rain or rapid snowmelt.

The relatively smooth, undissected character of much of the site area, and the presence of fine-grained eolian materials at the surface indicate the site area is relatively stable at the present time. There is no evidence that mudslides or landslides are occurring under present conditions. Erosion by the ephemeral gullies on the site seems to be the major geomorphic hazard. This problem can be mitigated by proper design of disposal facilities and proper setbacks from actively eroding gully systems.

Frost heave and solifluction are processes which pose a hazard to the long-term performance of any structure constructed to isolate the tailings at the site. Climatic conditions at the site favor the occurrence of these processes in winter.

Frost heave is the vertical displacement of matter in response to freezing. The process requires that adequate moisture be present to form ice lenses within a fine-grained soil. Growth of the ice lenses causes upward expansion, displacing the surface. In the tailings impoundment, ice lenses could form in the upper part of the radon attenuation layer. This process can be mitigated by using a radon attenuation layer that is sufficiently impermeable to prevent significant water penetration and an aggregate cover that is sufficiently porous to restrict water buildup over the clay.

Solifluction is the slow flowage of saturated soils above frozen subsoils. The saturation prerequisite for this process can also be mitigated by using permeable aggregate and impermeable radon attenuation materials.

The average wind speed of about eight mph (NOAA, 1982) in the Grand Junction area would not pose a hazard to the site. Average wind velocities may be somewhat higher at the Cheney Reservoir site, and gusting winds at speeds of 45 to 70 mph may occur throughout the year. Proper selection of aggregate cover to mitigate gullying and solifluction hazards will also mitigate this problem.

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ATTACHMENT E3

GEOMORPHIC EVALUATION

TWO ROAD ALTERNATE SITE FOR DISPOSAL OF
GRAND JUNCTION
URANIUM MILL TAILINGS

URANIUM MILL TAILINGS REMEDIAL ACTION PROJECT

AUGUST, 1985

PREFACE

The Uranium Mill Tailings Radiation Control Act of 1978, Public Law 95-604, 42 USC 7901, authorizes the U.S. Department of Energy (DOE) to undertake remedial actions at 24 DOE-designated processing sites. The Uranium Mill Tailings Remedial Action (UMTRA) Project Office of the DOE issued a Plan for Implementing EPA Standards for UMTRA Sites in January, 1984. In this report, under a section on long-term stability, the DOE stated that a design objective of 1000 years was established to be satisfied whenever reasonably achievable, but in any case with a minimum performance period of 200 years.

For the subject processing site, a remedial action plan is being developed to ensure the long-term stability of the proposed reclamation. This geomorphic evaluation report represents a portion of the site characterization efforts being completed. The major objective of this evaluation is to fully recognize which geomorphic processes may cause long-term changes at the existing disposal site or at alternate disposal areas. This report is provided as a reference document for use during the site selection process and/or design development of the remedial action plan.

This report was prepared by the Phoenix office staff of Sergeant, Hauskins & Beckwith Geotechnical Engineers, Inc., a part of the Jacobs-Weston Team, the UMTRA Project Technical Assistance Contractor to the DOE.

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E3.1 EXECUTIVE SUMMARY

Geomorphic studies were performed to characterize the long-term stability of a potential alternate site for the disposal of uranium mill tailings presently located in Grand Junction, Colorado. The alternate site is on Two Road near the Colorado-Utah border, about 30 miles west of Grand Junction.

The site area is on a Pleistocene pediment surface that may be 50,000 years or more in age. The surface is a remnant of a formerly more widespread surface and is subject to erosion by gully systems advancing into it from the east and west. Geomorphic evidence indicates that the rate of erosion is slow and should not affect structures which are set back more than 0.1 mile from deeply incised gullies for the 1000-year design life.

Processes such as frost heave, solifluction movements, sheet wash, and wind are currently acting on the site surface. Proper design and selection of adequate materials will mitigate the erosional impact of these hazards.

E3.2 INTRODUCTION

E3.2.1 PURPOSE AND SCOPE OF INVESTIGATION

The purpose of this geomorphic investigation was to characterize the conditions currently acting on the site area, and to evaluate the long-term stability characteristics of disposal facilities at the site.

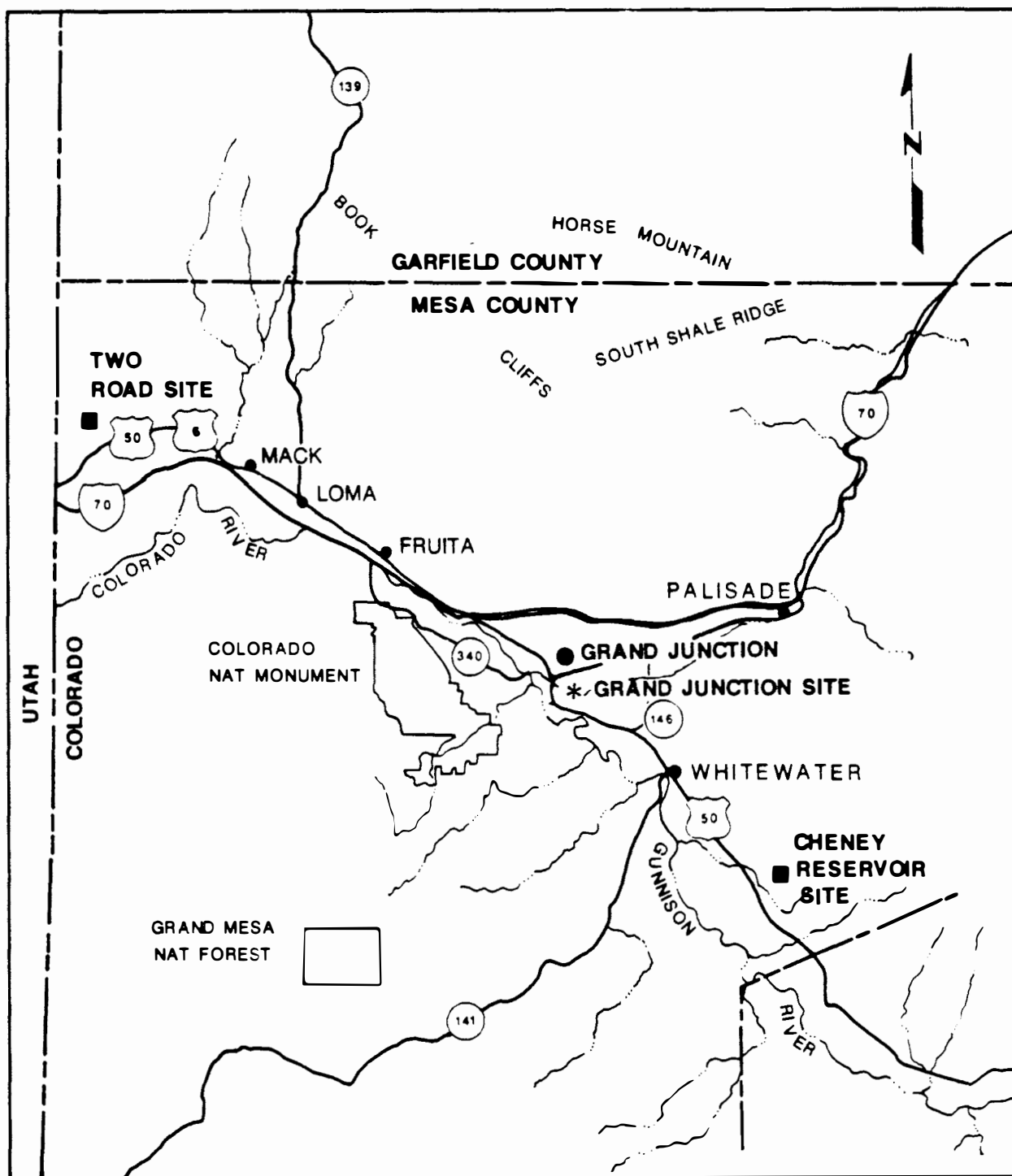
The site lies within about 0.5 mile of the Utah border and is crossed by Two Road. It is in R104W, T9S, Sections 7, 8, 17, 18, 19, 20, and 30 in western Colorado (Figure E3.2.1).

The evaluation is restricted to the assessment of natural processes, such as eolian and fluvial erosion, and the potential for landslides and mudslides, which could compromise the integrity of disposal facilities during the specified design life. The U.S. Environmental Protection Agency's (EPA) design life standard which regulates the designs of disposal facilities involved in the Uranium Mill Tailings Remedial Action (UMTRA) Project states that engineered design and site selection processes developed during the program should result in containment structures which are capable of resisting natural intrusion for a period of at least 1000 years whenever reasonably achievable (DOE, 1984). A minimum longevity standard of 200 years is imposed whenever the 1000-year design life is found to be impractical.

E3.2.2 FIELD INVESTIGATION AND RESEARCH

This investigation involved field work and research into the pertinent aspects of the geologic history of the site region, geomorphic conditions at the site area, and estimations of the potential impact of geomorphic processes on the planned facility during the design life. The program of field work and research carried out for this study included the following:

- o Acquisition and review of aerial photography, published geologic mapping, and pertinent literature and data, including geotechnical data and previous reports developed during UMTRA Project investigations.
- o Review of a previous geotechnical investigation (Golder Associates, 1983) carried out in the site area for a separate project.
- o Geologic and geomorphic field reconnaissance in the site region.



- * GRAND JUNCTION
- ALTERNATE SITES

FIGURE E3.2.1
LOCATION OF DISPOSAL SITES

E3.3 REGIONAL SETTING

E3.3.1 PHYSICAL SETTING

The study area is in western Colorado in the Canyon Lands section of the Colorado Plateau physiographic province (Hunt, 1967) (Figure E3.3.1). Structurally, this region is characterized by large upwards and intervening basins affecting upper Paleozoic and lower Mesozoic sandstones and shales. The most prominent landforms are broad mesas and pediment surfaces, narrow rock-walled gullies, and deeply incised canyons of the Colorado River and its tributaries. The Colorado River makes an abrupt bend from northeast to southwest about six miles east of the site and cuts across the trend of the Uncompahgre Uplift in Ruby Canyon.

The site is situated in an area of moderate relief in Grand Valley about 28 miles (45 km) west of the existing tailings site at Grand Junction. Elevations at the site range from about 4830 to 4960 feet. To the southwest the Uncompahgre Uplift, a large northwest-trending plateau uplift, reaches elevations of 9000 to 10,000 feet. The Book Cliffs border Grand Valley on the north, reaching elevations of 7000 to 8000 feet.

Annual precipitation at Grand Junction is eight to nine inches (NOAA, 1982) and is evenly distributed throughout the year (Table E3.3.1). Precipitation in the higher elevations which form the headwaters of the Colorado River system is somewhat higher, ranging from 10 to 25 inches per year. Climatological data for western Colorado are summarized in Table E3.3.1.

The lower valley areas, such as the Grand Valley, are protected by surrounding higher terrain. They experience higher summer temperatures and less extreme cold during the winter months. A spring flood potential results from the melting of the snowpack at higher elevations.

Natural vegetation in the lower elevations consists of cottonwood, willow, desert shrub, and grass. Juniper, sagebrush, pine, oak, and Douglas fir are prominent at elevations of 5000 to 8000 feet. From 8000 feet to the timberline, vegetation consists of aspen, spruce, sub-alpine fir, lodgepole pine, grasses, and shrubs. Alpine willow, grasses, and sedges are found above the timberline.

E3.3.2 BEDROCK GEOLOGY

The site region is situated in the northeastern portion of the Colorado Plateau, a major tectonic block composed of a core of Precambrian igneous and metamorphic rock overlain by Paleozoic, Mesozoic, and Tertiary sediments. The Paleozoic section is entirely absent in the Grand Junction area due to uplift of the Uncompahgre Arch in Middle Pennsylvania time, and Mesozoic units rest directly on the Precambrian. The total thickness of the Mesozoic section in the Grand Junction region is about 8000 feet (Lohman, 1965; Yeend, 1969). Thick Tertiary sections lie to the northwest and northeast in the Uinta and Piceance Basins. Basalt flows of Pliocene age cap Grand Mesa, east of Grand Junction.

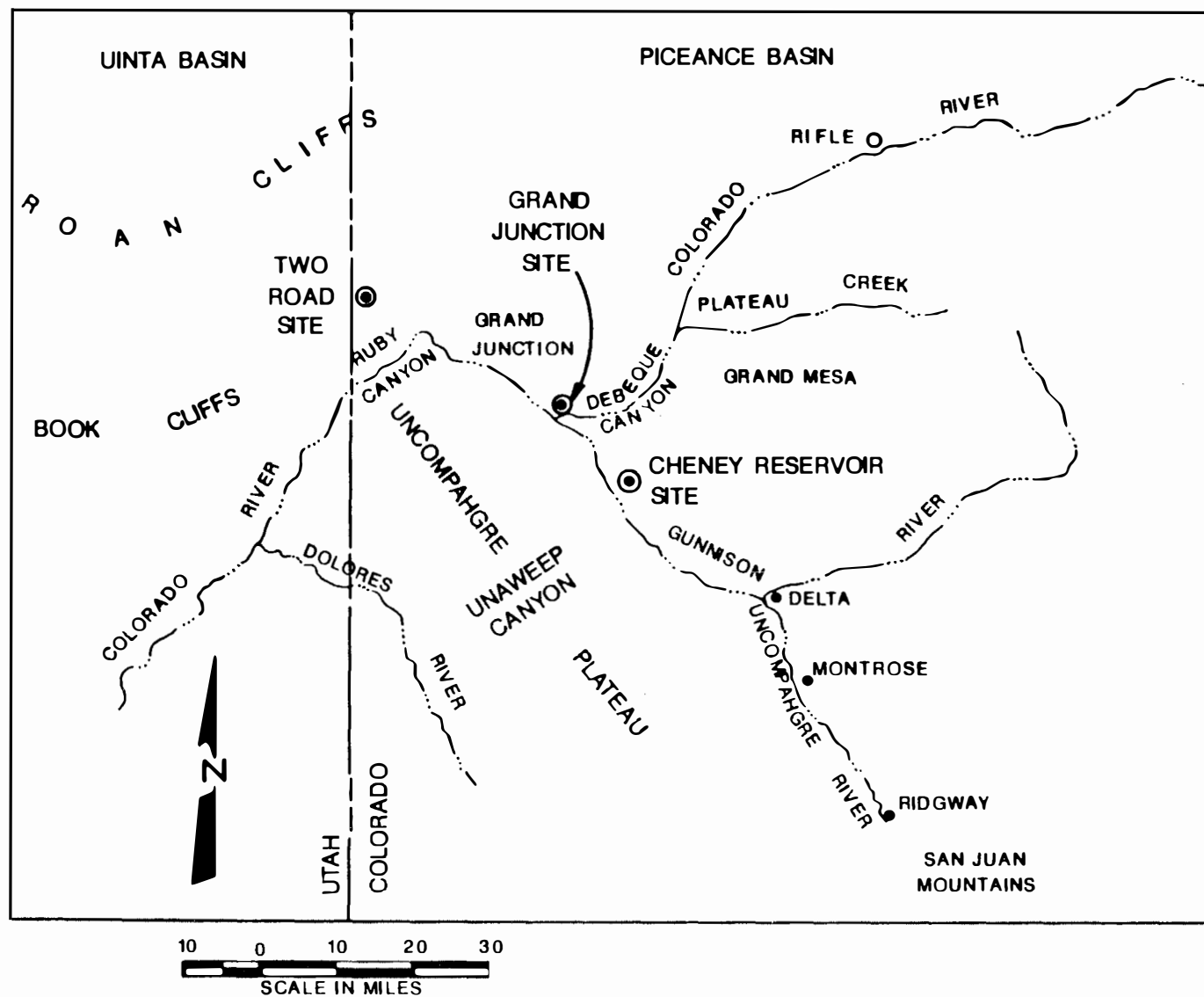


FIGURE E3.3.1
PHYSIOGRAPHIC SKETCH MAP OF GRAND JUNCTION REGION, SHOWING
LOCATIONS OF UMTRA SITES AND FEATURES DISCUSSED IN TEXT

Table E3.3.1 Climatological data for western Colorado

	Month	Mean temp. °F	Precipitation (inches)
Station: Grand Junction Elevation: 4843 Period: 1975	January	26.6	0.64
	February	33.6	0.61
	March	41.2	0.75
	April	51.7	0.79
	May	62.2	0.63
	June	71.3	0.55
	July	78.7	0.46
	August	75.4	1.05
	September	67.2	0.84
	October	54.9	0.93
	November	39.8	0.61
	December	29.5	0.55
	Annual	52.7	8.41
Station: Cedaredge Elevation: 6180 Period: 1951-1973	January	27.5	0.81
	February	32.3	0.77
	March	38.5	0.86
	April	47.1	0.90
	May	57.0	0.96
	June	65.6	0.81
	July	71.9	0.89
	August	69.5	1.36
	September	61.6	1.20
	October	50.9	1.40
	November	37.5	0.94
	December	28.5	1.02
	Annual	49.0	11.92
Station: Cortez Elevation: 6177 Period: 1951-1973	January	27.7	0.97
	February	32.4	0.73
	March	38.3	0.93
	April	46.7	0.97
	May	56.2	0.94
	June	65.2	0.45
	July	72.1	1.13
	August	69.8	1.66
	September	62.0	1.14
	October	51.1	1.54
	November	38.1	0.89
	December	28.5	1.23
	Annual	49.0	12.58

Table E3.3.1 Climatological data for western Colorado (Concluded)

	Month	Mean temp. °F	Precipitation (inches)
Station: Gunnison Elevation: 7664 Period: 1951-1973	January	10.3	0.99
	February	15.1	0.88
	March	25.5	0.81
	April	37.9	0.71
	May	47.6	0.61
	June	56.0	0.54
	July	61.9	1.56
	August	59.7	1.57
	September	51.9	1.11
	October	42.2	0.90
	November	27.8	0.75
	December	13.8	0.97
	Annual	37.5	11.40
Station: Telluride Elevation: 8800 Period: 1951-1973	January	21.9	1.37
	February	23.6	1.47
	March	27.8	1.62
	April	36.7	1.95
	May	46.1	1.66
	June	54.1	1.08
	July	59.5	2.54
	August	57.7	2.85
	September	51.4	2.06
	October	43.0	2.07
	November	30.7	1.46
	December	22.8	1.66
	Annual	39.6	21.79

Ref. NOAA, 1982.

The Two Road site is on the axis of the northwest-trending Bar X Anticline (Cashion, 1973), which lies along the extension of the northeast flank of the Uncompahgre Uplift. Bedrock underlying the site area consists of the Cretaceous Mancos Shale, dipping to the northeast and northwest at gradients of 250 to 350 feet per mile. The site is on surficial deposits that rest on a pediment formed on the Mancos Shale.

E3.3.3 SURFICIAL GEOLOGY AND GEOMORPHOLOGY

E3.3.3.1 Regional geomorphic history

A number of geologists have investigated the development of drainage patterns, terraces, sediments, and glacial moraines in the Grand Valley region. The following discussion is excerpted from articles by Hunt (1956), Lohman (1965, 1981), Yeend (1969), and Sinnock (1981a, b).

Until perhaps Pliocene time, the Grand Junction area and adjacent parts of the Colorado Plateau were undergoing erosion by the ancestral Colorado River. The course of the Colorado River may have been established by the end of the Miocene. Differential uplift of the Uncompahgre Arch was renewed during the Pliocene, causing major changes in the drainage pattern of the Colorado and Gunnison Rivers.

Some disagreement exists between various investigators on the question of whether tectonic activity essentially stopped before or shortly after the end of the Tertiary, or has continued up to the present time. The evolution of the modern drainage systems is also controversial. For example, Lohman (1965, 1981) presented evidence that the ancestral Colorado and Gunnison Rivers once flowed through Unaweep Canyon and that the present pattern evolved from successive stages of stream piracy by tributary streams cutting Mancos Shale north and west of the Uncompahgre Arch. The more rapid rate of stream downcutting in the Mancos than in the Precambrian granitic terrain of the Uncompahgre Uplift was the determining factor. Sinnock (1981b), on the other hand, believes that Unaweep Canyon was formerly occupied by the Gunnison alone, and that the Colorado River has been in essentially the same position relative to the Uncompahgre Uplift since the Miocene. The diversion of the Gunnison away from Unaweep Canyon is attributed to successive stages of uplift of the Uncompahgre Arch.

The development of the present landforms of the river valleys was strongly influenced by Pleistocene glaciations. Sinnock (1981a) identified four sets of glacial moraines of Bull Lake (?) and Pinedale (?) age in the Ridgeway area. These were correlated with glacial episodes in the San Juan Mountains to the south. Evidence for successive periods of Pleistocene glaciation were also recognized on Grand and Battlement Mesas by Yeend (1969). The glacial stages can be correlated with alluvial terraces along the Uncompahgre, Gunnison, and Colorado Rivers. Episodes of significant

erosion and incision of the rivers occurred during major readvances of the ice. At glacial minima and during interglacial periods, a general equilibrium exists. Hence, it appears that the level of the Colorado River in the Grand Junction region may have been fairly constant since the end of the Pleistocene.

Potassium-argon dating of the basalt flows capping Grand Mesa, about 5000 feet above the Colorado River, gives a Pliocene age of 9.7 plus or minus 0.485 million years (Yeend, 1969). Assuming that the basalt formerly covered the area now occupied by the river, an average rate of downcutting by the Colorado River of six inches per thousand years is obtained. This average rate includes downcutting during both glacial and interglacial stages, and the greater part of the downcutting probably will have occurred during the glacial intervals. There is some uncertainty related to the present rate of uplift of the Uncompahgre Arch, which may also affect rates of downcutting or cause aggradation. However, it is reasonable to assume that this value will not be greatly exceeded in the site region during the design life of the proposed facility.

E3.3.3.2 Surficial geology of the Grand Valley area

A surficial geologic map of the Grand Valley area was prepared by Whitney (1981). A portion of that map is presented as Figure E3.3.2.

Surficial deposits in the region range from Late Pliocene to Holocene in age. Glacial tills of Bull Lake (?) and Pinedale (?) age (Late Pleistocene) cover the surface of Grand Mesa (Yeend, 1969). These are composed of unsorted material ranging from clay to boulders deposited by at least four episodes of Pleistocene glaciation. The thicknesses of these materials range from a few meters to 25 meters.

Extensive landslide deposits of Pleistocene and Holocene age occur on the flanks of Grand and Battlement Mesas and in the area west of DeBeque. These deposits are the result of slumping, rock and debris falls, rockslides, and solifluction movements. These movements occurred throughout the Pleistocene and are continuing today.

Residual deposits, developed from Late Pleistocene to Holocene weathering of the Mancos Shale, floor much of the Grand Valley. The thickness of the clayey residuum generally varies from one to six feet.

Surficial deposits of Late Pliocene to Pleistocene age adjacent to Grand and Battlement Mesas are coarse deposits of poorly sorted pebbles, cobbles, and boulders, commonly 15 to 30 feet thick (locally thicker). The gravel is composed largely of basalt. These deposits are probably debris flows associated with Pleistocene glaciation.

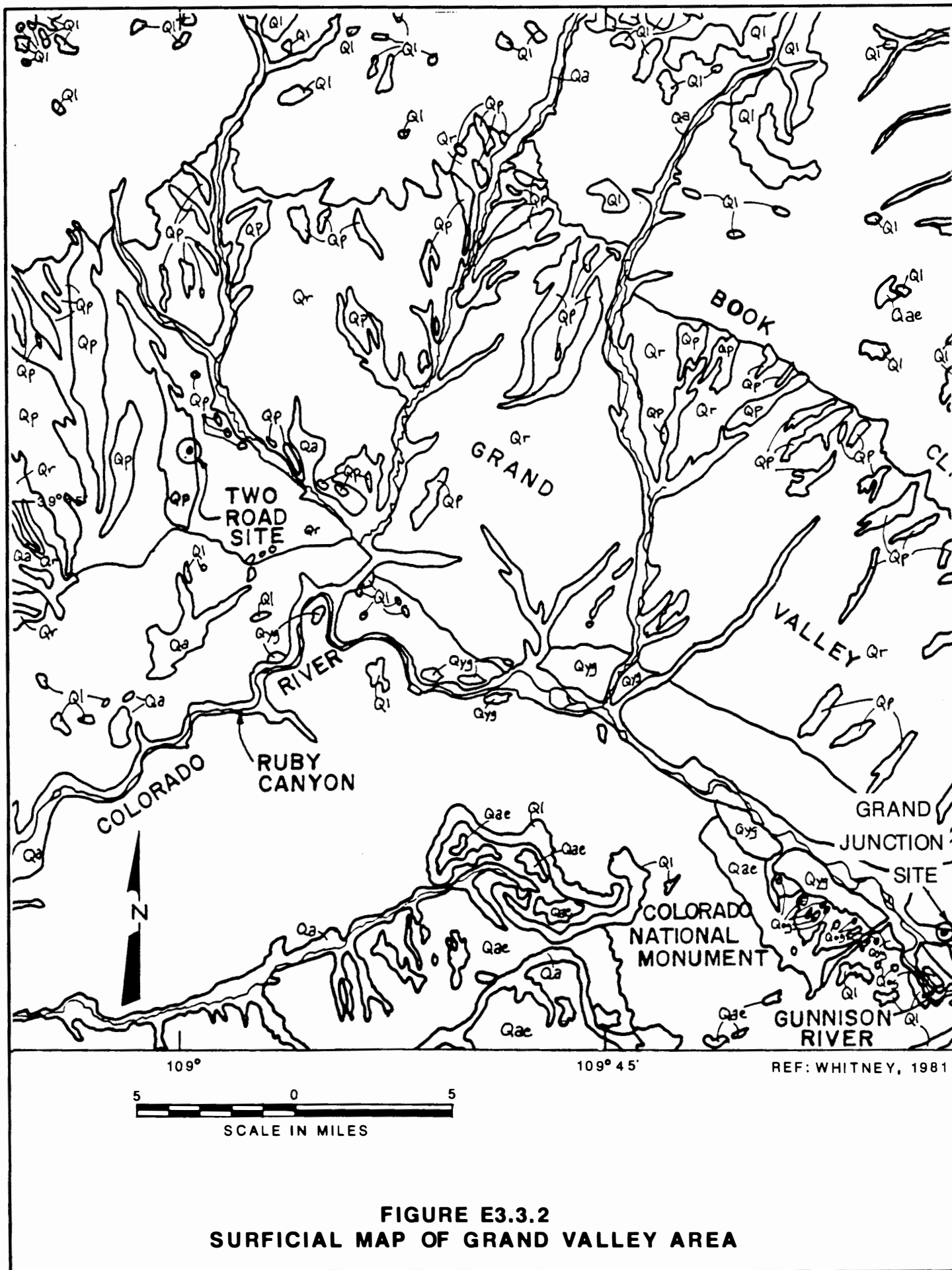


Figure E3.3.2 Surficial map of Grand Valley area
(Concluded)

LEGEND

Qa	Alluvium (Holocene). Clay, silt, sand, and gravel deposits underlying modern floodplains.
Qae	Locally deposited sand and silt (Holocene to Late Pleistocene). Locally derived and reworked by eolian and fluvial processes.
Qrg	Reworked gravel (Holocene to Late Pleistocene).
Qyg	Young gravel (Late Pleistocene). Terrace gravels of Pinedale (?) and Bull Lake (?) age.
Qog	Older gravel (Middle to Early Pleistocene). Terraces and terrace remnants of pre-Bull Lake age.
Qg	Gravel (undifferentiated; Late Pleistocene to Early Pleistocene). Terraces and terrace remnants.
Qp	Pediment deposits (Holocene to Pleistocene).
Qpc	Colluvial deposits on pediments (Pleistocene to Late Pleistocene).
Qr	Weathered shale (Holocene to Late Pleistocene). Residual soil formed on Mancos Shale.
Ql	Landslide deposits (Holocene and Pleistocene).
Qpt	Till of Pinedale (?) age (Late Pleistocene).
Qbt	Till of Bull Lake (?) age (Late Pleistocene).

Pediment deposits distinct from those described above are thin, discontinuous deposits of clayey silts, sand, and gravel, resulting from local flooding and slopewash. They range in age from Pleistocene to Holocene and are most common in areas underlain by Mancos Shale. These deposits are frequently mantled by a thin (three to six feet) cover of eolian silt and fine sand which may be strongly cemented by caliche.

Terraces occur at various elevations above the Colorado and Gunnison Rivers and Plateau Creek. They are underlain by gravels which range in age from Early to Late Pleistocene. The oldest gravels occur from 30 to 450 feet above modern stream levels, and may be of pre-Bull Lake age. Younger terraces correlated with Pinedale (?) and Bull Lake (?) glaciations (Yeend, 1969; Whitney, 1981; Sinnock, 1981a) generally occur between 18 and 70 feet above the modern channels.

The modern floodplains are underlain by unconsolidated clay, silt, sand, and gravel deposits. These may reach thicknesses of 20 feet or more along the Colorado River.

E3.4 GEOMORPHIC EVALUATION OF THE TWO ROAD SITE

E3.4.1 GEOLOGICAL DESCRIPTION

The site is on an alluvial surface formed by erosion of the Cretaceous Mancos Shale. The dominant surficial materials present in the site area are residual soils formed by weathering of the Mancos, gravels, and eolian deposits.

The subsurface profile, based on logs of exploratory boreholes and test pits on the site, consists of the following:

- o A surface layer of eolian deposits. This layer consists of clayey silt and fine sand which is deposited by wind and re-worked by solifluction, sheet wash, and intermittent flow in gullies. The thickness of this layer varies from about one foot to five or six feet in the site area.
- o Surficial deposits. This layer generally consists of inter-layered sand and gravelly sand, with occasional gravel lenses. This material is derived from erosion of Cretaceous and Tertiary sandstone and shale units of the Book Cliffs to the north and west of the site. This unit ranges from about 15 to 25 feet in thickness across the site, and may extend to depths of 30 feet or more. It is generally very strongly cemented by caliche.
- o Mancos Shale. Gray to olive or black marine shale with occasional beds of sandstone and limestone. In the site area, the Mancos varies from 500 to 1400 feet in thickness and the upper 10 to 20 feet are highly weathered, forming a residual soil in places.

E3.4.2 GEOMORPHOLOGY OF THE SITE AREA

The site is on a low ridge that is a remnant of a formerly more widespread surface. The age of this surface is not precisely known. However, exposures of gravels in a pit east of the site and in test pits on the site are strongly cemented by caliche and display a well-developed argillic B horizon. In comparison with other locations (Shroba and Birkeland, 1983), this degree of soil development suggests that the surface may be Late Pleistocene. The surface of the site is gently rolling, and covered by short grasses and shrubs. Deeply incised gullies are not present at the site, but flank it on the east and west (Figure E3.4.1).

E3.4.2.1 Rates of slope retreat

Measurements of hillslope erosion on the Mancos Shale near Grand Junction were made by Schumm and Chorley (1966). The upper portions of these slopes were lowered about 0.25 inch during four years. Seasonal frost action and downslope

creep of surficial soil aggregate were found to be the dominant courses of slope retreat.

Assuming the measured rate of erosion of 0.25 inch during four years to be broadly representative, a net lowering of slopes on Mancos Shale of 0.0625 inch per year, or approximately five feet per 1000 years, is obtained. Slopes in the site area are capped by more resistant, caliche-cemented gravels, which are more resistant than the Mancos Shale. Hence, the rate of slope retreat (excluding erosion by gully systems) will be negligible during the design life.

E3.4.2.2 Erosion by gully systems

Due to the narrow highland character of the site, it is subject to erosion by gully systems advancing headward into the site area from all sides. The surface of the site is supported by the resistant pediment gravels which cap the Mancos Shale. Erosion occurs along slopes where the less resistant Mancos Shale is exposed.

The rate of erosion of this surface is a very slow process and should not pose a serious threat to the proposed facility during the 1000-year design life. Gullies on the site are characterized by very gentle, grassy slopes and lack deeply incised channels. The incision of the deeper washes flanking the site is caused by intermittent streams draining from the Book Cliffs to the north. Subsidiary gully systems advancing into the site area from these washes are shallow and have gentle slopes, indicating a lack of rapid erosion by surface waters derived on the site. The dominant erosion processes currently acting on the site surface are sheet wash, wind, and solifluction movements. Assuming the site surface to be Late Pleistocene in age, and on the order of 50,000 years old, and a maximum gully advance of about 0.5 mile into the site area (the length of the largest gully advancing into the site from the east side), gives a rate of gully encroachment of about 0.1 mile per 10,000 years, or 0.01 mile per 1000 years. This is only a rough estimate; however, it seems reasonable to assume that rates of this order of magnitude will prevail in the site area during the 1000-year design life. Setting back the proposed facilities a minimum distance of 0.1 to 0.2 mile from the steep slopes bordering the site, or armoring the slopes with riprap, should provide adequate protection from erosion by natural processes of slope retreat. Care should be taken during excavation and construction that facilities are not placed on or near unprotected slopes underlain by Mancos Shale.

E3.4.2.3 Minor processes

Examination of the site surface indicates that significant erosion is not taking place at the present time.

Deposition of eolian silt and fine sand, and secondary redistribution of this material by frost heave and solifluction movements, sheet wash, and other processes are dominant on the site surface.

Frost heave and solifluction are processes which pose a hazard to the long-term performance of any structure constructed to isolate the tailings at the site. Climatic conditions at the site favor the occurrence of these processes in winter.

Frost heave is the vertical displacement of matter in response to freezing. The process requires that adequate moisture be present to form ice lenses within a fine-grained soil. Growth of the ice lenses causes upward expansion, displacing the surface. In the tailings impoundment, ice lenses could form in the upper part of the radon attenuation layer. This process can be mitigated by using a radon attenuation layer that is sufficiently impermeable to prevent significant water penetration and an aggregate cover that is sufficiently porous to restrict water buildup over the clay.

Solifluction is the slow flowage of saturated soils above frozen subsoils. The saturation prerequisite for this process can also be mitigated by using permeable aggregate and impermeable radon attenuation materials.

The average wind speed of about eight mph (NOAA, 1982) in the Grand Junction area would not pose a hazard to the site; however, gusting winds at speeds of 45 to 70 mph occur throughout the year. Proper selection of aggregate cover to mitigate gullyng and solifluction hazards will also mitigate this problem.

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ATTACHMENT E4
SEISMIC RISK EVALUATION
GRAND JUNCTION, COLORADO, AREA
URANIUM MILL TAILINGS REMEDIAL ACTION PROJECT
AUGUST, 1985

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E4.1 EXECUTIVE SUMMARY

A seismic hazard study of the Grand Junction, Colorado, area was undertaken as a part of an assessment of the long-term stability of an existing uranium mill tailings pile and two alternate disposal sites.

The sites are located within a few miles of the northeastern flank of the Uncompahgre Uplift. Several potentially active faults have been identified within this system. Locations of historical earthquake epicenters indicate that some faults may be active.

The occurrences of estimated Maximum Credible Earthquakes (MCEs) on known faults within this system could produce accelerations as high as 0.34g at the Grand Junction and Cheney Reservoir sites. Calculated accelerations at the Two Road site are lower, ranging up to approximately 0.18g. Higher accelerations may result from the occurrence of earthquakes of magnitude as high as 6.6 on previously unknown faults within less than five miles of the sites.

There is no direct evidence of any potential for on-site fault rupture at any of the sites. However, the possibility cannot be ruled out completely, especially at the existing Grand Junction site.

The potential for seismically-induced liquefaction is remote at the Two Road and Cheney Reservoir sites but cannot be ruled out at the Grand Junction site.

E4.2 INTRODUCTION

E4.2.1 LOCATION AND PURPOSE OF STUDY

This report presents the findings of a seismic hazard evaluation study of the Grand Junction, Colorado, area. The study was undertaken as a part of an assessment of the long-term stability of an existing uranium mill tailings pile in the city of Grand Junction and two alternate disposal sites located at Cheney Reservoir and Two Road, as shown in Figure E4.2.1.

The U.S. Environmental Protection Agency (EPA) issued standards for the remedial action of all sites involved in the Uranium Mill Tailings Remedial Action (UMTRA) Project. The EPA design-life standard requires that engineered design and site selection processes developed during the program should ultimately result in containment structures that are capable of resisting natural intrusion for a period of at least 1000 years after reclamation (DOE, 1984). The design-life objective of 1000 years is to be met whenever reasonably achievable. The minimum longevity standard is 200 years. The intent of the EPA standards is to design the construction of isolation structures which will perform satisfactorily with a minimum amount of custodial maintenance, monitoring, and use of contingency response measures.

For the purposes of this study, seismic risk is defined as the potential for damage to uranium mill tailings disposal facilities during the EPA-designated design life caused by:

- o On-site ground motions.
- o On-site fault rupture.
- o Liquefaction-induced ground failure.

E4.2.2 SCOPE OF WORK

The seismic characterization developed for this study is based on a review and interpretation of published geological, seismological, and geophysical literature, geologic and geomorphic field investigations, and analysis of the historical earthquake record.

For the purposes of this study, an active fault is defined as one that has had displacement during the present seismotectonic regime and may, therefore, have renewed displacement in the future. The fault activity may be indicated by historical, geological, seismological, geomorphic, or geodetic evidence. The duration of the present seismotectonic regime is difficult to define precisely, especially in a region of relatively low activity such as the area of the present study. The most widely used definition of an active fault in current engineering practice is a fault with evidence of Holocene displacement (approximately the last 10,000 to 12,000 years) and the term is used herein in that sense. Faults or fault systems which show evidence of recurrent movements during the late Quaternary (approximately the last 500,000 years) will be referred to as potentially active faults.

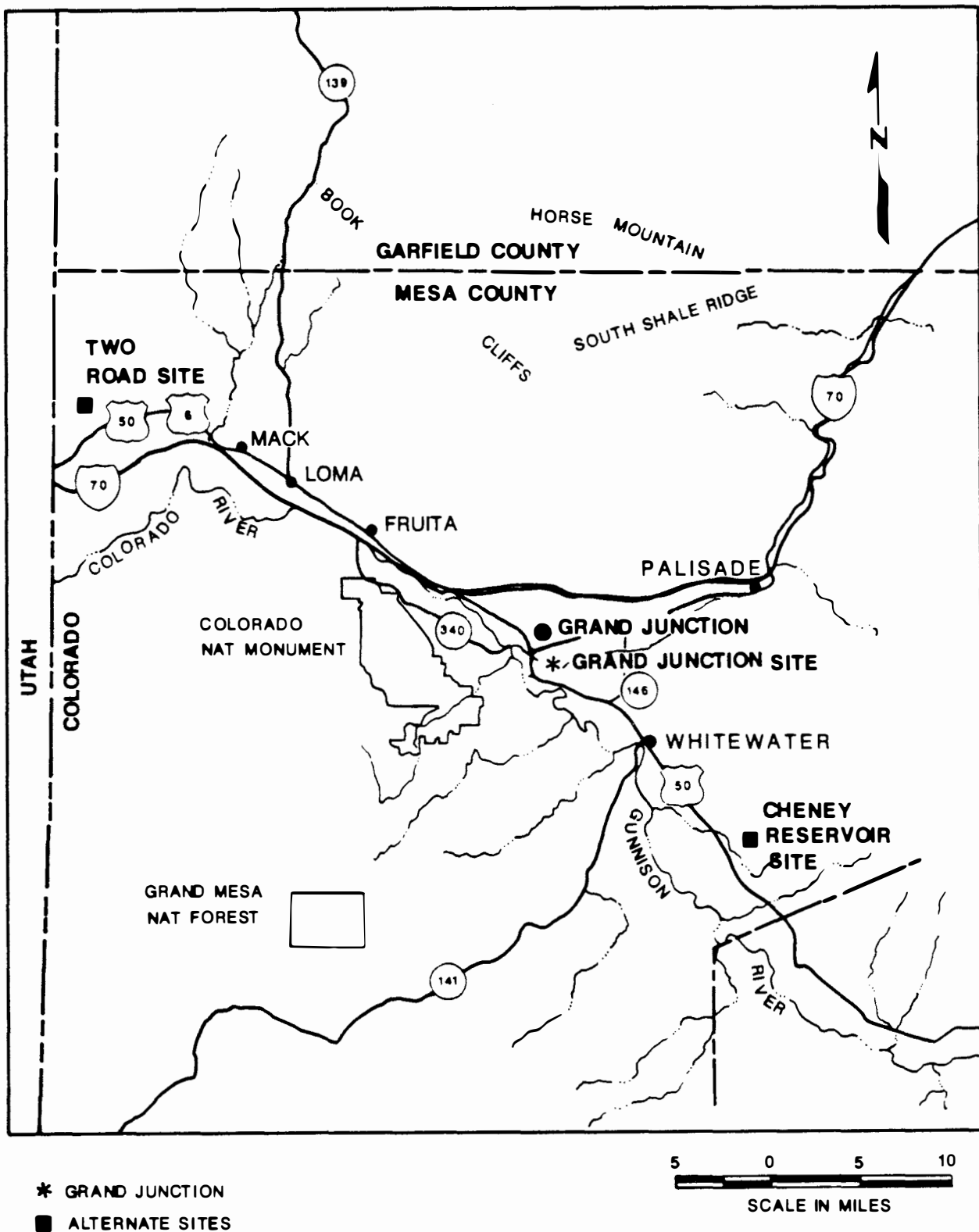


**FIGURE E4.2.1
LOCATION OF DISPOSAL SITES**

Recurrence intervals of seismic activity in the site region are not known, so the probability that faults designated as active or potentially active will experience movements during the design life of the proposed facilities cannot be estimated with a high level of confidence. Similarly, the magnitudes of the MCE associated with specific features are approximations based on currently available information. The results of this analysis should, therefore, be interpreted conservatively.

E4.3 SEISMOTECTONIC SETTING

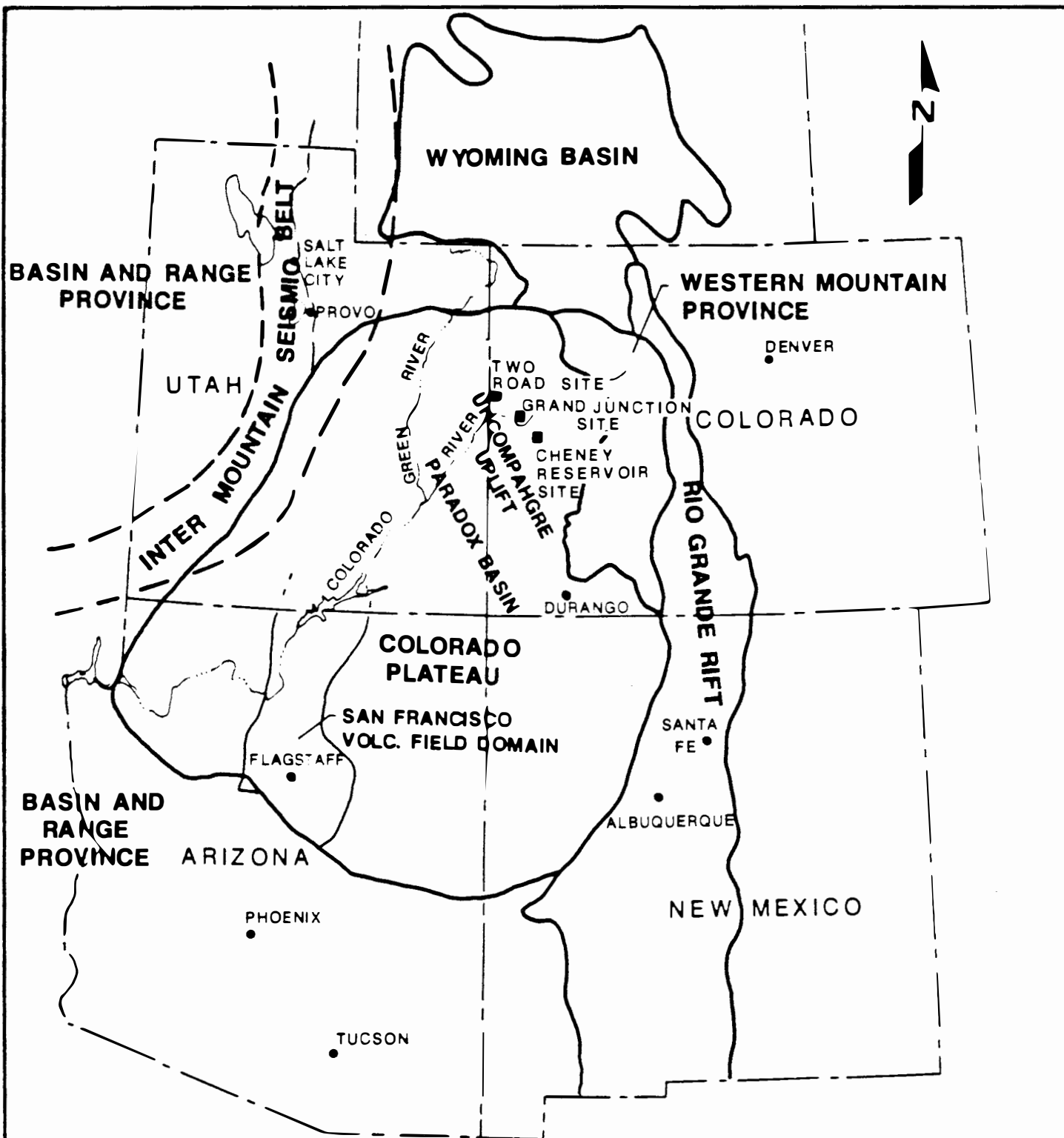
E4.3.1 REGIONAL SETTING

The first recorded earthquake in the State of Colorado occurred in 1870 (Kirkham and Rogers, 1981); therefore, the historical record covers only about 115 years. This is too short a time period for use in developing a completely reliable data base for the analysis of future seismic risk. The length of the record for the adjoining states is comparable. The historical record for Wyoming dates to about 1882 (Coffman et al., 1982); for Utah, to 1850 (Arabasz et al., 1979); for Arizona, to 1776 (DuBois et al., 1982); and for New Mexico, to 1849 (Sanford et al., 1981). The instrumental record is considerably shorter, generally dating to the early 1960s. As a general rule, the historical record for the region is probably reliable for earthquakes of magnitude greater than 4.5 occurring after 1960 (von Hake, 1984). In order to predict future earthquakes associated with faults which may have recurrence intervals of thousands to tens of thousands of years, studies of the geologic and seismotectonic setting, recent geologic history, and evidence of recent fault movements are used.

Colorado has been divided into seismotectonic provinces by Kirkham and Rogers (1981) based on the distribution and characteristics of Neogene (later Tertiary, or Miocene to Holocene) faults, historical earthquakes, major structural and physiographic regions, and interpretations of earthquake potential. Those provinces which are significant to a seismic hazard evaluation of the Grand Junction area are shown on Figure E4.3.1, which also delineates the major seismotectonic provinces in the neighboring portions of Wyoming, Utah, Arizona, and New Mexico. The Grand Junction UMTRA Project sites are located in the northeastern part of the Colorado Plateau physiographic province.

The seismotectonic setting of the Colorado Plateau has been described in two monographs on Cenozoic tectonics and regional geophysics of the western Cordillera and the Rio Grande Rift (Smith and Eaton, 1978; Riecker, 1979). Those studies and other studies of surface wave and seismic refraction data (Keller et al., 1979), heat flow (Reiter et al., 1975; Eggleston and Reiter, 1984), crustal stress (Zoback and Zoback, 1980), and the seismic history of the region all indicate that the Colorado Plateau is composed of a seismically stable interior portion bounded on three sides by more active border zones (Figure E4.3.2). The border zones are transitional to major structural zones that have experienced large components of Cenozoic strain, magmatic activity, and high levels of seismicity (Thompson and Zoback, 1979). These major structural zones are as follows:

- o The Intermountain Seismic Belt (Smith and Sbar, 1974), which coincides with the transition zone between the basin and range province on the west, and the Colorado Plateau and Middle Rocky Mountains on the east.
- o The Rio Grande Rift, which borders the plateau to the east in Colorado and New Mexico.



KELLY & CLINTON, 1960

HUNT, 1967

SMITH & SBAR, 1974

KIRKHAM & ROGERS, 1981

NEW MEXICO GEOLOGICAL SURVEY, 1982

MENGES, 1983

PEARTREE & OTHERS, 1983

50 0 50 100 150
SCALE IN MILES

■ CANDIDATE
DISPOSAL SITE

FIGURE E4.3.1
REGIONAL SEISMOTECTONIC SETTING

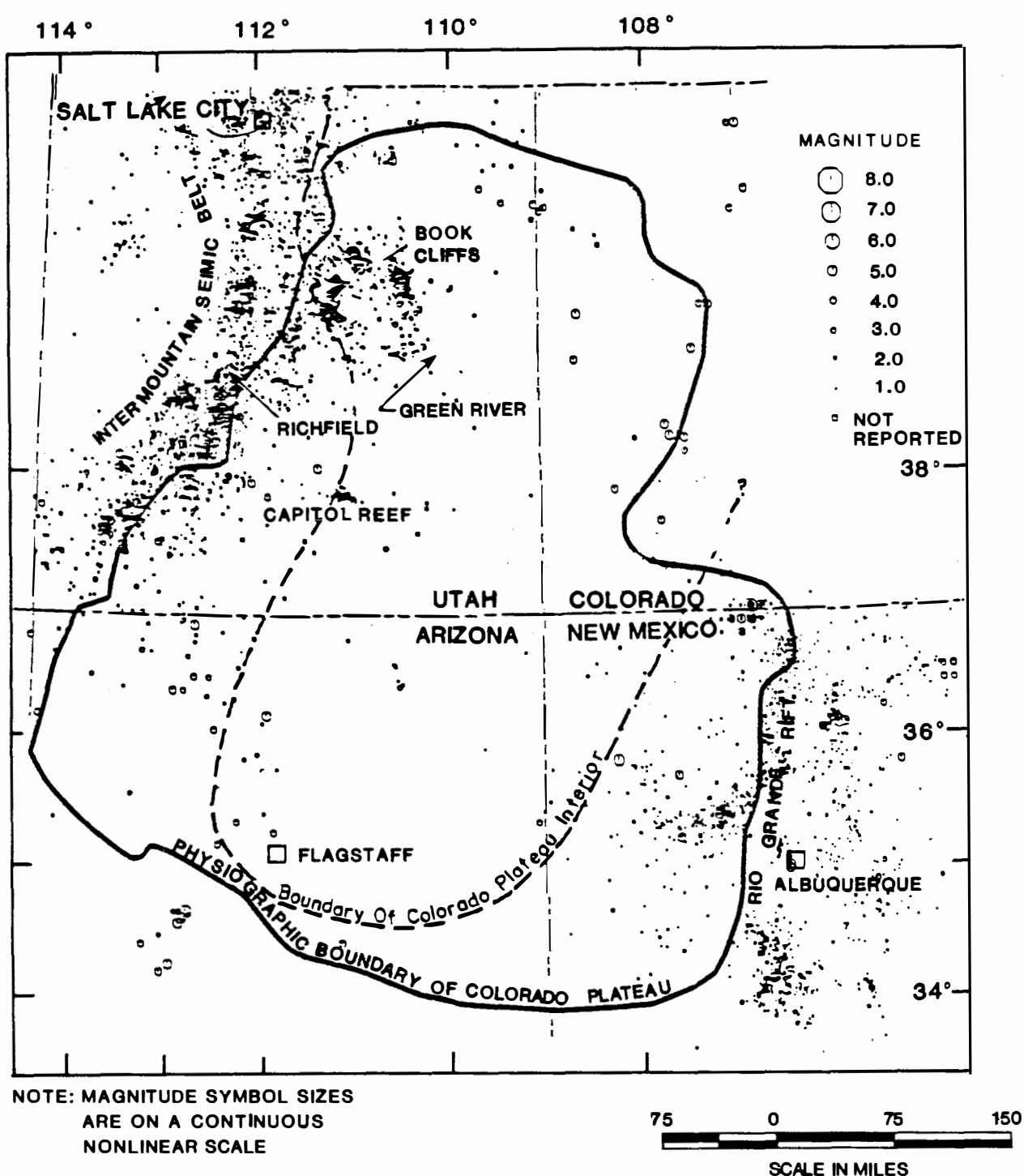


FIGURE E 4.3.2
SEISMICITY MAP OF THE COLORADO PLATEAU, 1962 TO 1980
 (AFTER WONG, 1984), SHOWING LOCATION OF GRAND JUNCTION
 UMTRA PROJECT SITES & BOUNDARY OF COLORADO PLATEAU INTERIOR
 (AFTER ZOBACK AND ZOBACK, 1980)

- o The Colorado Plateau/basin and range transition zone in north-central Arizona.

The Grand Junction UMTRA Project sites are in the stable interior portion of the Colorado Plateau. However, they lie within a few miles of potentially active faults associated with the Uncompahgre Uplift. The sites are from about 120 to 160 miles (190 to 260 km) east of the Intermountain Seismic Belt (ISB), and 100 to 140 miles (160 to 225 km) west of the Rio Grande Rift. The above are considered to be the major potential sources of large earthquakes which could impact the Grand Junction area.

E4.3.2 COLORADO PLATEAU PROVINCE

The Colorado Plateau is a major tectonic block composed of Paleozoic and Mesozoic rock, underlain by a core of Precambrian rock, that has been uplifted at a rate of about two mm/yr since Late Tertiary time (Gable and Hatton, 1980). It covers an area of approximately 114,000 square miles (295,000 square km) in western Colorado and adjoining parts of Utah, Arizona, and New Mexico. The site area lies in the northeastern part of the plateau.

Neogene faulting is generally rare within the Colorado Plateau, except for faulting associated with the Uncompahgre Uplift and the collapsed salt anticlines of the Paradox Valley (see Figure E4.3.1). Earthquakes are not common within the plateau, except in the border zones, as discussed above. The stable interior portion of the plateau is, thus, considered to be an area of relatively low seismic risk. Some of the largest earthquake magnitudes recorded within the Colorado Plateau, and in the Grand Junction region, are as follows:

- o Events of estimated magnitudes 5.5 to 5.75 (M_L) at Lockett Tanks, Arizona, in 1912, and Fredonia, Arizona, in 1959 (DuBois et al., 1982). These events may have occurred within the border zone separating the Colorado Plateau from the basin and range province to the south.
- o The Dulce, New Mexico, earthquake of January 23, 1966, of magnitude (M_b) 5.5 (NOAA, 1984). This event apparently occurred in the zone of transition between the Colorado Plateau and the Rio Grande Rift (Herrmann et al., 1970).
- o The earthquake of October 11, 1960, of magnitude 5.5, located northeast of Ridgway, Colorado, which was strongly felt in the Ridgway-Montrose area. This event was one of the larger earthquakes that has occurred in Colorado during the historical period (Kirkham and Rogers, 1981). The epicenter was located about 67 miles (118 km) southeast of Grand Junction, and may have been associated with the Uncompahgre Uplift.

The historical seismicity of the interior portion of the Colorado Plateau was classified by Wong (1984) as very low level, having events of small to moderate magnitude, with diffusely distributed epicenters. The largest instrumentally recorded events within the interior of the plateau have had a magnitude of 4.5 to 5.5.

This magnitude range is approximately equal to the largest recorded magnitudes for any of the stable blocks of the continental and eastern United States (excluding tectonically unique and highly active regions such as the New Madrid, Missouri; Charleston, South Carolina; and La Malbaie, Quebec areas). Liu and Kanamori (1980) compiled records for intraplate earthquakes within many stable parts of the North American plate, the Atlantic Ocean, and intraplate settings in other parts of the world. These data indicate that most larger earthquakes in intraplate settings have magnitudes in the range of 5.8 to 6.4. This range in magnitude, therefore, appears to be a conservative estimate for scattered, non-predictable earthquakes that could occur within the stable interior portion of the Colorado Plateau. Kirkham and Rogers (1981) estimated an MCE of 5.5 to 6.5 for the Colorado Plateau. Slemmons (1985) considers the upper bound magnitude 6.5 to be unrealistic for the Colorado Plateau, and has suggested a value in the range of 5.7 to 6.2.

However, in the case of the Grand Junction UMTRA Project sites, estimates of seismic risk which are based on regional seismotectonic analysis for the entire Colorado Plateau may not have validity, since the sites are located within a few miles of potentially active faults associated with the Uncompahgre Uplift. These structures may be unique features which will require special consideration. The geologic history and seismotectonic setting of the Uncompahgre Uplift are discussed in greater detail in the following section.

E4.3.2.1 Uncompahgre Uplift

The Uncompahgre Uplift, which lies immediately to the south of the Grand Junction area, is one of the few features lying within the stable interior portion of the Colorado Plateau that has been identified as potentially active (Kirkham and Rogers, 1981). It is a large, northwest-trending, asymmetrical block within the Colorado Plateau, composed of Precambrian igneous and metamorphic rock overlain by Mesozoic sedimentary rock, that rose during the Neogene from the crest of an older, much larger highland that was a prominent structural feature during the Late Paleozoic (Cater, 1966; Kirkham and Rogers, 1981). The modern Uncompahgre Uplift is a northeast-tilted block that has experienced considerable movement during the Pliocene and Quaternary along bounding faults and monoclines. Movement may have persisted well into the Pleistocene and may be continuing at the present time. Kirkham and Rogers (1981) have identified about 25 faults of Late Cenozoic age that flank the uplift on both the northeast and southwest (Figure E4.3.3).

These faults range in length from about five to 25 miles (eight to 40 km). Known potentially active faults on the northeastern flank lie at distances ranging from five to 20 miles (eight to 36 km) from the Grand Junction site and the Cheney Reservoir site, and from about 15 to 45 miles (24 to 72 km) from the Two Road site. Faults that lie along the southwestern flank of the Uplift lie at greater distances from the UMTRA Project sites; however, these faults may be capable of

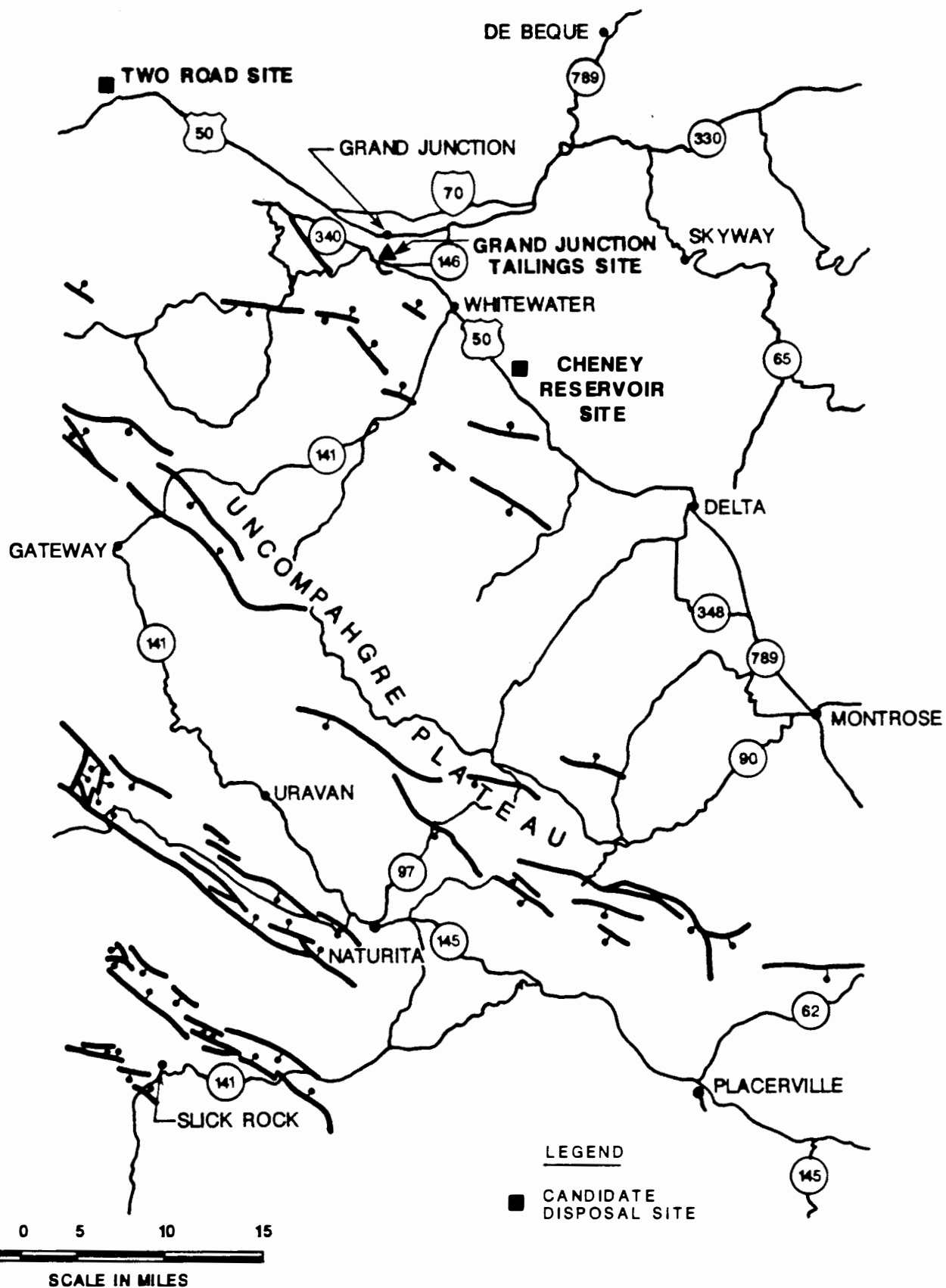


FIGURE 4.3.3
POTENTIALLY ACTIVE FAULTS ASSOCIATED
WITH THE UNCOMPAHGRE UPLIFT

producing larger earthquakes due to their greater lengths. Kirkham and Rogers (1981) state that all of these faults should be considered as potentially active.

Fault No. 74 is the only fault associated with the northeastern flank of the Uplift which can be shown by direct geologic evidence to have moved during the Quaternary. The fault displaces Cretaceous Mancos Shale and overlying Pre-Wisconsin (?) Quaternary pediment gravels in a roadcut on U.S. Highway 50, about 12 miles east of the Cheney Reservoir site (Kirkham and Rogers, 1981).

The Ridgway Fault (Fault No. 179 of Kirkham and Rogers, 1981), which lies on the southwestern flank of the Uplift about 55 miles southeast of the site area, reportedly offsets a Pre-Wisconsin Quaternary gravel exposed in a gravel pit near Ridgway (Sullivan et al., 1980). Kirkham and Rogers (1981) report that a microearthquake survey conducted during 1978 and 1979 located a number of microearthquakes that centered on the Ridgway Fault.

Table E4.3.1 lists the MCEs associated with some typical mapped faults of the Uncompahgre Uplift and also lists calculated maximum horizontal accelerations at the UMTRA Project sites which could result from the occurrences of calculated MCEs, along with calculated durations of seismic shaking in rock and soil. The values of maximum horizontal acceleration in rock listed in Table E4.3.1 are derived from attenuation curves of Seed and Idriss (1982). The values calculated represent mean values of acceleration and may in reality represent a broad scatter of values. Accelerations as high as 0.34g could possibly be experienced at the Grand Junction and Cheney Reservoir sites. Lesser values, ranging up to approximately 0.18g, are possible at the Two Road site.

The fact that known faults exist within the overall system which are estimated to be capable of producing magnitudes of up to 6.6 can be interpreted as meaning that similar magnitudes can be produced anywhere within the system. In that case, even higher accelerations can be assumed. For example, the occurrence of a magnitude 6.6 on the Redlands Fault, within six miles of the existing site, could produce an on-site acceleration of up to 0.42g. Accelerations ranging up to about 0.22g could be produced at the Two Road site.

Historical earthquake data for a 200-km radius surrounding Grand Junction (obtained from the NOAA Earthquake Data File, NOAA, 1984) are illustrated in Figure E4.3.4. Several trends are apparent.

Numerous events have occurred in the Ridgway-Montrose area. These events are broadly scattered and do not clearly define any specific fault system. The events scattered over the area south of Ridgway lie within the San Juan Mountains. To the northwest of Ridgway, an alignment of epicenters may

Table E4.3.1 Estimated maximum horizontal acceleration at UMTRA Project sites from earthquakes on potentially active faults associated with the Uncompahgre Uplift

Fault	MCE magnitude ^a	Distance from center of site area	Maximum horizontal acceleration in rock expected at site area ^b (fraction of unit gravity)	Duration of acceleration in rock ^c (>0.05g), in seconds	Duration of acceleration in soil ^c (>0.05g), in seconds
E4-14	#65 Length 9 mi 1/2 length 4.5 mi	6 mi (9.5 km) (existing site)	0.34	10-12	17-19
		18 mi (29 km) (Cheney site)	0.14	6-8	13-15
		16 mi (26 km) (2 Rd. site)	0.18	7-9	14-16
	#66 Length 8 mi 1/2 length 4 mi	9 mi (14 km) (existing site)	0.25	9-11	15-17
		19 mi (30 km) (Cheney site)	0.13	6-8	13-15
		24 mi (38 km) (2 Rd. site)	0.10	4-6	10-12
	#71 Length 6 mi 1/2 length 3 mi	18 mi (29 km) (existing site)	0.11	5-7	12-14
		5.5 mi (9 km) (Cheney site)	0.34	10-12	16-18
		43 mi (69 km) (2 Rd. site)	0.02	--	4-6
	#80 Length 18 mi 1/2 length 9 mi	30 mi (48 km) (existing site)	0.10	4-6	9-11
		30 mi (48 km) (Cheney site)	0.10	4-6	9-11
		38 mi (61 km) (2 Rd. site)	0.07	2-4	3-5

Table E4.3.1 Estimated maximum horizontal acceleration at UMTRA Project sites from earthquakes on potentially active faults associated with the Uncompahgre Uplift (Concluded)

Fault	MCE magnitude ^a	Distance from center of site area	Maximum horizontal acceleration in rock expected at site area ^b (fraction of unit gravity)	Duration of acceleration in rock ^c (>0.05g), in seconds	Duration of acceleration in soil ^c (>0.05g), in seconds
#81	6.6	40 mi (64 km)	0.07	2-4	8-10
Length 22 mi		(existing site)			
1/2 length		34 mi (54 km)	0.09	4-6	9-11
11 mi		(Cheney site)			
		56 mi (90 km)	0.02	--	--

^aBased on rupture length equal to 1/2 fault length and relationships in Slemmons (1977).

^bExtrapolated from curves of Seed and Idriss (1982).

^cExtrapolated from curves of Krinitzsky and Chang (1977).

follow the trend of the northeastern flank of the Uncompahgre Uplift as far as Montrose. This grouping includes the October 11, 1960, magnitude 5.5 events.

The area from Montrose northwest to Grand Junction has apparently experienced no activity during the period of record.

A second clustering of events occurred in the Grand Junction area. The epicenters of those events are plotted on Figure E4.3.3. One event, with an intensity (Imm) of II (NOAA, 1984), which occurred on March 1, 1915, is very closely related to the Redlands Fault Complex (Fault No. 65 of Kirkham and Rogers, 1981). It should be emphasized that the epicentral location is approximate so the very close coincidence of the epicenter with the Redlands Fault Complex is partly fortuitous. However, the possibility that the event occurred on the Redlands Fault complex cannot be ignored. The Redlands Fault may be active.

The event of March 1, 1915, was preceded on February 28, 1915, by an event of estimated intensity (Imm) III whose epicenter apparently was located about 4.5 miles to the northeast, on the opposite bank of the Colorado River. A second event occurred very close to the epicenter of the February, 1915, event on January 30, 1975. This event had a body wave magnitude of 4.4, and an intensity (Imm) equal to V. No faulting has been recognized to date in the area of these epicenters. The activity in the area suggests the presence of an undetected, possibly unexposed, active fault system.

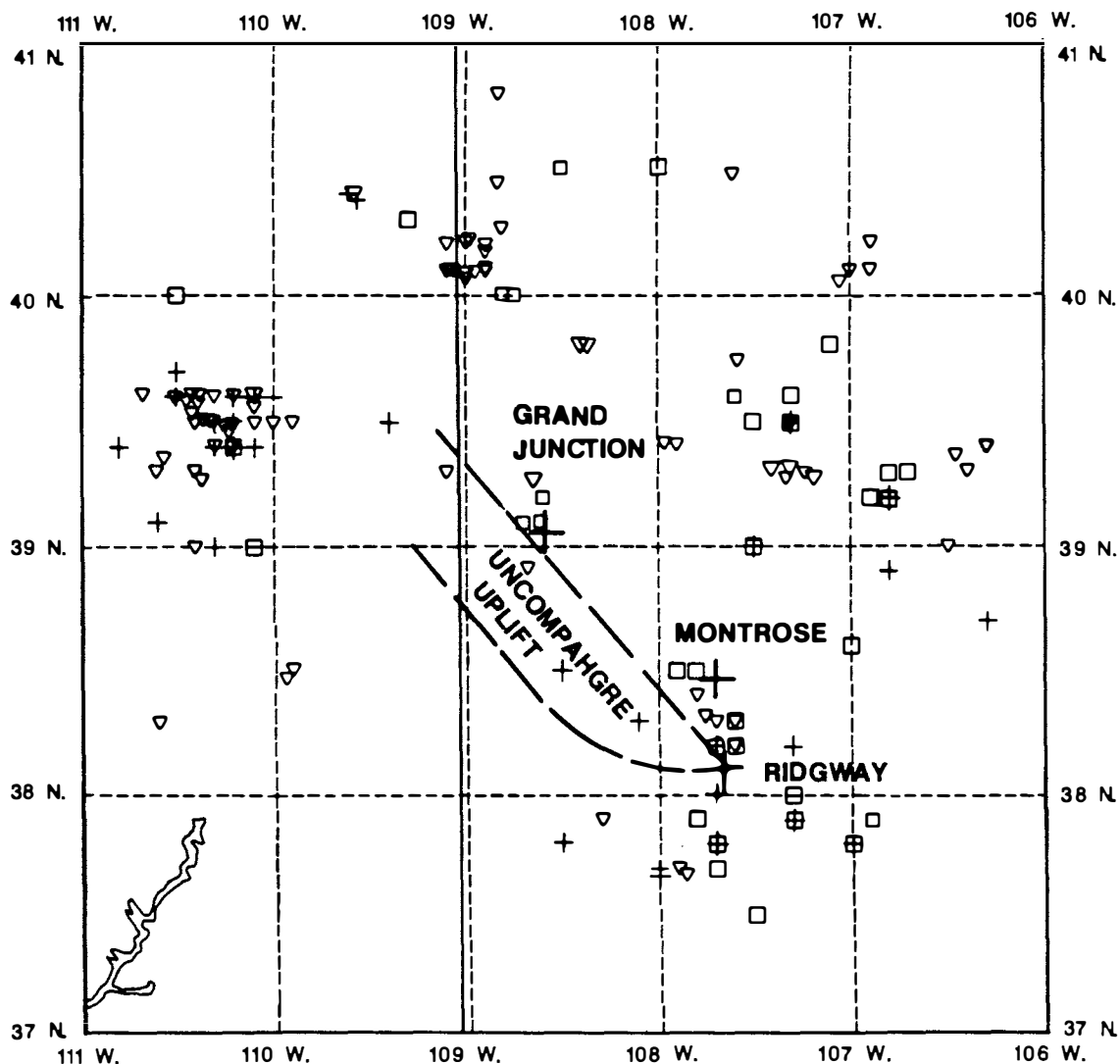
It must be concluded from the above that known faults lying within five or six miles of the Grand Junction site may be active. Furthermore, undetected active faults may also exist, and may lie even closer to the site.

Estimated accelerations at the UMTRA Project sites resulting from the occurrence of earthquakes of magnitude 6.6 on known faults could range up to 0.42g. Accelerations resulting from earthquakes on undetected faults could possibly be higher.

The probability that on-site fault rupture, particularly at the Grand Junction site, may occur as a result of fault movements cannot be defined with the present data. It cannot be ruled out for the 1000-year design life of the proposed facilities.

E4.3.2.2 Paradox Basin

The Pennsylvanian-aged Paradox Basin is located about 45 miles (72 km) to the southwest of the site area, and southwest of the Uncompahgre Uplift. Associated with this basin are northwest-trending, salt-cored anticlines that collapsed along their crests in a grabenlike fashion during the Neogene. The



NO INTENSITY OR MAGNITUDE +
NATIONAL GEOPHYSICAL DATA CENTER / NOAA BOULDER, CO. 80303

MAGNITUDES

▽	4.0
▽	5.0
▽	6.0
▽	7.0

INTENSITIES

□	I - III
□	IV - VI
□	VII - IX
□	X - XII

FIGURE E4.3.4
HISTORICAL EARTHQUAKE DATA FOR A 200 km RADIUS
SURROUNDING GRAND JUNCTION, SHOWING APPARENT RELATIONSHIP
OF EPICENTERS TO REGIONAL STRUCTURES.

anticlines are believed to be controlled by large subsurface faults which apparently have experienced several episodes of activity since the Late Paleozoic. The anticlines themselves experienced movement in the Quaternary and may well be active today (Hunt, 1956; Cater, 1970). The current episode of collapse may have begun when the Colorado Plateau was uplifted during the Miocene, during which the anticlines were breached and their cores exposed by erosion. Rapid solution and flowage followed exposure, causing complex faulting.

It is unlikely that these features can generate earthquakes having a magnitude larger than 4 or 5 (Kirkham and Rogers, 1981). Considering their distance from the site area, they do not appear to represent a critical factor in seismic hazard analysis. However, the large subsurface faults which control the locations of the anticlines are not exposed, and it is not known if they are still active. They might represent a potential source of typical Colorado Plateau earthquakes.

The occurrence of a magnitude 5.7 or 6.5 earthquake at a distance of 45 miles (75 km) from any one of the Grand Junction UMTRA Project sites would produce accelerations of about 0.03g to 0.04g at the site (Table E4.3.2).

E4.3.2.3 Artificially-induced earthquakes

The region of the Colorado Plateau east of the ISB lacks prominent natural earthquake activity. Several clusters of earthquakes have been recorded in the region that are apparently artificially-induced (Smith and Sbar, 1974). A number of events have occurred along the Book Cliffs in the eastern Utah coal mining district (see Figure E4.3.1). These events, the largest of which had a magnitude of 4.5, are thought to be triggered by subsurface coal mining (Smith et al., 1972). A number of earthquakes have been experimentally induced by fluid injection in the Rangely oil field (Raleigh et al., 1973). Due to the small magnitudes of these events, the distances from the site area, and their unnatural mode of occurrence, they are not considered to be significant to the analysis of seismic risk at the Grand Junction UMTRA Project sites.

E4.3.3 INTERMOUNTAIN SEISMIC BELT (ISB)

The following discussion is largely excerpted from Smith and Sbar (1974). The ISB is a zone of pronounced earthquake activity extending north from Arizona through Utah, eastern Idaho, and western Wyoming, and terminating in northwestern Montana (see Figures E4.3.1 and E4.3.2). It is coincident with the boundary between the basin and range province and the Colorado Plateau-Middle Rocky Mountains in central Utah, 120 miles

Table E4.3.2 Estimated maximum horizontal acceleration at site area from MCEs on regional seismotectonic features

Source area	MCE magnitude ^a	Distance from site area (miles)	Maximum horizontal acceleration in rock expected at site area ^b (fraction of unit gravity)
Paradox Basin	4.0-5.0	45	0.03 - 0.04
Intermountain Seismic Belt	7.0-7.5	120	<0.05
Rio Grande Rift	6.5-7.5	120	0.02 - 0.03
Wyoming Basin	5.7-6.5	75	0.02
Colorado Plateau/ Western Mountain province transi- tion zone	6.5	40	0.05 - 0.06

^aSee text for explanation of values assumed.

^bExtrapolated from Seed and Idriss (1982).

to the west of the Grand Junction UMTRA Project sites. The largest historical event of the Intermountain Region was the 1959 earthquake of magnitude 7.1 at Hebgen Lake, Montana. More than 15 events with magnitudes greater than 6 have been reported since the mid-1800s.

The ISB includes the Wasatch Frontal Fault System and other major potentially active faults of northern and central Utah, which lie at distances of 140 miles (224 km) or more to the west of the site region.

Though the seismic activity associated with the ISB is irregularly distributed over a broad area, there is no evidence that seismicity associated with it has occurred within the interior of the Colorado Plateau. It therefore appears that the closest approach of potential earthquakes associated with the ISB to the Grand Junction UMTRA Project sites is 120 miles. A magnitude 7.5 earthquake occurring at the closest approach of the ISB would produce accelerations of less than 0.05g at the sites (see Table E4.3.2).

E4.3.4 RIO GRANDE RIFT

The Rio Grande Rift is a north-south-trending extensional graben feature of great length and tectonic significance. It extends from Chihuahua, Mexico, through west Texas, New Mexico, and most of central Colorado, almost to the Wyoming state line. The rift was initiated in Neogene time and has experienced continued activity through the Quaternary. It is characterized by fault scarps in young alluvium, abrupt mountain fronts that exhibit faceted spurs, deep, narrow linear valleys, Neogene basin-fill sedimentary rocks, and a bimodal suite of mafic and silicic igneous rocks.

A high percentage of all the potentially active faults in Colorado and New Mexico lie within this province. The rift has been subdivided into northern and southern subprovinces in Colorado by Kirkham and Rogers (1981) on the basis of young faulting. Well-defined evidence of repeated Late Quaternary movement is abundant on several faults in the southern subprovince, whereas such evidence is obscure in the northern subprovince.

The closest approach of active or potentially active faults associated with the Rio Grande Rift to the Grand Junction UMTRA Project site area is about 120 miles (200 km).

The estimated magnitude of an MCE associated with the Rio Grande Rift in Colorado (Kirkham and Rogers, 1981) is 6.5 to 7.5. An event of magnitude 7.5 occurring at a distance of 120 miles from the site area would result in a horizontal rock acceleration of less than 0.02 to 0.03g, as detailed in Table E4.3.2.

E4.3.5 WYOMING BASIN

The Wyoming Basin consists of a series of broad structural and topographic basins that connect with and resemble the adjoining part of the

Colorado Plateau (Hunt, 1967). These basins are partly filled with Tertiary deposits and are separated by low anticlinal uplifts of older rocks.

The earthquake history of the Wyoming Basin is apparently similar to the widely distributed, low to moderate magnitude pattern of the stable interior portion of the Colorado Plateau. Witkind (1975) identified numerous suspected active faults in the Wyoming Basin along the Colorado/Wyoming border between 107 degrees and 108 degrees West Longitude, which may represent a continuation of structures associated with the Rio Grande Rift in Colorado. However, these faults are not known to have been associated with seismic activity.

Coffman et al., (1982) list 38 earthquakes of moderate intensity within the entire State of Wyoming; however, most of these have occurred within the ISB in the western part of the state, especially in the Yellowstone Park region.

The MCE for the Wyoming Basin may be about equal to that of the Colorado Plateau, i.e., in the range of 5.7 to 6.0 or possibly ranging as high as 6.5. The closest approach of the physiographic boundary of the Wyoming Basin to the site area is about 75 miles (120 km). The occurrence of magnitude 5.7 or 6.5 events at the closest approach would be expected to produce on-site accelerations of only about 0.02g at the Grand Junction UMTRA Project sites (see Table E4.3.2).

E4.3.6 WESTERN MOUNTAIN PROVINCE

The Western Mountain province comprises the mountainous areas to the west of the Rio Grande Rift extending as far as the border of the Colorado Plateau. This province includes the San Juan, Elk, and West Elk Mountains, the west flank of the Sawatch Range, and the White River and Gunnison uplifts. Relatively few Neogene faults are known in this province. Neogene rocks in the San Juan Mountains are offset by faults related to caldera collapse; however, these are not considered to be active faults. Several faults associated with evaporite flowage or solution also offset Neogene rocks. These faults are generally not considered capable of generating earthquakes having magnitudes larger than about 4 or 5.

Minor evidence of Neogene reactivation of west-to-northwest-trending Precambrian faults, such as the Cimarron fault (Fault No. 94 of Kirkham and Rogers, 1981), and a few other Neogene faults scattered throughout the province, has been identified; however, none are major tectonic faults that have experienced any known significant Quaternary activity.

E4.3.6.1 Border zone of Colorado Plateau and Western Mountain province

Earthquake epicentral maps of the Colorado Plateau region show a slightly heightened level of seismic activity within the narrow border zone along the contact with the Western Mountain province, which is located within 40 to 60 miles (64

to 96 km) of the Grand Junction UMTRA Project sites. The MCE magnitude for the Colorado Plateau, according to Kirkham and Rogers (1981), is 5.5 to 6.5, and for the Western Mountain province is 6.5. Therefore, the MCE associated with the border zone of the two provinces is assumed herein to have a magnitude of 6.5.

The maximum horizontal acceleration in rock expected at the site area, from a possible MCE event having a magnitude of 6.5, occurring within 40 miles of the site area, is 0.05 to 0.06g, as detailed in Table E4.3.2.

E4.4 PREVIOUS SEISMIC ZONING STUDIES

Several probabilistic earthquake maps, which plot contours of maximum horizontal accelerations, velocities, and intensities for various return periods, have been prepared for the contiguous United States. Examples of such studies are those by Liu and DeCapua (1975), Algermissen and Perkins (1976), the Applied Technology Council (1978), and Algermissen et al. (1982). These were utilized to estimate the maximum value of each parameter for the site area. The resulting values are listed in Table E4.4.1.

Liu and DeCapua (1975) developed 100-year contour maps of intensity and acceleration for the Rocky Mountain states. On their 100-year contour map of maximum predicted intensity, the site area lies in a region characterized by modified Mercalli Intensity IV and V, which lies to the east of the ISB. Considering this, it would be reasonable to assume that a modified Mercalli Intensity IV to V event would be experienced in the site area once every 100 years. Based on their 100-year contour map of peak accelerations for the Rocky Mountain states, an acceleration of 0.02g to 0.03g is predicted.

Contours of horizontal acceleration having a 90 percent probability of not being exceeded in 50 years were presented for the contiguous United States by Algermissen and Perkins (1976). On their map, the site area lies near the margin of a zone of maximum predicted horizontal acceleration ranging from 0.04g to 0.05g. This zone roughly corresponds to a Rio Grande Rift/Colorado Plateau transition zone and includes much of the Western Mountain province.

The preliminary study of Algermissen and Perkins (1976) was updated by Algermissen et al. (1982), who presented probabilistic estimates of maximum acceleration and velocity in rock for periods of 10, 50, and 250 years. In comparison with the 1976 study, the 1982 study resulted in only minor modification of their estimates of peak accelerations for the Grand Junction area.

The study performed by the Applied Technology Council (1978) presented a map showing effective peak accelerations for the contiguous United States, in which the geographic contours of seismic source zones and horizontal accelerations in the site area are the same as those presented by Algermissen and Perkins (1976) and Algermissen et al. (1982).

The accelerations calculated in these previous studies are uniformly lower than the maximum values calculated in this study. The principal cause of this discrepancy is probably that the previous studies are of a regional nature and do not give consideration to unique features such as the Uncompahgre Uplift. Also, it is not possible to estimate recurrence intervals for the faults associated with the Uplift in the study area, so they cannot be evaluated using a probabilistic approach.

Table E4.4.1 Probabilistic estimates of maximum acceleration, velocity, and intensity in the Grand Junction area from various published sources

Source	Return period or probability	Maximum acceleration G-units	Maximum velocity cm/sec	Modified Mercalli Intensity
Liu & Decapua (1975)	100 years	0.02 to 0.03	---	IV
Algermissen & Perkins (1976)	90% probability of not being exceeded in 50 years	0.03 to 0.04	---	---
Applied Technology Council (1978)	---	0.04 to 0.05	---	---
Algermissen et al. (1982)	90% probability of not being exceeded in 10 years	<0.04	<2	---
Algermissen et al. (1982)	90% probability of not being exceeded in 50 years	0.04 to 0.05	2	---
Algermissen et al. (1982)	90% probability of not being exceeded in 250 years	0.10 to 0.12	4-6	---

E4.5 POTENTIAL FOR SOIL LIQUEFACTION

A review of published earthquake reports by Youd and Hoose (1977) indicates that shallow, saturated, Holocene fluvial, deltaic, and eolian deposits and poorly compacted artificial sand fills have the highest susceptibility to liquefaction and subsequent ground failure. Holocene alluvial fan, alluvial plain, beach, terrace, and playa deposits were found to be less susceptible. Pleistocene sand deposits are generally even less susceptible, and glacial till, clay rich, and pre-Pleistocene deposits are usually immune to liquefaction. The degree of sorting, the degree of compaction during sedimentation or construction, and the grain-size distribution are major factors controlling liquefaction potential. The greater the sorting and the looser the packing, the greater the liquefaction potential. Most episodes of liquefaction have developed at relatively shallow depths (probably less than 30 feet) and in areas where the water table (free or perched) was located within a few meters of the ground surface.

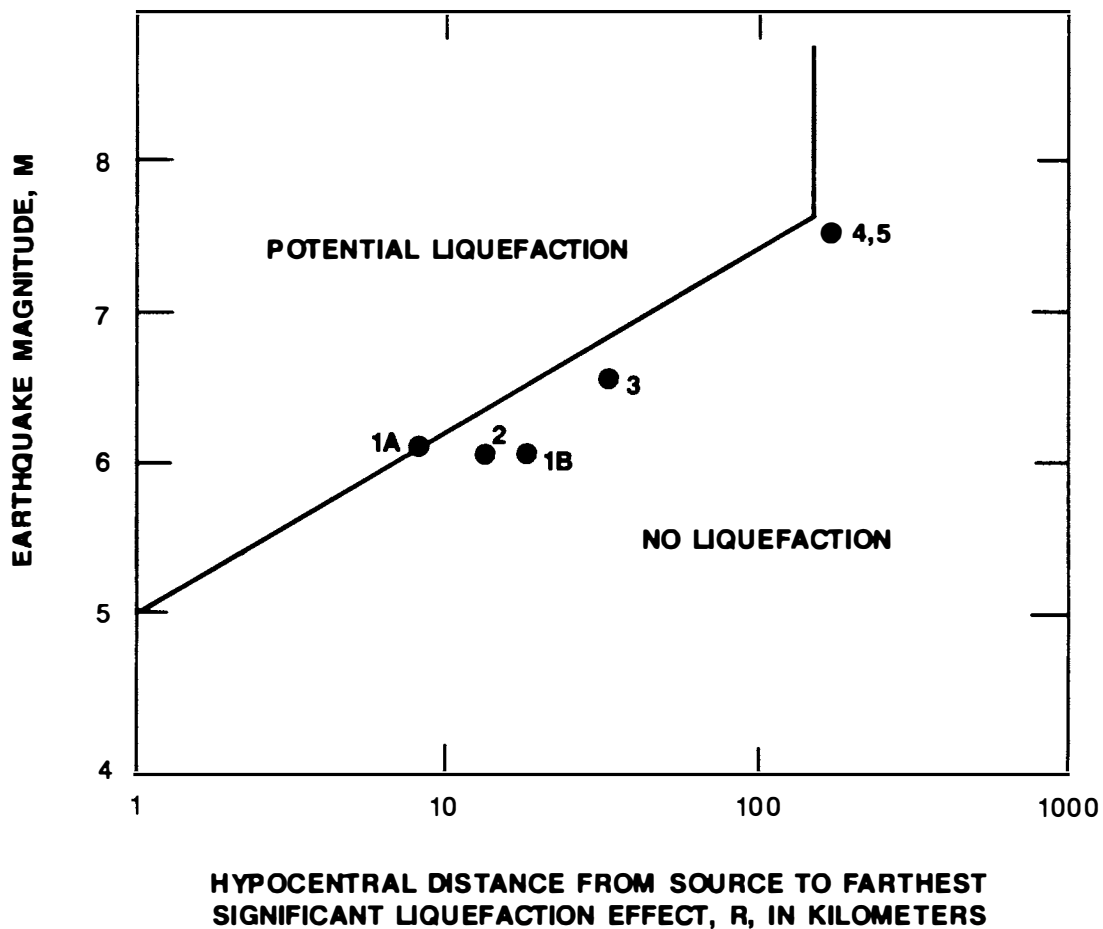
The potential for liquefaction also depends on the degree of seismic shaking. The opportunity for ground failure in a given area is a function of the seismicity of the area and the rate of occurrence of earthquake ground motions of sufficient intensity to produce ground failure in susceptible materials. The maximum distance from a seismic source to potentially damaging ground failures as a function of earthquake magnitude was determined by Youd and Perkins (1978), as plotted in Figure E4.3.4. Liquefaction is not likely to be produced by earthquakes of magnitudes less than about 5 or at a distance greater than 75 to 150 km (47 to 93 miles) from the hypocenter.

Several hypothetical earthquakes that might affect the Grand Junction site area are shown on Figure E4.5.1. The level of seismic shaking expected to occur at the sites is barely sufficient to induce liquefaction in susceptible materials during the most extreme events. However, these estimates are based on various approximations and should be interpreted conservatively. The possibility of large events occurring on previously undetected faults at closer distances, especially to the Grand Junction site, cannot be ruled out. The potential for seismically-induced liquefaction in susceptible materials should be carefully considered in the design of permanent disposal facilities.

E4.5.1 EXISTING TAILINGS PILE

Exploratory test borings advanced at the Grand Junction site indicate that the tailings range in thickness from about 10 to 52 feet and consist of a heterogeneous mixture of clean sands, silts, and slimes which are irregularly distributed throughout the existing piles. Natural materials underlying the site consist of a thin layer (zero to two or three feet) of sandy silt, overlying coarse river gravels containing cobbles and boulders which range from three to eight feet in thickness. Bedrock beneath the site is composed of the Cretaceous Mancos Shale.

Ground water was encountered in test borings at the site at depths ranging from a few feet to 20 or 30 feet below the ground surface. The variations in depth to ground water depend on elevations of the surface of the piles. Ground water is generally encountered within a few feet of the level of the Colorado River. The ground water was generally



Events shown on graph:

1. Redlands Fault (No. 65 of Kirkham and Rogers, 1981).
A. Effect at Grand Junction site.
B. Effect at 2 Road site.
2. Fault No. 66 of Kirkham and Rogers (1981); effect at Grand Junction site.
3. Fault No. 80 of Kirkham and Rogers (1981); effect at Grand Junction site.
4. Effect of MCE's in Intermountain Seismic Belt & Rio Grande Rift in general site area.

FIGURE E4.5.1
GRAPHICAL PLOT OF LIQUEFACTION POTENTIAL AS
A FUNCTION OF MAGNITUDE AND HYPOCENTRAL
DISTANCE (AFTER YOUNG AND PERKINS, 1979), SHOWING HYPOTHETICAL
EARTHQUAKES THAT MIGHT AFFECT GRAND JUNCTION UMTRA SITES.

encountered in alluvial gravels five to 10 feet below the base of the tailings. Zones of perched ground water were not encountered during drilling; however, these zones may exist.

As noted above, unconsolidated materials such as clean sands, silty sands, and slimes in the tailings piles and silty sand below the piles may be susceptible to liquefaction when in the saturated condition and when subjected to sufficient seismic shaking.

While ground water was not encountered in these materials during the exploratory drilling program, the level of the water table may vary sufficiently with time to cause occasional saturation of the lower tailings and the underlying silty sand. Such a condition might occur during the higher flows of the Colorado River. Infiltration of rainwater and melting snow into the surface of the piles may result in local zones of perched ground water as well.

As shown in Figure E4.5.1, the level of seismic shaking expected to occur at the existing site is barely sufficient to produce liquefaction during the most extreme events. Coupled with the general non-saturated conditions of the piles and underlying materials, these estimates indicate a low potential for seismically-induced liquefaction. However, considering the approximate nature of these estimates, the possibility of undetected active faults near the site, and the probable variations in the level of the water table, the potential for liquefaction cannot be ruled out. It should be carefully considered in the design of permanent facilities at the site.

The possibility of occurrence of landslide failures of riverbanks both at and near the piles during seismic shaking could also impact the existing tailings piles. Failures of the riverbank have occurred near the site in the recent past due to undercutting of the banks by the Colorado River. Some minor failure of the bank at the site was also noted during field reconnaissance conducted for this study.

E4.5.2 CHENEY RESERVOIR SITE

Three exploratory boreholes drilled at the Cheney Reservoir site during the initial site investigation encountered Cretaceous Mancos Shale at depths ranging from 31 to 42 feet. The Mancos was overlain by sediment gravels composed of gravely to cobbly silt and clay and residuum developed on weathered shale. The age of these materials is not precisely known; however, they appear to be at least Pleistocene in age. An eolian silt layer, ranging in thickness from zero to one or two feet, is locally present.

Ground water was encountered in Mancos Shale in one boring at a depth of about 39 feet, while other borings, generally advanced to depths of about 50 feet, did not encounter ground water.

It is apparent from these data that saturated materials may be encountered in local zones of perched ground water only, and may not be encountered within 20 to 30 feet of the ground surface at the Cheney Reservoir site.

Considering the age and composition of the materials present at the site and the apparent lack of saturated zones near the surface, the potential susceptibility to soil liquefaction is apparently very slight to zero, and should not pose a significant threat to the potential stability of properly designed and constructed tailings disposal facilities at this site.

E4.5.3 TWO ROAD SITE

The report of a detailed study of the Two Road site performed by Golder Associates (1983) contains a detailed description of the stratigraphic units underlying the Two Road site. Surficial materials consist of pediment gravels, mainly of Pre-Wisconsin age, composed of silty and clayey sands and gravels containing cobbles and boulders, locally cemented; Quaternary alluvial deposits and mixed alluvium-colluvium; and residuum developed on the Cretaceous Mancos Shale. These surficial materials are generally overlain by a thin veneer (zero to six feet) of eolian silt and clay, which also is cemented in places. The surficial materials range from five to 31 feet in thickness, and are underlain by Mancos Shale.

Ground water was not encountered during test drilling and most borings remained dry to depths of 30 feet or greater, except near stockponds.

Considering the age and composition of the materials present at the site and the apparent lack of saturated zones near the surface, the potential susceptibility to soil liquefaction is apparently very slight to zero, and should not pose a significant threat to the potential stability of properly designed and constructed tailings disposal facilities at this site.

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HYDROLOGY REPORT

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F.1 SURFACE WATER

F.1.1 SURFACE-WATER FEATURES

F.1.1.1 Grand Junction tailings site

The tailings pile at the Grand Junction site is on the north side of the Colorado River about 0.75 mile upstream from its confluence with the Gunnison River (Figure F.1.1). The Colorado River is braided by several islands from the upstream end of the pile to a point about 0.5 mile past its downstream end. The northern channel of the braided segment passes extremely close to the toe of the pile.

The northern edge of the tailings varies between 4569 and 4578 feet above sea level. The stream bed of the Colorado River is about 4559 feet above sea level.

The southern side of the river banks against a steep cliff, approximately 60 feet high, with the lower segment composed of Mancos Shale.

The northern bank of the river along the site boundary is now stabilized to some degree with riprap, consisting of broken slabs and blocks of concrete, bricks, and "river-run" gravels. The crest of the protective bank is about 15 feet above the surface of the river.

There are industrial and residential developments around the tailings site. A highway and a railroad bridge are located less than 3500 feet downstream of the site and another highway bridge is located further downstream.

The only surface-water bodies at the site are two drainage ditches that divert overland runoff around the tailings pile to the Colorado River. One drainage ditch, east of the pile, extends to the east of the abandoned filtration plant (Figure F.1.2) and along the upstream face of the pile to the Colorado River. The other drainage ditch is on the west (downstream) side of the pile and runs from the mill site to the Colorado River.

The basin upstream of the site comprises 8150 square miles of steeply sloped terrain. The basin is bounded on the north by basins of the White and North Platte Rivers; on the east by basins of the South Platte and Arkansas Rivers; and on the south by the Gunnison River Basin. Major tributaries to the upper Colorado River include the Roaring Fork River, Eagle River, and Blue River. Elevations in the basin range from 4560 feet at Grand Junction to more than 14,000 feet in the highest headwater areas. Watershed boundaries are shown in Figure F.1.3. Approximate drainage areas, channel lengths, and slopes for the streams taken from USGS topographic maps are presented in Table F.1.1.

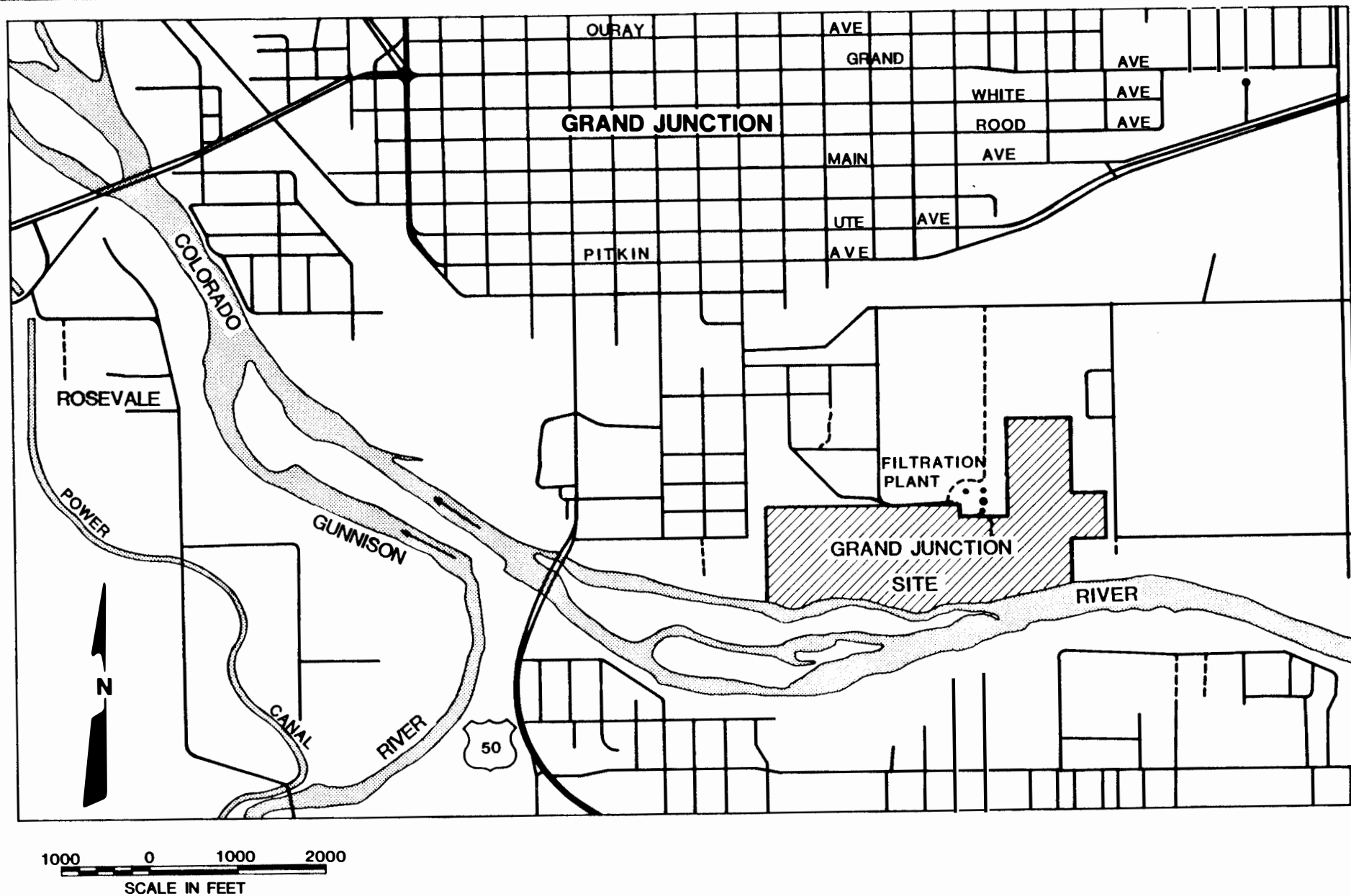


FIGURE F.1.1
LOCATION OF GRAND JUNCTION SITE

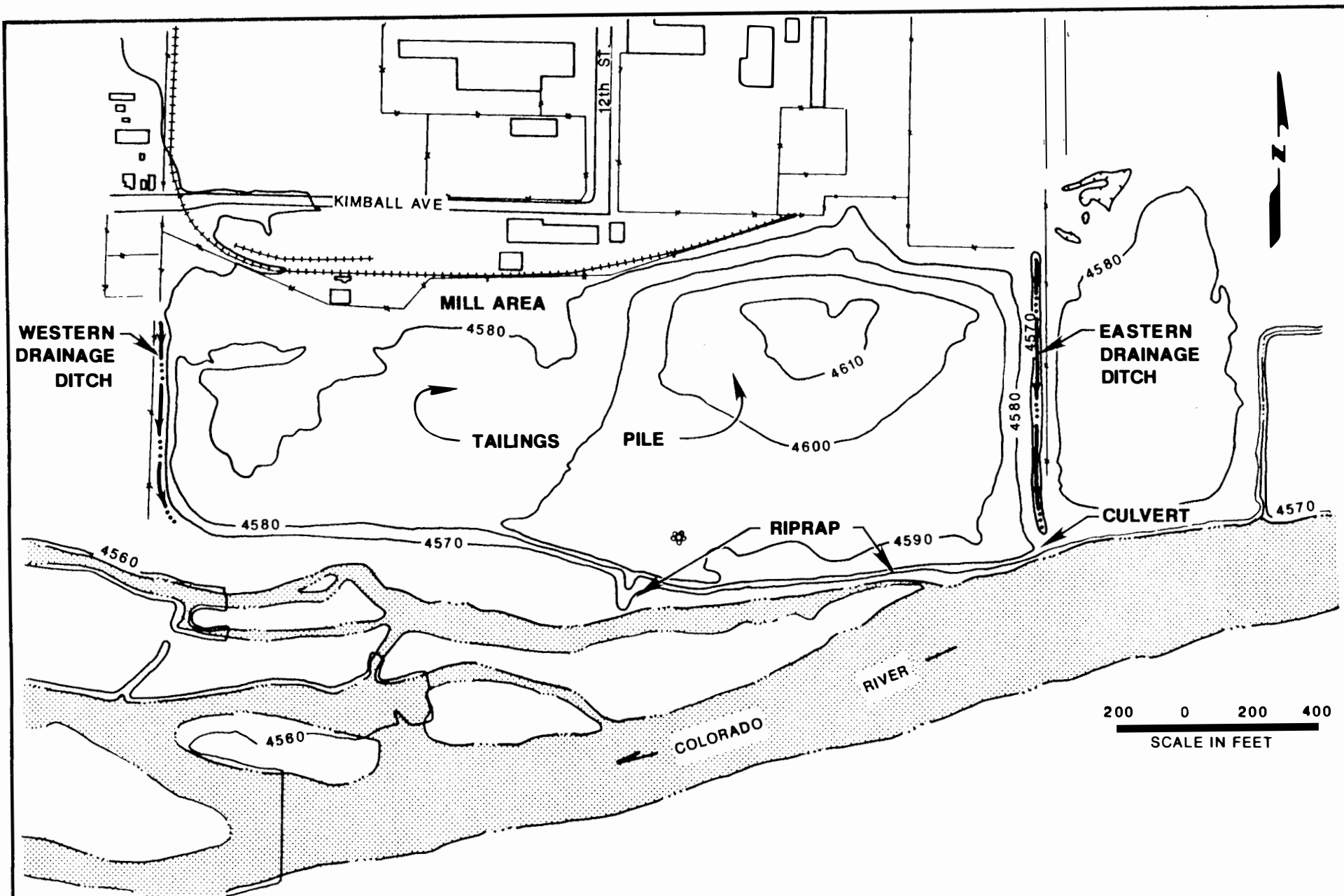


FIGURE F.1.2
DRAINAGE CHARACTERISTIC - GRAND JUNCTION SITE

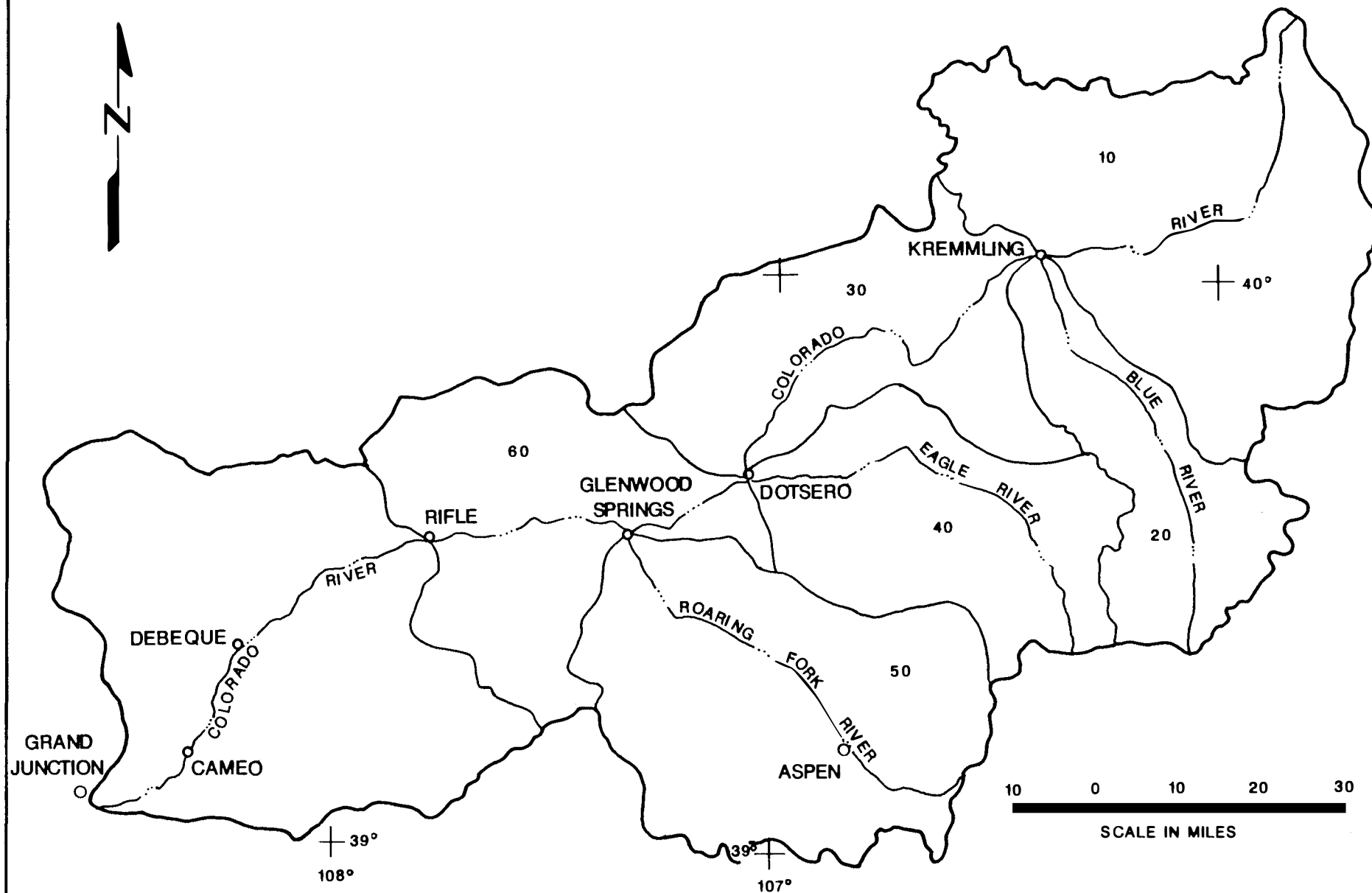


FIGURE F.1.3
WATERSHED BOUNDARY MAP OF COLORADO RIVER ABOVE GRAND JUNCTION, COLORADO

Table F.1.1 Select characteristics of subbasins of the Colorado River above Grand Junction, Colorado

Watershed	Area (square miles)	Channel length (miles)	Elevation (feet)	Slope (ft/ft)
Colorado River above Kremmling	1648	56.8	10,100-7200	0.009
Blue River	668	56.8	12,500-7200	0.017
Colorado River between Kremmling and Dotsero	1147	56.0	7200-6250	0.003
Eagle River	965	54.8	10,200-6250	0.013
Roaring Fork	1450	60.0	13,000-5700	0.022
Colorado River between Dotsero and Rifle	1072	42.0	6250-5300	0.004
Colorado River between Rifle and Grand Junction	<u>1200</u>	57.6	5300-4560	0.002
TOTAL	8150			

Detailed geologic descriptions of the site area and the lower portions of the drainage basin are contained in Appendix E, Soils, Geologic, and Seismic Information.

Soils in the watershed are mostly deep to moderately deep, well drained residuals of sandstones and mudstones. The Soil Conservation Service (SCS) classified most of the soils as hydrologic group B interspersed with some C soils and minor amounts of A and D soils (USDA, 1978; 1982; 1983).

The climate of the area ranges from semi-arid to mountainous, with yearly precipitation averaging about eight inches at Grand Junction, 10 to 15 inches near Rifle, and 40 inches in the headwater regions. Most of the annual precipitation in the higher elevations occurs as snow; temperatures in the lower areas are often above 90°F in the summer and below 32°F in the winter, while arctic conditions prevail in the highest areas almost year-round. Natural vegetation in valley areas consists primarily of cottonwood and willow, desert shrub, and an understory of hearty grasses. Prominent between 5000 and 8000 feet are juniper, pinion pine, oak, big sagebrush, and Douglas fir. From 8000 feet to timberline, vegetation consists mainly of aspen, spruce, sub-alpine fir, lodge pole pine, and native grasses and shrubs. Vegetation is sparse above timberline, but includes grasses, sedges, and alpine willow (COE, 1976).

The tailings site is in a meander path of the Colorado River and lies on five to 15 feet of unconsolidated alluvial material. Particle sizes of the alluvium at the site vary from cobbly gravels to gravelly sands. Given these site conditions, the river could affect the integrity of the site if not properly controlled or protected against.

As discussed by Schumm and Harvey (1983), no major shift in location of the Colorado River channel at the site has occurred in the past 100 years. The islands near the site are heavily vegetated, which indicates relative stability over the past 20 years, although some shifts in island locations were noted during the floods that occurred in 1984.

In contrast, the meandering patterns displayed both upstream and downstream of the site are characteristic of less stable rivers. Significant shifts have occurred in the reach upstream of the site as evidenced by cutoff meander loops, abandoned channels, and oxbow lakes visible on topographic maps and aerial photographs. Similar features are evident south of the confluence with the Gunnison River but not in the immediate site area probably because the much greater density of human activities in this area has obliterated natural contours.

Regarding localized erosion, the existing islands indicate that aggradation normally occurs near the site.

Several factors tend to cause sediment aggradation including a decrease of channel gradient, proximity of the confluence with the Gunnison River, and the broad floodplain along the northern bank. Aggradation also would likely occur during the receding portion of a large flood.

On the other hand, erosion which is presently occurring at the southeast corner of the pile would be accelerated during major flood flows. The area to the east of the site is unprotected, except by the floodplain. High channel and overbank flows could result in significant erosion of the surficial materials in this area and result in northward channel shifts. This would redirect the flow of the river against the east boundary of the pile. The pile would act as a constriction during major flood events causing unstable flow conditions, accelerated velocities, and scouring of alluvium at the site. A detailed geomorphic analysis included is in Appendix E, Soils, Geologic, and Seismic Information.

The U.S. Army Corps of Engineers conducted its latest flood study of the Colorado River near Grand Junction and concluded that the flows for the 100-year and 500-year floods would be 63,000 and 82,000 cubic feet per second, respectively (COE, 1976). The flows for the 200-year and 1000-year floods (72,000 and 90,000 cubic feet per second, respectively) were calculated from these values by interpolation and extrapolation. The corresponding maximum flood elevations at the edge of the pile would be 4577 and 4579 feet above mean sea level, respectively. Because the flood flows at the Grand Junction site would be obstructed by the tailings pile on one side of the river and by the steep cliff on the other side, the velocity of flood water in the main channel of the floodway would be high, reaching 11.8 and 13.2 feet per second for the 200- and 1000-year floods, respectively. The velocity of flood waters immediately adjacent to the face of the pile would be somewhat lower because of friction drag.

The average monthly river flows adjacent to the tailings pile can be represented by flow measured at a U.S. Geological Survey gauging station on the Colorado River near DeBeque, approximately 30 miles upstream of the site. The average maximum monthly flow at DeBeque from 1966 through the present was 11,210 cubic feet per second, occurring in late spring, and the average minimum monthly flows are approximately 1580 cubic feet per second. Downstream from the site, at the Colorado-Utah border, the average maximum and minimum monthly flows were approximately 3140 and 16,700 cubic feet per second from 1951 through the present. These higher flows were attributable mainly to the Gunnison River. U.S. Geological Survey gauging stations are also located northeast of Cameo, approximately 22 miles upstream of the site, and at Fruita, approximately 14 miles downstream of the tailings pile.

Grand Junction has experienced a number of severe late-spring floods, the result of the rapid melting of the deep snow pack accompanied by heavy rains. Ice jams are not a flooding problem for the Colorado River in the vicinity of Grand Junction. The uniform and fairly high temperature of the Gunnison River (since the construction of flood-protection dams) prevents extensive ice formation on the Colorado River between Grand Junction and the Colorado-Utah state line.

The flooding of June-July, 1884, is considered the most severe known on the upper Colorado River (COE, 1976). This flood resulted from rapid melting of snow pack and concurrent heavy rains. In recent times, the floods of 1983 and 1984 were the most significant. The 1884 flood peak would have been approximately 73,600 cubic feet per second (cfs) at Grand Junction, if discharge versus area relationships of the 1984 flood are representative. Information relative to these past floods is shown in Table F.1.2. Other major floods on the Colorado River were recorded in 1917, 1920, 1921, 1935, 1952, and 1957.

There are no major domestic users of Colorado River water for 200 miles downstream from Grand Junction. The normal water supplies for Grand Junction are obtained from Grand Mesa surface water, the Juniata and Perdy Mesa Reservoirs being the major sources. During dry spells, Grand Junction can use Gunnison River water; the intake is approximately one mile upstream from the confluence with the Colorado River. The Ute Water District uses Colorado River water during dry spells, but its intake is just upstream of Palisade and therefore upstream from the pile.

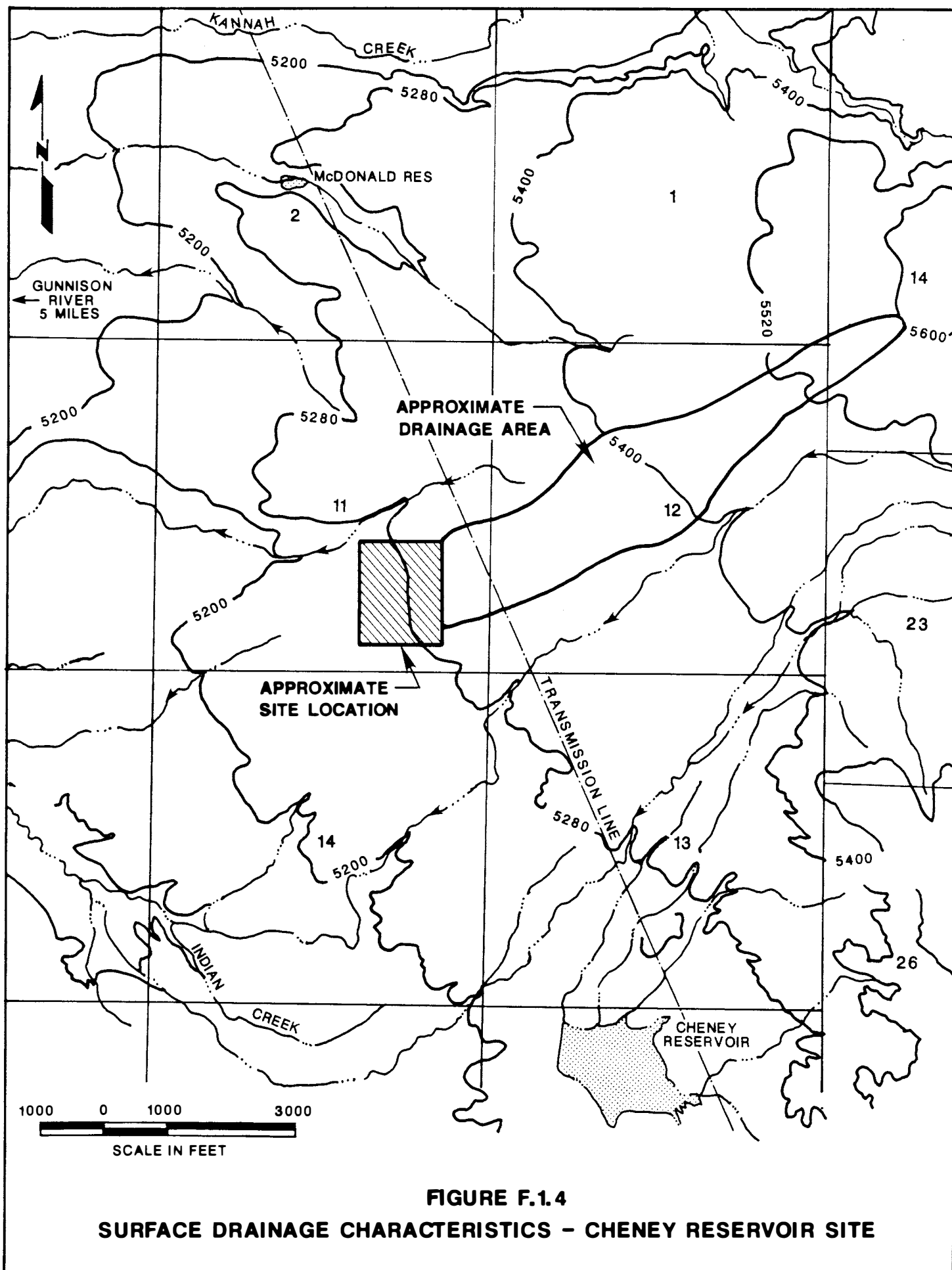
F.1.1.2 Cheney Reservoir alternate disposal site

The Cheney Reservoir site is located on a drainage divide that gently slopes to the southwest at approximately two percent. Total relief across the proposed disposal area is approximately 60 feet. The site is located on a pediment surface that forms a divide between two small ephemeral washes, one approximately 800 feet north of the proposed pile location and one approximately 1700 feet to the south. These washes merge with Indian Creek 0.1 to 0.5 mile below the site. Indian Creek flows into Kannah Creek four to five miles below the ephemeral wash confluences, and Kannah Creek empties into the Gunnison River approximately two miles below the Indian Creek confluence. Figure F.1.4 shows the surface drainage characteristics of the Cheney Reservoir site.

An area of approximately 240 acres drains toward the Cheney Reservoir site. Slopes in the watershed range from two to five percent. Elevations range from 5250 feet to approximately 5600 feet above mean sea level. The maximum flow length is approximately 8000 feet.

Table F.1.2 Maximum recorded streamflow of the Colorado River
near Grand Junction, Colorado

Station name	Basin area (square miles)	Period of record	Maximum recorded peak flow (cfs)	Date
Colorado River near Colorado-Utah state line	17,843	1951-present	68,000	June, 1984
Colorado River near Fruita	197,100	1884, 1907-1923	125,000	July, 1884
Colorado River near Cameo	8050	1933-present	39,300	June, 1984
Colorado River near DeBeque	7370	1966-present	32,000	June, 1984
Colorado River below Glenwood Springs	6013	1966-present	31,200	June, 1984



Soils in the watershed range from fine-grained, strongly cemented sandy, clayey silts in the site area to basalt cobbles and boulders in a fine-grained matrix of clay, silty sand, and gravel at higher elevations (above 5400 feet). Large boulders, probably deposited by glacial streams or colluvial processes, are present in some of the larger ephemeral washes in the vicinity of the site. Vegetation is sparse, consisting mainly of sagebrush and grasses.

Sheet wash and rill wash are the primary erosive forces currently active on the Cheney Reservoir site. Minor gullyng is occurring on the small ephemeral washes that flank the site. Moderate to intense gullyng was observed along Indian Creek. Most of the Cheney Reservoir site is classified as having only a moderate potential for future erosion (CGS, 1982). A detailed geomorphic description of the disposal site is provided in Appendix E, Soils, Geologic, and Seismic Information.

No data exist on historical floods for the Cheney Reservoir site.

F.1.1.3 Two Road alternate disposal site

The Two Road site is located in the Upper Colorado subbasin of the Colorado River basin. There are no major streams, lakes, springs, or irrigation ditches on or within two miles of the Two Road site. Several ephemeral creeks occur in the area. The site lies on a drainage divide between two unnamed ephemeral creeks. These creeks join Bitter Creek 0.5 to one mile below the site. McDonald Creek flows approximately 1.5 miles east of the site. West Salt Wash and Badger Wash combine approximately six miles southeast of the disposal area. The Colorado River flows over 10 miles south of the site.

An area of only 35 acres drains toward the site. Elevations in the watershed range from 4945 to 4965 feet above mean sea level.

The surface of the Two Road site is gently rolling, and covered by short grasses and shrubs. Deeply incised gullies are not present at the site, but flank it approximately 1500 feet to the east and west. Due to the narrow highland character of the site, it is subject to erosion by gully systems advancing headward into the site from all sides; however, the surface of the site is supported by resistant pediment gravels which cap the underlying Mancos Shale. Erosion occurs along slopes where the less resistant Mancos Shale is exposed. A detailed geomorphic description of the disposal site is provided in Appendix E, Soils, Geologic, and Seismic Information. Drainage characteristics of the Two Road site are shown in Figure F.1.5.

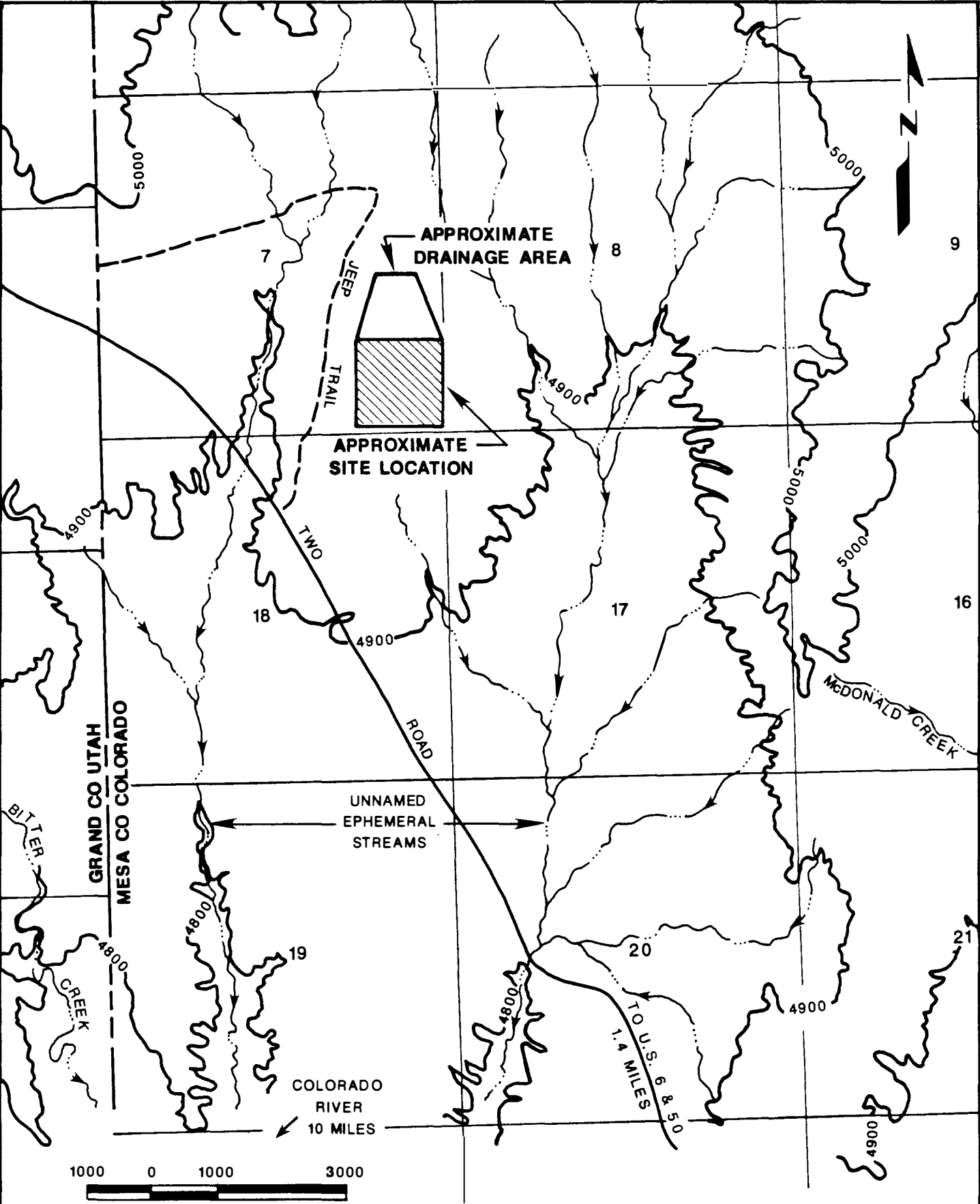


FIGURE F.1.5
SURFACE DRAINAGE CHARACTERISTICS, TWO ROAD SITE

No data on historical floods exist for the Two Road site.

F.1.1.4 Borrow sites

The 32 and C $\frac{1}{2}$ Roads borrow areas are located on private land along the south bank of the Colorado River east of the Grand Junction tailings site. The area is approximately 80 to 120 feet above the river surface. Four ephemeral channels drain Central Orchard Mesa in the borrow site area, two on either side of 32 Road. The discussion on Colorado River flows in Section F.1.1.1 is applicable to this borrow area.

The Fruita borrow areas are also located adjacent to the Colorado River, south of the town of the Fruita, Colorado. The area is approximately 11 miles downstream of the Colorado River and Gunnison River confluence. The site is located on private land on the northeast bank of the river. The area is drained by Little Salt Wash to the northwest and Adobe Creek to the southeast. There are a number of irrigation ditches and canals in the area. Maximum stream flows from a USGS gauge located on the Colorado River near Fruita are provided in Table F.1.2.

The Unaweep Canyon borrow area is located west of the Unaweep Divide in Unaweep Canyon. West Creek flows toward the Dolores River in the vicinity of the borrow site. East of Unaweep Divide, East Creek flows towards Whitewater, Colorado, where it flows into the Gunnison River. A number of small creeks and ephemeral streams drain the upland area adjacent to Unaweep Canyon and feed East and West Creeks. Borrow site activities would be located to avoid these drainages and to minimize the potential for flooding of the site.

F.1.2 FLOOD ANALYSIS

F.1.2.1 Grand Junction tailings site

A flood analysis has been performed to assure that the remedial action design for the uranium mill tailings site at Grand Junction, Colorado, satisfactorily addresses short-term and long-term flood protection. Short-term flood protection simply 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 for compliance with floodplain and wetlands environmental review requirements in 10 CFR Part 1022. To accomplish the objective of long-term flood protection, the standard design approach of the DOE is to determine the magnitude and potential impacts resulting from a Probable Maximum Flood (PMF) event. If a design is not practical, then alternative design events or solutions are assessed.

The use of the PMF as the design flood event to achieve long-term control of uranium tailings is not clearly defined. The EPA standards (Appendix A, EPA Standards) require that control of the uranium tailings must be effective for 1000 years (to the extent reasonably achievable) and, in any case, for at least 200 years. The standards do not specifically state that a PMF event must be used for design in order to achieve the stated containment life. An analysis of exceedence probabilities for various events with respect to the containment life (Junge and Dezman, 1983) suggests that design events with a very long return period (e.g., 10,000 years) must be used to meet a long-term containment objective. However, the limited statistical data that are available cannot be extrapolated accurately to such long return periods. The generally accepted alternative, therefore, is to use maximum credible events, such as the PMF, for design purposes. Since a maximum credible event has a very small chance of being exceeded; a tailings disposal system designed to withstand these events would have a very small risk of failure and, thus, would meet both the intent and long-term containment objective of the EPA standards.

The PMF analysis, for this site, first requires the use of Hydrometeorological Report No. 49 (USDOC, 1977) to determine the appropriate Probable Maximum Precipitation (PMP) that could occur over the contributing drainage basins. The analysis then involves the consecutive use of the U.S. Army Corps of Engineers 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 100-year and 500-year discharges were estimated with a methodology developed by McCain and Jarrett (1976). As in the PMF analysis, water-surface profiles and velocities were estimated with the HEC-2 model.

100-year and 500-year floods

Estimates of the 100-year and 500-year floods were prepared in order to comply with 10 CFR Part 1022 and to compare major historic and predictable floods with the PMF estimate. Peak discharges and depths for various return intervals were approximated by use of a multiple regression analysis of flood data from stream gauges in the vicinity of the study area (McCain and Jarrett, 1976). The method is based on correlating results of Log Pearson III analysis for 90 gauging stations in the region. Of the 90 gauging stations utilized, only eight stations were for basin areas greater

than 1000 square miles. The results of the approximations are, therefore, expected to overestimate the flood peaks for large watersheds. Predicted peak flows and depths for select recurrence intervals for the Colorado River at Grand Junction are presented in Table F.1.3.

A 100-year flow of 61,600 cfs and a 500-year flow of 84,200 cfs were used for the Colorado River at the site. These flows compared favorably with the results of the U.S. Army Corps of Engineers estimate in which the 100-year and 500-year flood flows were estimated to be 63,000 and 82,000 cfs, respectively (COE, 1976). The Corps of Engineers have a revised flood study underway on the Colorado River near Grand Junction; however, the completion date of their report is beyond the expected completion date of this Environmental Impact Statement. Cross-section data prepared for their study have served as a basis in the HEC-2 model for this analysis and the PMF analysis.

Values of Mannings roughness coefficients "n" were varied to account for conveyance differences and to impose constrictions where topography alone would not adequately define flow paths. The basis of determination of n values was 0.020 to 0.025 for clear channels and 0.060 to 0.100 for floodplains including mid-channel islands. Published values for the Colorado River near Grand Junction are 0.017 to 0.040 for the main channel, and 0.035 to 0.070 for the floodplain (FEMA, 1982). Some artificially high n values were used in some of the floodplains in order to model dead spots due to constrictions.

As previously stated, highway and railroad bridges cross the Colorado River downstream of the site. Since the tailings pile was in the 100-year and 500-year floodplains even without backwater effects from the bridges and since the PMF would likely destroy the bridges before the peak would occur (the bridges would be overtopped by more than 20 feet of water) no attempt was made to model for bridge effects.

As shown in Figure F.1.6, the HEC-2 model indicates that the site is within the 100-year floodplain (Figure F.1.6 also shows HEC-2 cross-section locations). The water surface at the site varies from 4572 to 4576 along the pile with mean velocities of six to 10 fps. The approximate boundaries of the 500-year floodplain are shown in Figure F.1.7. The water surface at the site varies from 4574 to 4578 along the pile with mean velocities of six to 12 fps. The expected elevation of scour ranges from three to 3.5 feet below the present channel bottom for the 500-year event.

PMF hydrologic analysis. The PMF estimate at Grand Junction is based on a HEC-1 model of the Colorado River watershed above Rifle which was prepared as part of the design

Table F.1.3 Peak flows and depths of selected recurrence-interval floods for the Colorado River at Grand Junction with a basin area of 8150 square miles

Regression equation ^a	Standard error of ^a estimate in percent	Discharge (cfs)	Depth (feet)
$Q_{10} = 59.7A^{0.709}$	47	35,400	--
$Q_{50} = 89.1A^{0.709}$	50	52,830	--
$Q_{100} = 103A^{0.710}$	53	61,600	--
$Q_{500} = 137A^{0.713}$	65	84,200	--
$D_{10} = 1.25A^{0.261}$	25	--	13.1
$D_{50} = 1.54A^{0.254}$	34	--	15.2
$D_{100} = 1.64A^{0.254}$	36	--	16.2
$D_{500} = 1.98A^{0.239}$	44	--	17.0

^aTaken from McCain and Jarrett (1976).

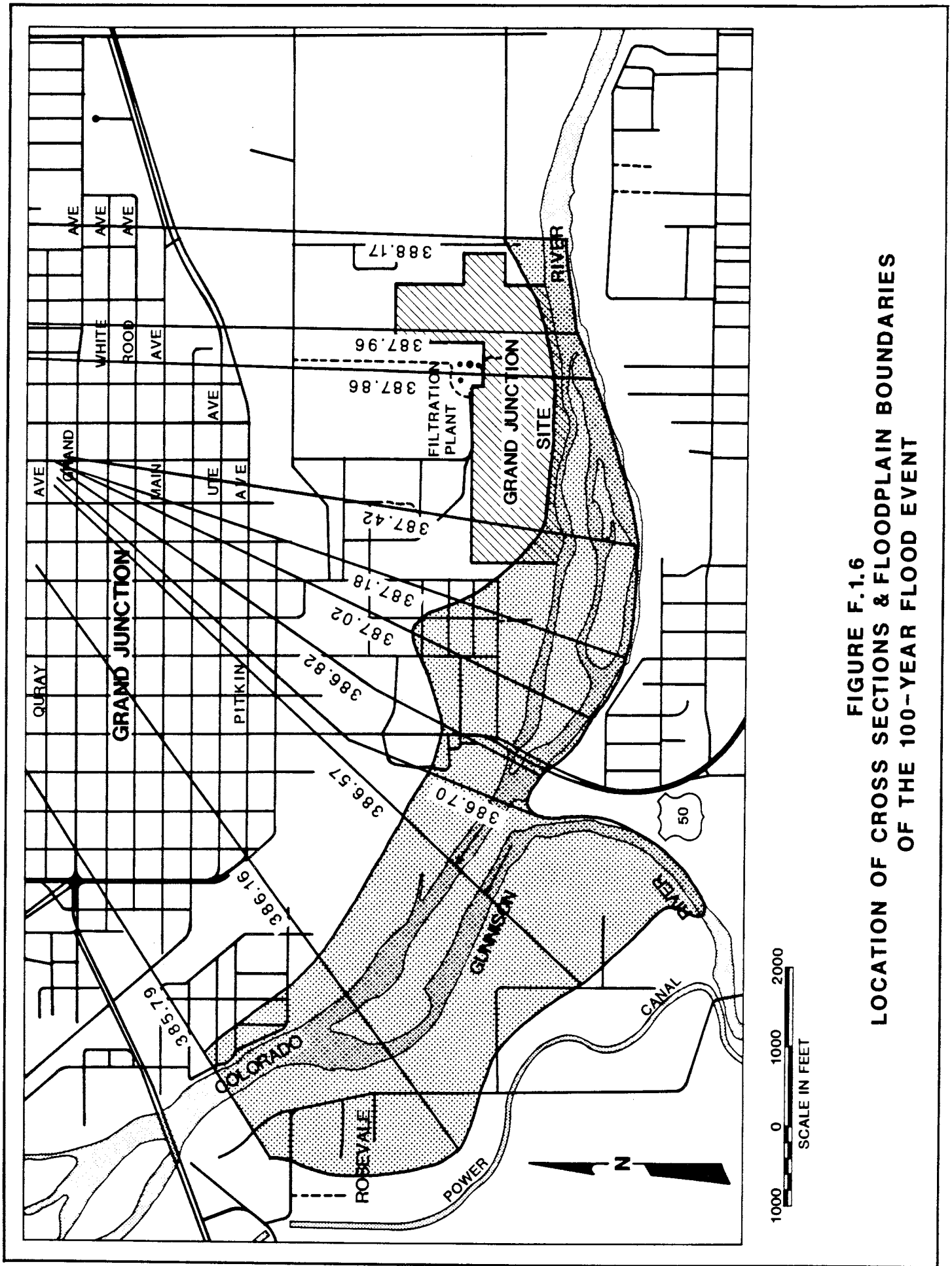


FIGURE F.1.6
LOCATION OF CROSS SECTIONS & FLOODPLAIN BOUNDARIES
OF THE 100-YEAR FLOOD EVENT

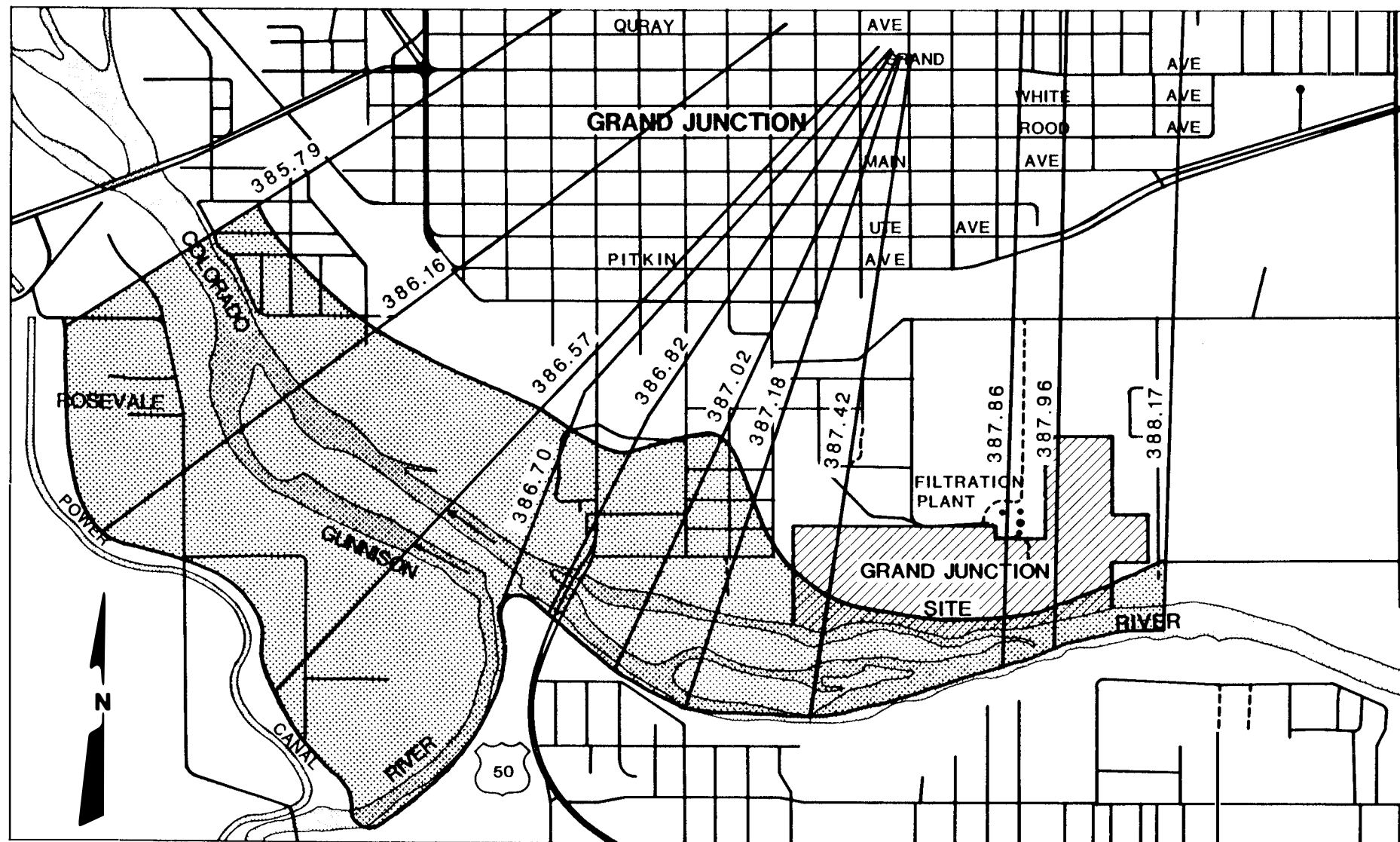


FIGURE F.1.7
LOCATION OF CROSS SECTIONS & FLOODPLAIN BOUNDARIES
OF THE 500-YEAR FLOOD EVENT

effort for the two existing tailings sites at Rifle. The larger watershed above Grand Junction was not modelled because a Probable Maximum Precipitation (PMP) could not be readily estimated with any degree of certainty. Hydrometeorological Report (HMR) No. 49 (USDOC, 1977) presents procedures for PMP estimates for the project area; however, the procedures are limited to areas of less than 5000 square miles. Extrapolating the PMP to the study area of 8150 square miles could not be done any more reliably than extrapolating the PMF from the Rifle watershed.

A description of the HEC-1 analysis for Rifle is followed by a discussion of the method used to extrapolate the Rifle PMF. The HEC-1 model is designed to simulate the runoff response of a river basin to precipitation by representing the basin as an interconnected system of hydrologic and hydraulic components. 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 PMP was determined according to procedures outlined in Hydrometeorological Report (HMR) No. 49 (USDOC, 1977). The month with the highest 72-hour precipitation was found to be June with 13.4 inches, indicating that the rainfall would likely occur on snow or on a very wet watershed. The PMP was distributed temporally by arranging three-hour incremental amounts in a sequence such that they decrease progressively to either side of the greatest three-hour increment. Since the total volume of flow is not critical in this study, only the greatest 24-hour increment of the 72-hour storm was modeled.

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

- o Overland flow and upland channel flow with velocities of 3.5 feet per second and eight feet per second, respectively, for slopes of 12 to 15 percent (DOI, 1973). Allowance was also made for detention time due to lakes and ponds.
- o Secondary channels draining areas of 42 to 103 square miles with velocities of 10 to 12 feet per second.
- o Primary channels with velocities varying from 12 to 14 feet per second.

Lag times for each subbasin are shown in Table F.1.4.

The shortest lag time is 3.8 hours, which corresponds to a time of concentration of 6.3 hours. A selection of a compu-

Table F.1.4 Lag time estimation for subbasins of the Colorado River above Rifle

Watershed	Time overland flow (hrs)	Secondary channel			Main channel			Total	
		$\frac{L}{v}$ (mi) (fps)	$\frac{L}{v}$ (mi) (fps)	$\frac{L}{v}$ (mi) (fps)	$\frac{L}{v}$ (mi) (fps)	$\frac{L}{v}$ (mi) (fps)	$\frac{L}{v}$ (mi) (fps)	T_C (hrs)	T_L (hrs)
Colorado River above Kremmling	1.6	25	10	3.7	30	12	3.7	9.0	5.4
Blue River	2.1	15	12	1.8	45	14	4.7	8.6	5.1
Colorado River between Kremmling and Dotsero	0.9	24	16	2.2	35	11	4.7	7.8	4.7
Eagle River	0.6	29	12	3.5	29	12	3.5	7.6	4.5
Roaring Fork	0.7	23	11	3.1	40	14	4.2	8.0	4.8
Colorado River near Rifle	0.5	25	11	3.3	22	13	2.5	6.3	3.8

Velocities were estimated using Mannings equation: $T_L = 0.6 \cdot T_C$

L = Length

v = velocity

t = flow time

T_C = time of concentration

T_L = Lag time

tation interval, "T", of one hour meets the criteria that it be less than $0.25 \times T_{PEAK}$ (COE, 1981),

where

$$1.7 \times T_{PEAK} = T + T_C$$

Soils in the Rifle watershed, as with those in the Grand Junction watershed, are classified by the Soil Conservation Services (SCS) as hydrologic group B interspersed with some C soils and traces of A and D soils (USDA, 1978; 1982; 1983). B and C soils have moderate to slow infiltration rates (0.08 to 0.30 inch/hour) when thoroughly wetted.

Although actual major floods are the result of rain on top of the snow pack, the volume of runoff resulting from snow melt is small in comparison to the volume of runoff resulting from the intense rainfall. However, the presence of the snow pack creates severe hydrologic soil conditions. Therefore, runoff resulting from snow melt was not estimated in the analysis because the magnitude of the PMP would make snow melt a minor component of the flood. To account for the severe hydrological conditions created by the presence of snow, no initial loss of precipitation was assumed, and a uniform loss rate based on saturated "B-C" soils of 0.20-inch per hour was selected (DOI, 1973). This value was also selected by the U.S. Army Corps of Engineers for the "C" soils in the lower basin (COE, 1976).

Flows were routed through primary channel reaches by use of the Modified Puls method available in the HEC-1 model. Reach characteristics were determined by field inspection and from topographic maps.

McCain and Jarrett (1976) found that discharge varied with area raised to a power ranging from 0.709 to 0.713 depending on the return interval. The 1984 flood discharges in the Colorado River varied with area raised to a power of 0.68. Therefore, a power of 0.70 was used for the extrapolation estimates at Grand Junction. Two PMF discharges were estimated. The first is for a PMF on the Colorado River only and the second is for a PMF on the Gunnison River and Colorado River combined. The discharges are shown in Table F.1.5.

Crippen and Bue (1977) prepared curves which envelop maximum measured flood flows for regions in the conterminous United States. Grand Junction is in Region 14 near the division with Region 13. The maximum flood peak in the Colorado River near Grand Junction is given as 130,000 cfs for Region 14 and 380,000 cfs for Region 13.

Table F.1.5 Probable Maximum Flood discharges in the Colorado River near Grand Junction, Colorado

Location	Basin area (square miles)	Discharges ^a (cfs)
Rifle	6950	795,200
Grand Junction above Gunnison River	8150	889,000
Grand Junction below Gunnison River	17,100	1,493,500

^aNotes: $Q = 795,200 \times \left(\frac{A}{6950} \right)^{0.70}$

Flow in the Colorado River above the confluence is assumed to be proportional with the 1984 flood; therefore, the flow in the Gunnison River is 630,300 cfs and the flow in the Colorado River above the confluence is 863,200 cfs.

The estimated PMF at Grand Junction of 889,000 cfs is approximately 2.5 to seven times the maximum expected discharge estimated by Crippen and Bue, 11 times the estimated 500-year peak, and 12 times the maximum recorded flow.

PMF hydraulic analysis. Hydraulic characteristics of the river at flood stage are important design considerations for stabilization of the tailings. Water surface profiles were estimated with the HEC-2 model to obtain flow depths and velocities during flood stage. These values were then used to estimate scour depths and riprap requirements. An empirical formula suitable for the Colorado River was utilized to calculate the scour depth (Pemberton and Lara, 1984):

$$D_S = Z \times d_{fo}$$

where

D_S = depth of scour below ELMIN (from HEC-2) in feet

d_{fo} = depth for zero bed sediment transport in feet

Z = 0.6, coefficient developed by the U.S. Bureau of Reclamation for use on moderate river bends

$$d_{fo} = \frac{(q_f)^{2/3}}{(F_{bo})^{1/3}}$$

q_f = design discharge per unit width in ft^3/s per foot.

F_{bo} = Blench's "zero bed factor" in ft/s^2

Values of Mannings roughness coefficients, "n", were varied to account for conveyance differences and to impose constrictions where topography alone would not adequately define flow paths. Values (n) of 0.020 to 0.025 for clear channels and 0.060 to 0.100 for floodplains including mid-channel islands were used. Published values for the Colorado River near Grand Junction are 0.017 to 0.040 for the main channel, and 0.035 to 0.070 for the floodplain (FEMA, 1982).

The Colorado River banks were extended beyond the normal bank locations to account for a dramatically different river regime during PMF conditions. It was assumed that normal floodplains would be covered at great depth, and that vegetation, buildings, and other topographic features would be submerged or removed, greatly reducing n values. As a rule, an n value of 0.025 was used where depths were greater than five feet and 0.060 where less than five feet, although some

variance from this rule occurred in order to achieve reasonable conveyance values for differing topographic conditions along the profile. Values of n in the widened channel varied from 0.022 to 0.030, while some artificially high n values were used in some of the floodplains to model dead spots due to constrictions.

A PMF occurring in only the Colorado River above the site was found to be slightly more critical than a PMF occurring in the Gunnison River and Colorado River simultaneously. At the tailings pile the velocity for a PMF of only the Colorado River was slightly greater than for the combined PMF (19.2 to 18.4 fps); however, the water surface elevation was slightly lower (4595.6 to 4595.8 feet). Upstream and downstream of the pile the situation was reversed. Therefore, the rock erosion protection and scour analysis was performed using the higher velocities encountered during a PMF of only the Colorado River. For this first condition, a floodway of 4000 to 8000 feet wide as shown in Figure F.1.8 would be required to convey the PMF. Many residential and industrial structures would be inundated, and all sides of the site would be exposed to channel flow. The peak water surface elevation was estimated to vary from 4589 to 4600 along the pile and mean channel velocities were estimated to be approximately 12 to 19 fps.

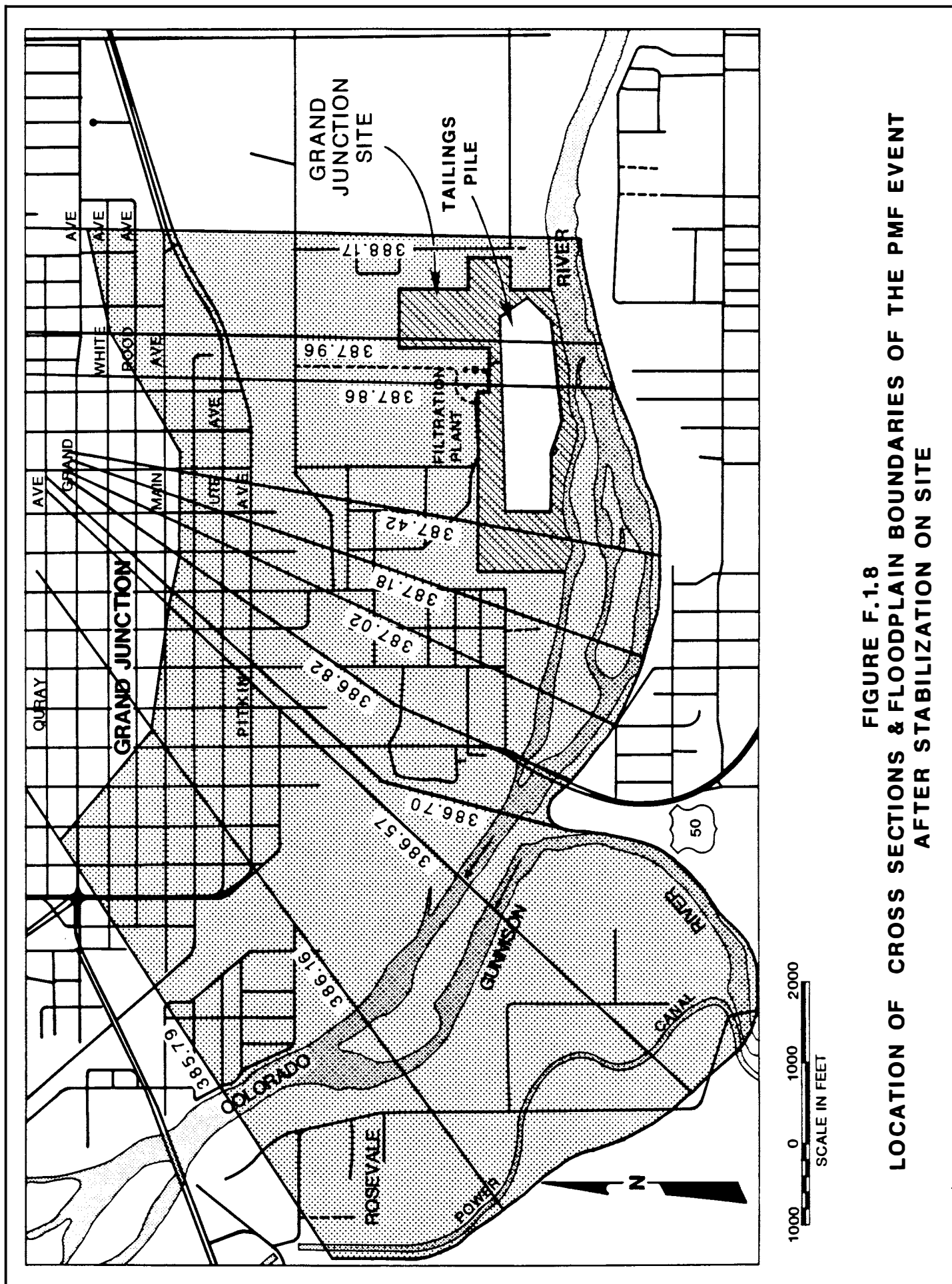
Floodway constrictions at the site cause unstable flow conditions in the form of near critical flow to occur. The river will attempt to moderate the steep energy grade slope the model shows occurring and stabilize the flow by scouring alluvium. A depth of zero sediment transport of 12.4 feet below the channel bottom was determined using the previously described equation. The expected elevation is therefore 4544.4 at station 387.42, 4547.7 at station 387.86, and 4548.7 at station 387.96. A cross-section at station 387.86 presented in Figure F.1.9 shows maximum water surface and scour elevations for the PMF event.

F.1.2.2 Cheney Reservoir alternate disposal site

There are no major streams or rivers within 2.4 miles of the Cheney Reservoir site. The site is at least five miles from the floodplain of the Gunnison River. Kannah Creek and Indian Creek flow at an elevation approximately 200 feet below the site. The Gunnison River flows approximately 500 feet below the site at its closest point.

No data on historical floods exist for the Cheney Reservoir site and because of the distance from and differences in elevation between any major flows and the site, the site is not subject to river flooding.

The effects of a PMP over the pile and the contributing drainage areas are analyzed in order to design erosion protection requirements. Preliminary calculations for the Cheney Reservoir site using very conservative assumptions, indicate



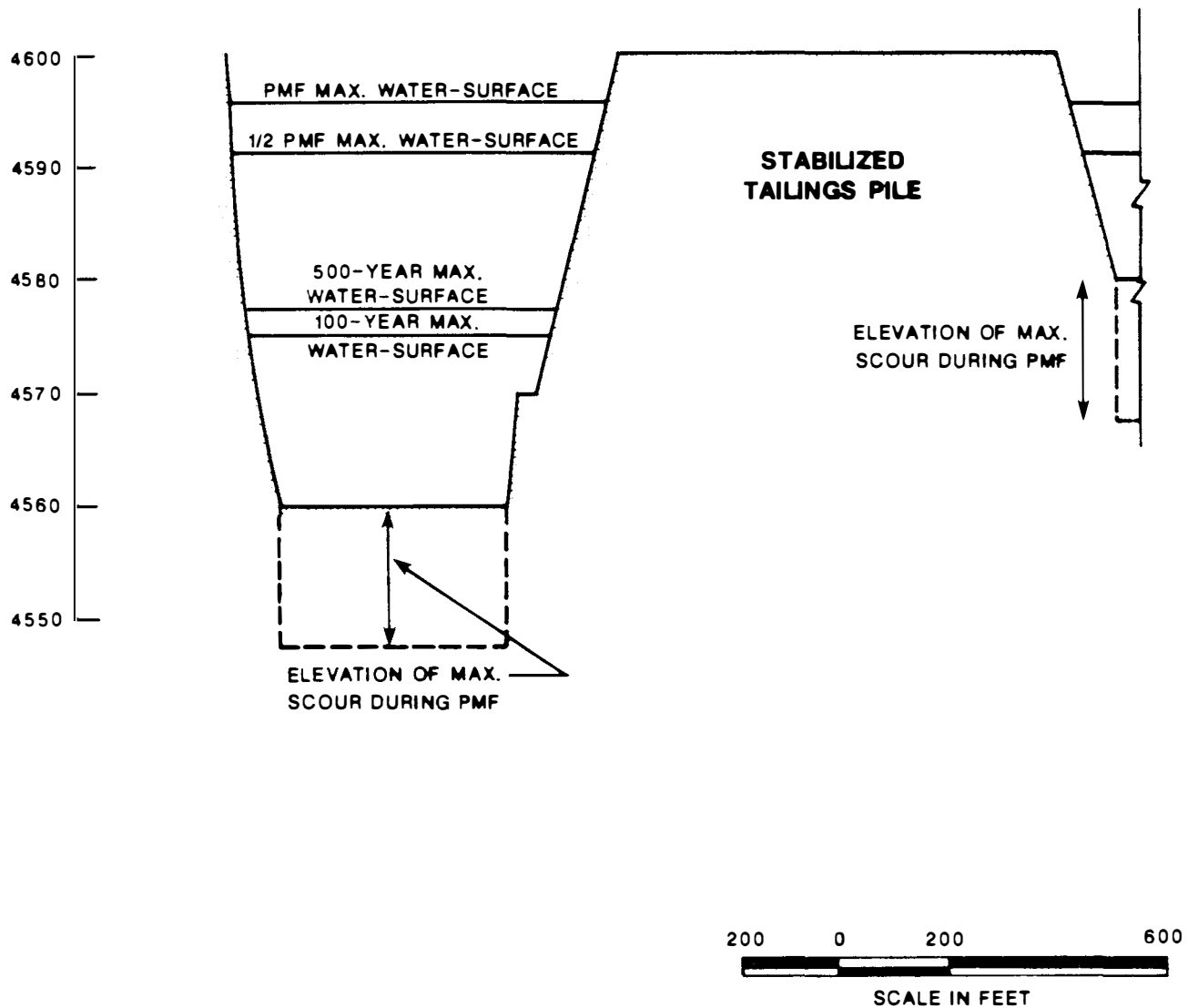


FIGURE F.1.9
CROSS SECTION AT STATION 387.86 AFTER STABILIZATION ON SITE

that the flow resulting from the occurrence of a PMP (8.5 inches in one hour) over the Cheney Reservoir watershed would be in excess of 2000 cfs. Details are provided in Appendix B, Engineering Designs.

F.1.2.3 Two Road alternate disposal site

There are no major streams or rivers in the vicinity of the Two Road site. The site is at least 10 miles from the floodplain of the Colorado River, and over 500 feet higher in elevation. The ephemeral streams in the site area, including Bitter Creek and McDonald Creek, have small watersheds and do not present a flood hazard to the site.

As with the Cheney Reservoir design, the effects of the occurrence of a PMP were analyzed to determine erosion protection requirements. Preliminary calculations indicate that a flow in excess of 350 cfs would result from the occurrence of a PMP over the Two Road site watershed. Details are provided in Appendix B, Engineering Designs.

F.1.2.4 Borrow sites

Both the Fruita and 32 and C $\frac{1}{2}$ Roads borrow areas may be affected by flooding of the Colorado River; however, a separate flood analysis of these sites would not be performed. Since the sites are on privately owned land and are either active or have been recently active, it is expected that the operator of the site would take the appropriate measures to control flooding and minimize impacts to their own structures and equipment.

Due to the high canyon walls separating the site from West Creek and the relatively small watershed above the borrow area, flood flows are not expected to impact the borrow site in Unaweep Canyon.

F.1.3 SURFACE-WATER QUALITY

F.1.3.1 Grand Junction tailings site

In general, the quality of water in the Colorado River depends on the flow, and the flow is determined by the source of water. During low-flow periods, when surface runoff is low and the river flow is basically discharged ground water, the concentration of metals and inorganics leached from the soil is high. During high-flow periods, when the river flow is mainly surface runoff, the concentration of metals and inorganics is low and the concentration of organics and suspended solids is high (DOE, 1983).

The results of measurements made at Cameo, approximately 15 miles upstream from the site, show that the mean concentra-

tions of all constituents except mercury are within the Colorado drinking-water standards; however, the maximum concentrations of many constituents (e.g., cadmium and chloride) exceed the standards. A comparison of the Cameo data with data collected at Fruita, approximately 15 miles downstream from the site, does not indicate any effects of the existing pile on the quality of river water.

It is difficult to draw any conclusions regarding the change in water quality along the Colorado River; however, certain observations are possible. For example, mixing of the Gunnison River, which has a flow approximately equivalent to that of the Colorado River, results in decreases in chloride and molybdenum concentrations in the Colorado River and increases in the concentrations of selenium, fluoride, sulfate, and total dissolved solids. The concentration of total iron appears to increase significantly along the Colorado River independent of the mixing with Gunnison River water.

Additional discussions on water quality are provided in Section F.2, Ground Water.

F.1.3.2 Cheney Reservoir alternate disposal site

No surface-water quality data exist for the ephemeral streams in the vicinity of the Cheney Reservoir site. Limited data exist for Kannah Creek and the Gunnison River downgradient of the site; however, these data indicate that the quality of these bodies is influenced more by ground-water recharge than the flow that enters from the small creeks and ephemeral streams in the Cheney Reservoir disposal site area. A detailed discussion of the quality of the ground water in the Cheney Reservoir site area is included in Section F.2, Ground Water.

F.1.3.3 Two Road alternate disposal site

No water-quality monitoring gauging stations exist on any of the creeks or ephemeral streams in the Two Road alternate disposal site area. Data taken on West Salt Creek east of the site indicate that the major chemical constituents of the water are sodium, magnesium, calcium, and sulfate. During flow events TDS values were high, ranging from several hundred mg/l to over 10,000 mg/l. It is expected that the water quality during flow events would be similar in the drainages adjacent to the site (URS, 1983).

F.1.3.4 Borrow sites

The discussion on water quality of the Colorado River (Section F.1.3.1) is also applicable to the Fruita and 32 and C½ Roads borrow areas. No water-quality data exist for the streams and creeks in the vicinity of the Unaweep Canyon borrow area.

F.2 GROUND WATER

F.2.1 INTRODUCTION

EPA standards (40 CFR Part 192) require site 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 CFR 32274)." Based on these two sets of requirements, it has been determined that fourteen primary items must be addressed during a ground-water characterization at an UMTRA Project site (Brinkman et al., 1985). These fourteen items are:

- o Applicable water-quality standards.
- o Characterization of the potentially affected hydrogeologic environment.
- o Proximity of the site to surface water.
- o Physical and chemical characterization of waste in terms of contaminant migration in ground water and hydraulically connected surface water.
- o Effect of climate on the movement of contaminants.
- o Impact of contaminant sources other than those attributable from the UMTRA Project site.
- o Proximity, withdrawal rates, uses, and sources of presently used water.
- o Present value of affected water resource.
- o Availability of alternate water supplies.
- o Potential and expected use of affected resource.
- o Future value of affected water resource.
- o Potential health risks to humans and potential damage to wildlife, crops, and vegetation caused by exposure to contaminants in ground or surface water.
- o Persistence and permanence of adverse effects.
- o Aquifer restoration or protection.

Following is a discussion of these fourteen items, for the processing site and alternate disposal sites.

F.2.2 APPLICABLE WATER-QUALITY STANDARDS

The Grand Junction uranium mill tailings are located in Colorado. There are two sets of water-quality standards applicable to characterization of affected or potentially affected ground-water systems: Federal and State of Colorado. Federal and State of Colorado drinking water standards are shown in Table F.2.1. The State of Colorado has no ground-water quality standards in place at this time, but has proposed standards for ground water. Colorado surface-water and proposed ground-water quality standards are based on a classification system which establishes use categories. Both standards include an antidegradation standard which protects existing use classifications of waters, thereby protecting both existing and potential uses of water.

Applicable surface-water quality standards for the State of Colorado are shown in Table F.2.2. In addition, all surface waters of the Colorado River Basin are subject to a policy for uranium. This can be summarized as:

- o Uranium levels in surface waters shall be maintained at the lowest practicable level.
- o In waters assigned a water supply classification, uranium concentration shall not exceed 40 pCi/l. The Colorado River from immediately below the confluence with Parachute Creek to immediately above the confluence of the Gunnison River is assigned a water supply classification (CDH, 1983).

Table F.2.1 State of Colorado and EPA National Interim Drinking Water Standards (40 CFR 141,143)

Parameter	EPA Drinking water standards ^a		Colorado ^b primary drinking water standards ^a
	Primary	Secondary	
Arsenic	0.05	--	0.05
Barium	1.0	--	1.0
Cadmium	0.01	--	0.010
Chromium	0.05	--	0.05
Copper	--	1.0	--
Fluoride	1.4-2.4 ^c	--	1.4-2.4 ^c
Lead	0.05	--	0.05
Mercury	0.002	--	0.002
Nitrate	10.0	--	10.0
Selenium	0.01	--	0.01
Silver	0.05	--	0.05
Zinc	--	5.0	--
Chloride	--	250.0	--
Iron	--	0.3	--
Manganese	--	0.05	--
pH (standard unit)	--	6.5-8.5	--
Sulfate	--	250.0	--
TDS	--	500.0	--
Uranium (health advisory level) (in picocuries per liter)	10.0	--	--
Radium 226-228 combined (in picocuries per liter) ^d	5.0	--	--
Gross alpha (in picocuries per liter)	15.0	--	--
Gross beta (health advisory level) ^e (in picocuries per liter)	50.0	--	--

^aAll values in mg/l unless otherwise noted.

^bRef. CDH, 1981.

^cStandard varies depending on water temperature.

^dDoes not include uranium or radon.

^eFor man-made radionuclides.

Table F.2.2 State of Colorado surface-water standards for water-quality parameters of interest^a

(Permissible concentration mg/liter)			
Constituent	Colorado River between Parachute Creek and Gunnison River	Colorado River between Gunnison River and Colorado- Utah state line	Tributaries between Parachute Creek and Colorado- Utah state line ^b
Aluminum, soluble	0.1 ^c	0.1 ^c	--
Ammonia	0.06	0.06	--
Arsenic	0.05	0.05	0.1 ^d
Cadmium	0.0017	0.001	0.01 ^d
Chloride	250		
Copper	0.018	0.012	0.2 ^d
Iron			
soluble	0.3		--
total	1.0	1.5	
Lead	0.025	0.025	0.1 ^d
Manganese			
soluble	0.05		
total	1.0	1.0	0.2 ^d
Mercury	0.00005	0.00005	--
Selenium	0.02	0.02	0.02 ^d
Sulfate	250	--	--
Zinc	0.07	0.085	2.0 ^d
pH(standard unit)	6.5-9.0	6.5-9.0	6.5-9.0

^aNo numerical standards have been established by the State of Colorado for calcium, carbonate, molybdenum, sodium, and vanadium. A dash indicates that the permissible concentration is to be established on a case-by-case basis, by the Colorado Department of Health.

^bExcept Wallace, Roan, Plateau, and Rapid Creeks and Little Dolores River.

^cColorado Water Quality Standards, Part 1, Table III, Aquatic Life Class I, April, 1981.

^dColorado Water Quality Standards, Part 1, Table III, Agricultural Uses, April, 1981.

F.3 POTENTIALLY AFFECTED HYDROGEOLOGIC ENVIRONMENT-PROCESSING SITE

F.3.1 CHARACTERIZATION OF HYDROGEOLOGIC ENVIRONMENT

F.3.1.1 Previous investigations

Several previous investigators have reported on regional and site-specific hydrogeology in the vicinity of the Grand Junction tailings site. The U.S. Geological Survey conducted a national study on the distribution of uranium and radium in ground water (Scott and Barker, 1962). The U.S. Geological Survey investigated the geology and artesian water supply of the Grand Junction area (Lohman, 1965). The U.S. Bureau of Reclamation has studied shallow ground water in the Grand Valley as part of the Colorado River Water Quality Improvement Program. The Bureau of Reclamation published a report for Phase I of its study, for the area surrounding Fruita; however it has not yet published a report for the area surrounding Grand Junction. Data from this study include stratigraphic information, water-quality analyses, and water-level measurements (U.S. Bureau of Reclamation, no date).

Surface water has also been studied on both a regional and a site-specific basis for the Grand Junction tailings environment. The EPA monitored concentrations of radionuclides along the Colorado River mainstream both upstream and downstream of the Grand Junction tailings from 1961 through 1972 (EPA, 1973). The U.S. Geological Survey also reports water-quality data for the Colorado River Basin (USGS, various dates). The occurrence of molybdenum, a substance associated with uranium mill tailings, has been studied for the surface waters of Colorado (Voegeli and King, 1969). On a site-specific basis, an assessment was made of the potential for contamination of the Colorado River by the Grand Junction tailings (Bush et al., 1980).

Extensive research connected with low-level nuclear waste disposal and the UMTRA Project has centered on or included the Grand Junction tailings. Ambient soil moistures were reported for the Grand Junction area (Rogers et al., 1981). Research on cover design has included studies on movement of water in the unsaturated zone of the Grand Junction tailings (Beedlow, 1984; Mayer et al., 1981).

The geochemistry of the tailings and of the ambient environment has been extensively interpreted (Markos and Bush, 1983a) and reported (Markos and Bush, 1983b), including statistical evaluation of contaminant transport mechanisms (Bush and Markos, 1982). A geotechnical characterization of the tailings included extensive information on stratigraphy, water levels, and hydraulic properties (Nelson and Wardwell, 1982).

Ford, Bacon, and Davis Utah, Inc. (FBDU) reported on the site-specific hydrogeology and hydrogeologic setting of the tailings at a reconnaissance level, and also reported limited site-specific data (FBDU, 1981; FBDU, no date). A site-specific study of the hydrogeology of the tailings and the surrounding area was based on an extensive field program (Doty and Versaw, 1984).

Additional data relating to the area surrounding the tailings were gathered from various investigators. Geotechnical borings for the Highway 50 bridge were obtained from the State of Colorado Department of Highways, (Colorado Department of Highways, 1964), and helped to define the stratigraphy of the area. Drillers logs for the Grand Junction area were obtained from the State of Colorado (Colorado Division of Water Resources, no date), although these provided little information not reported by the U.S. Geological Survey (Lohman, 1965).

F.3.1.2 Recent investigations

Recent investigations have included exploratory drilling, hydraulic testing, monitoring well installation, and water sampling in two phases. The first phase was begun with drilling in October, 1982, to January, 1983, and February and March, 1985.

In the first phase, eight exploratory borings were drilled and sampled for stratigraphic logging and to obtain samples for laboratory testing. An additional 10 borings were drilled for the installation of monitoring wells.

In the second phase, 23 borings were drilled and sampled for stratigraphic logging. Packer-permeability tests were conducted in three of the borings. Monitoring wells were installed in 22 of the borings. Well-construction details for both phases are presented in Table F.3.1, and monitoring well locations are presented in Figure F.3.1.

All field and laboratory work was performed in accordance with standard operating procedures. The first phase was conducted in accordance with a Work Plan for geotechnical and ground-water hydrology work (Golder Associates, 1982). The second phase was performed in accordance with standard operating procedures on file with the DOE UMTRA Project Office in Albuquerque, New Mexico.

F.3.1.3 Stratigraphy

The stratigraphy at the processing site has been defined through a series of borings (Figures F.3.1 through F.3.9). The

Table F.3.1 Grand Junction processing site borehole and well information

LOCATION ^a ID	NORTH ^b COORDINATE	EAST ^b COORDINATE	WELL DIAMETER [IN.]	TOTAL DEPTH [FT.]	SURFACE ELEVATION [FTMSL]	TOP OF CASING [FTMSL]	SCREENED INTERVAL		BOREHOLE DEPTH [FTFD]
							BEG DP [FTFD]	LENGTH [FT.]	
581	59439.6	33674.9	2.000	31.00	4585.20	4586.33	27.00	4.0	35.00
582	59310.4	33151.8	2.000	43.20	4585.30	4586.22	35.70	7.5	42.50
583	59316.8	33141.5	2.000	33.73	4585.10	4587.04	28.73	5.0	32.00
584	59321.0	33153.8	2.000	26.70	4585.40	4586.73	24.70	2.0	25.50
585	59179.4	32541.9	2.000	13.90	4566.00	4567.38	11.90	2.0	13.50
586	59191.9	32539.8	2.000	9.50	4566.20	4567.77	5.50	4.0	8.70
587	60599.9	34829.2	4.000	13.10	4575.00	4575.00	7.60	5.5	15.50
588	59447.6	35959.7	4.000	17.90	4571.50	4571.45	7.90	10.0	17.00
589	59399.1	31876.9	4.000	17.90	4566.80	4566.84	5.90	12.0	18.00
590	59531.2	31295.8	4.000	15.20	4564.70	4566.19	7.20	8.0	15.50
591	59404.6	32728.1			4581.60				20.00
592	59215.1	33788.2	2.000	34.90	4590.90	4592.80	29.90	5.0	33.00
593	59245.2	34957.7			4589.60				27.00
594	59789.8	34559.6	2.000	61.40	4612.40	4614.34	56.40	5.0	59.50
595	59845.7	33863.1	2.000	25.30	4579.80	4583.31	20.30	5.0	21.80
596	59767.3	32805.2	2.000	23.40	4581.60	4583.00	18.40	5.0	22.00
597	59530.7	34098.0	2.000	39.60	4596.70	4598.30	34.60	5.0	38.00
710 ^c	59541.5	36658.1	72.000	40.00	4574.35	4574.35			40.00
711 ^d	58650.0	49280.0		24.50	4600.00	4601.00			23.50
712 ^d	60780.0	49410.0		30.80	4608.00	4608.80			30.00
724	59894.5	31371.5	2.000	143.00	4564.70	4566.50	131.00	10.0	142.00
725	59394.9	31268.0	2.000	101.00	4566.80	4567.30	69.00	30.0	140.00
726	59393.0	31257.3	4.000	141.00	4566.80	4566.83	110.50	30.0	140.00
727	59380.3	31265.3	2.000	56.20	4566.40	4567.10	44.00	10.0	55.20
728	59518.5	31296.1	2.000	19.00	4565.00	4565.38	12.00	5.0	17.00
729	59738.7	32572.3	2.000	67.00	4565.30	4567.21	55.00	10.0	65.00
730	60200.0	33200.0			4575.00				67.00
731	60671.6	29820.3	2.000	36.50	4559.70	4561.34	25.50	10.0	46.00
732	60659.1	29817.6	2.000	23.00	4559.50	4561.80	16.00	5.0	21.00
733	60997.4	28704.7	2.000	23.00	4556.40	4558.00	16.00	5.0	21.00
735	60211.6	31261.7	2.000	40.00	4564.70	4566.36	26.00	10.0	50.00
736	60197.9	31270.5	2.000	17.00	4564.70	4566.50	10.00	5.0	15.00
737	61898.9	32967.7	2.000	29.00	4575.30	4577.30	22.00	5.0	27.00
738	60039.1	30049.4	2.000	20.00	4561.00	4563.60	13.00	5.0	18.00
739	60273.6	31970.1	2.000	32.00	4572.90	4574.90	25.00	5.0	30.00
740	59908.3	32001.1	2.000	19.00	4566.10	4568.11	12.00	5.0	17.00
741	60796.0	33048.8	2.000	47.00	4572.90	4574.64	35.00	10.0	45.00
742	60774.6	33047.2	2.000	25.00	4572.70	4574.78	18.00	5.0	23.00
743	59491.7	37069.7	2.000	37.00	4575.10	4576.70	25.00	10.0	35.00
744	59492.2	37051.3	2.000	17.00	4574.80	4576.78	10.00	5.0	15.00
745	61040.0	36958.2	2.000	22.00	4579.40	4581.31	15.00	5.0	20.00
746	62365.1	35806.3	2.000	26.90	4586.90	4588.50	19.60	5.0	25.00
747	60207.8	36378.8	2.000	19.00	4574.30	4576.07	12.00	5.0	17.00

^a 581-590 correspond to GWGJ-1 through GWGJ-10 in DOE(1983); 591-597 correspond to GGJ-1 through GGJ-7 in DOE(1983).

^b Site coordinate system is based on a truncation of modified Colorado coordinate system.

^c 710 is an industrial drainage well.

^d 711 and 712 are U.S. Bureau of Reclamation monitoring wells.

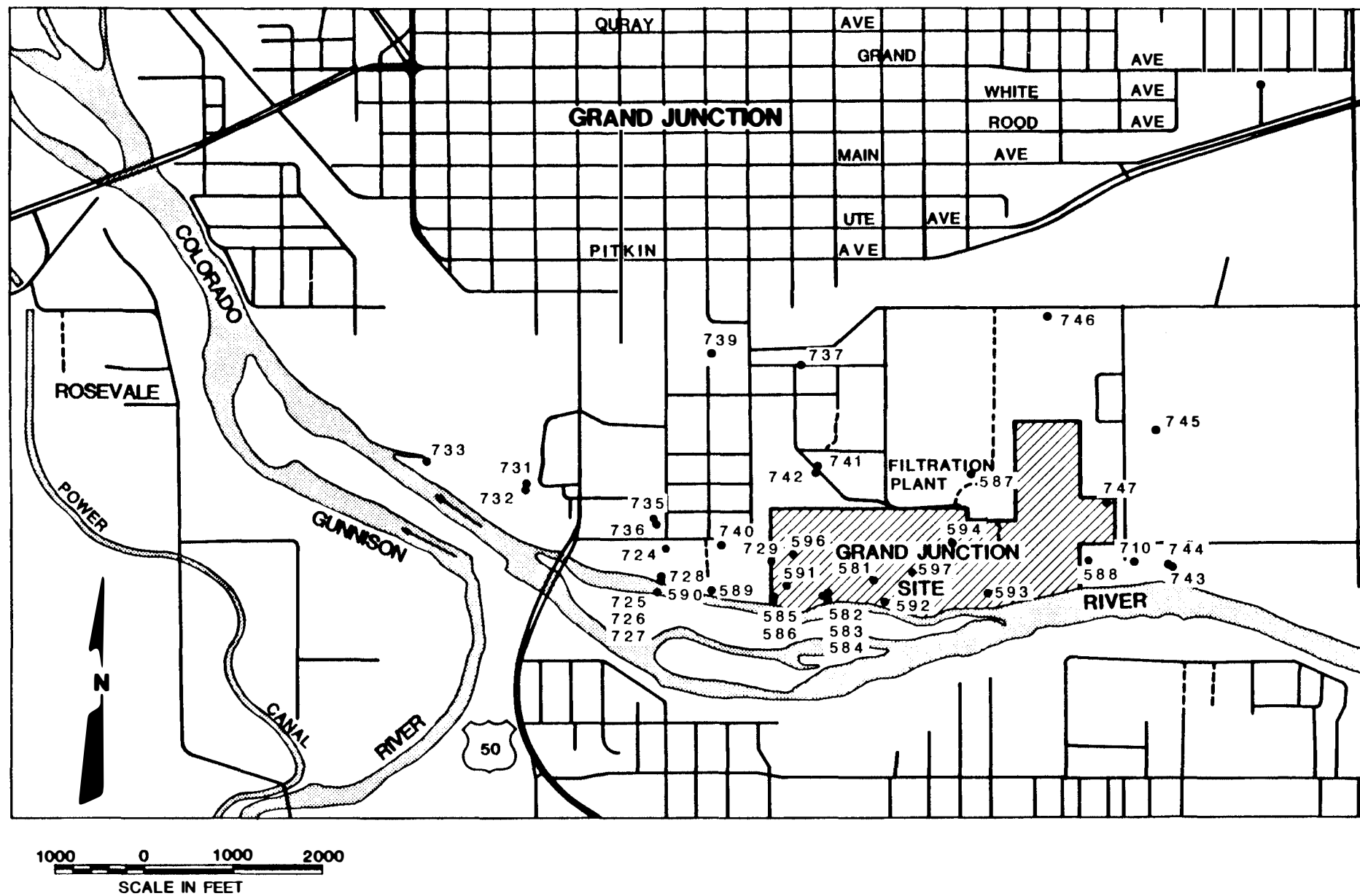


FIGURE F.3.1
MONITORING WELL LOCATIONS NEAR GRAND JUNCTION SITE

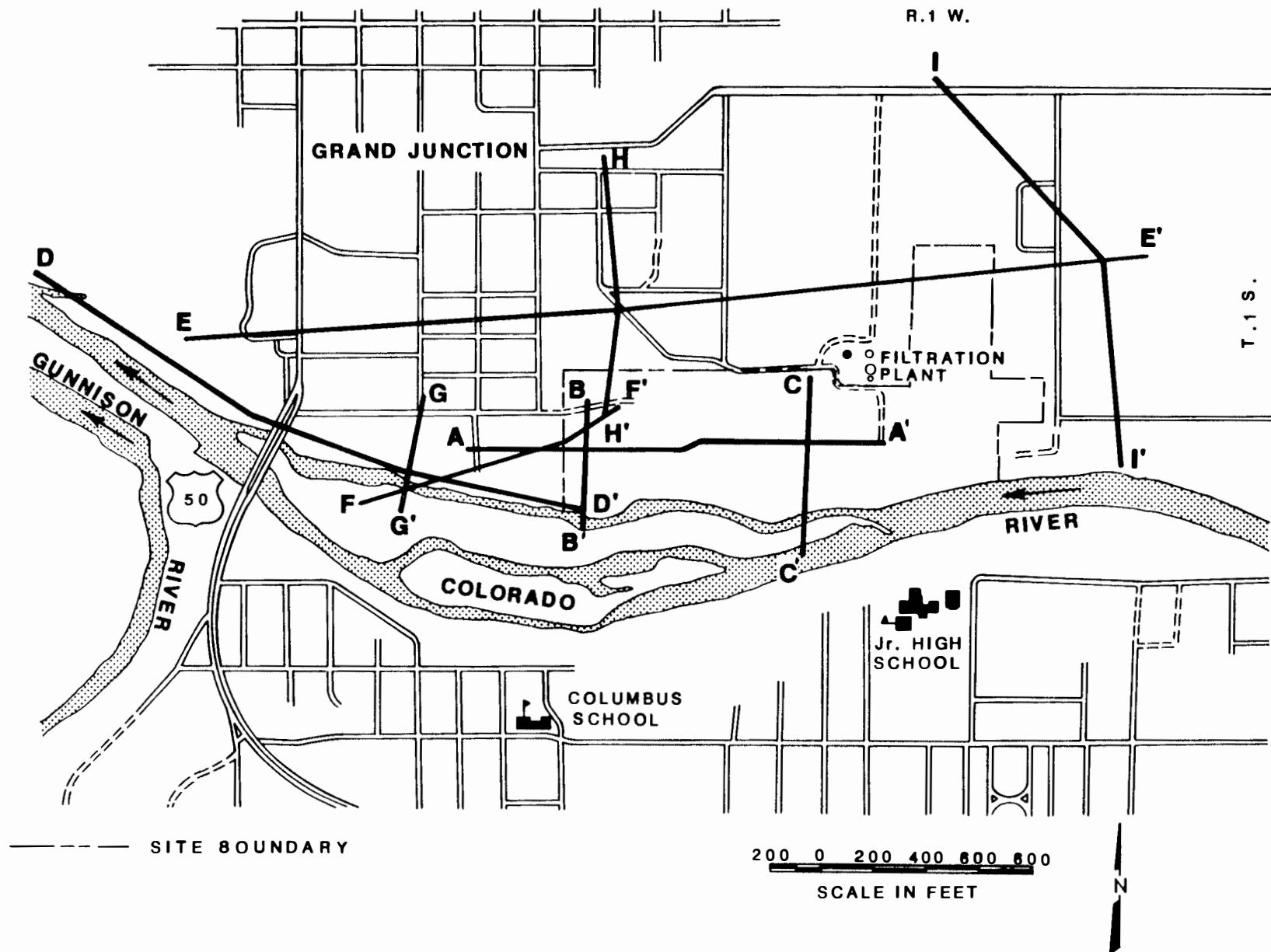


FIGURE F.3.2
CROSS-SECTION LOCATIONS FOR PROCESSING SITE

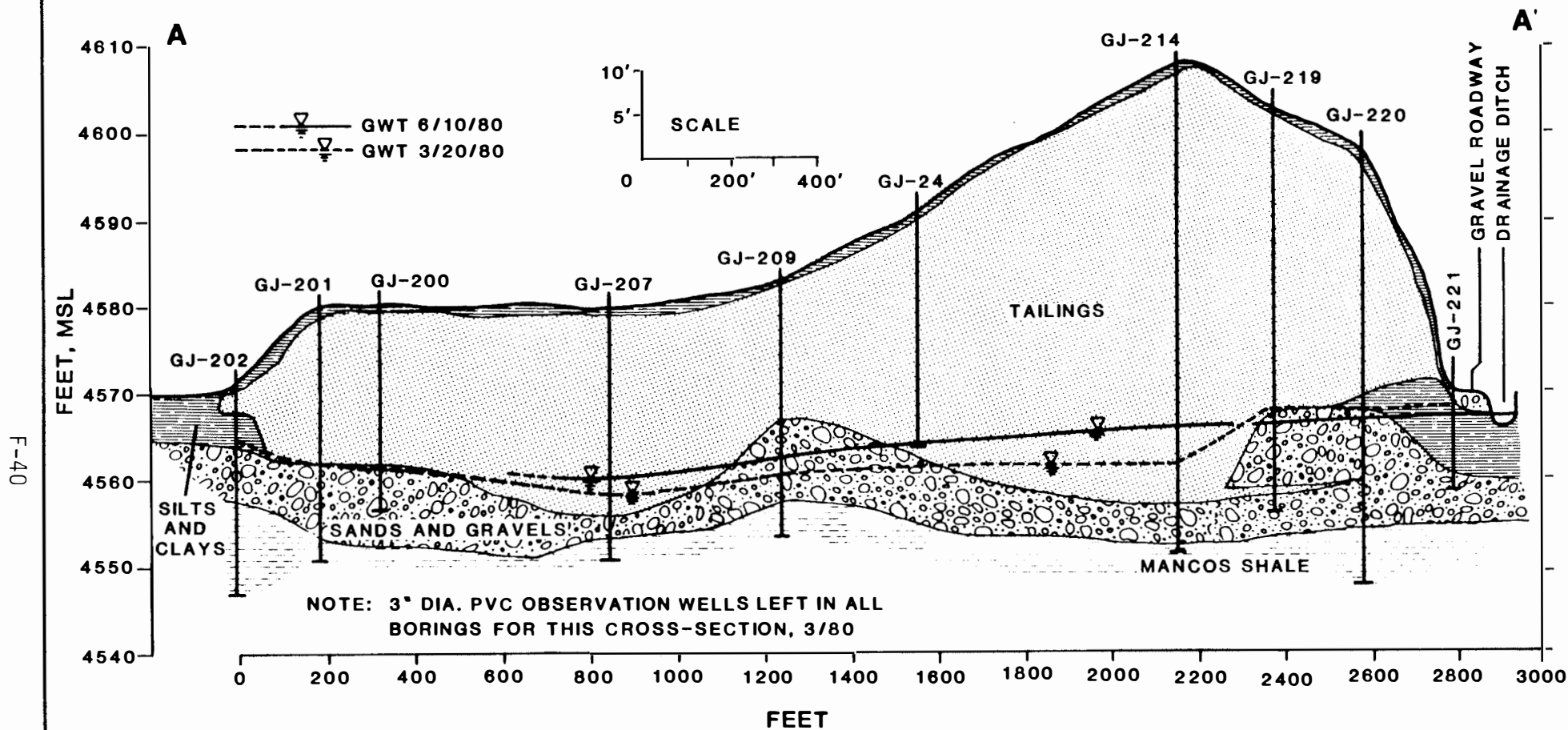
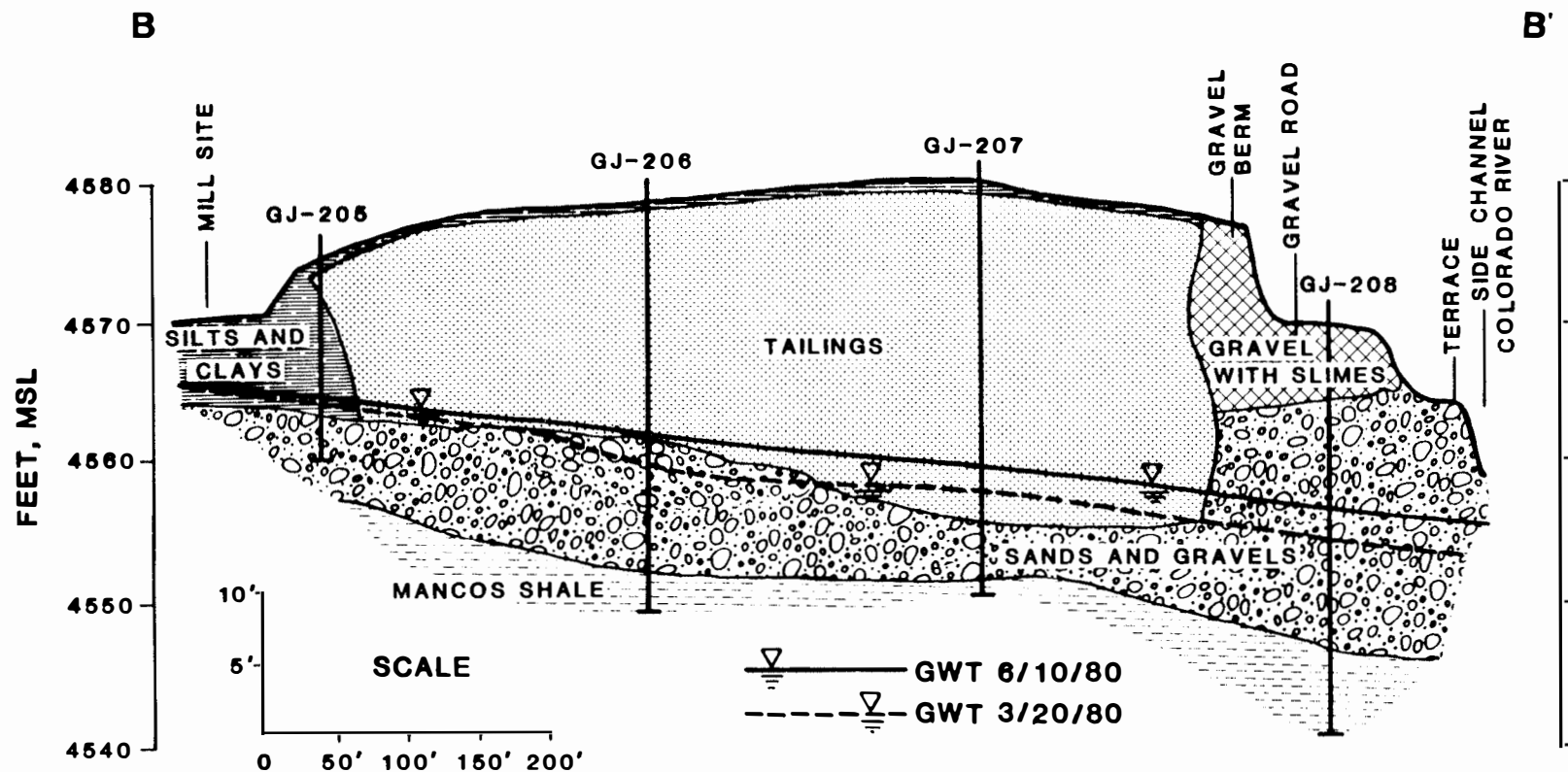


FIGURE F.3.3
GEOLOGIC CROSS SECTION: SECTION A-A'

REFERENCE: NELSON AND WARDWELL (1982)



NOTE: 3" DIA. PVC OBSERVATION WELLS LEFT IN ALL BORINGS FOR THIS CROSS-SECTION, 3/80

FIGURE F.3.4
GEOLOGIC PROFILE: SECTION B-B'

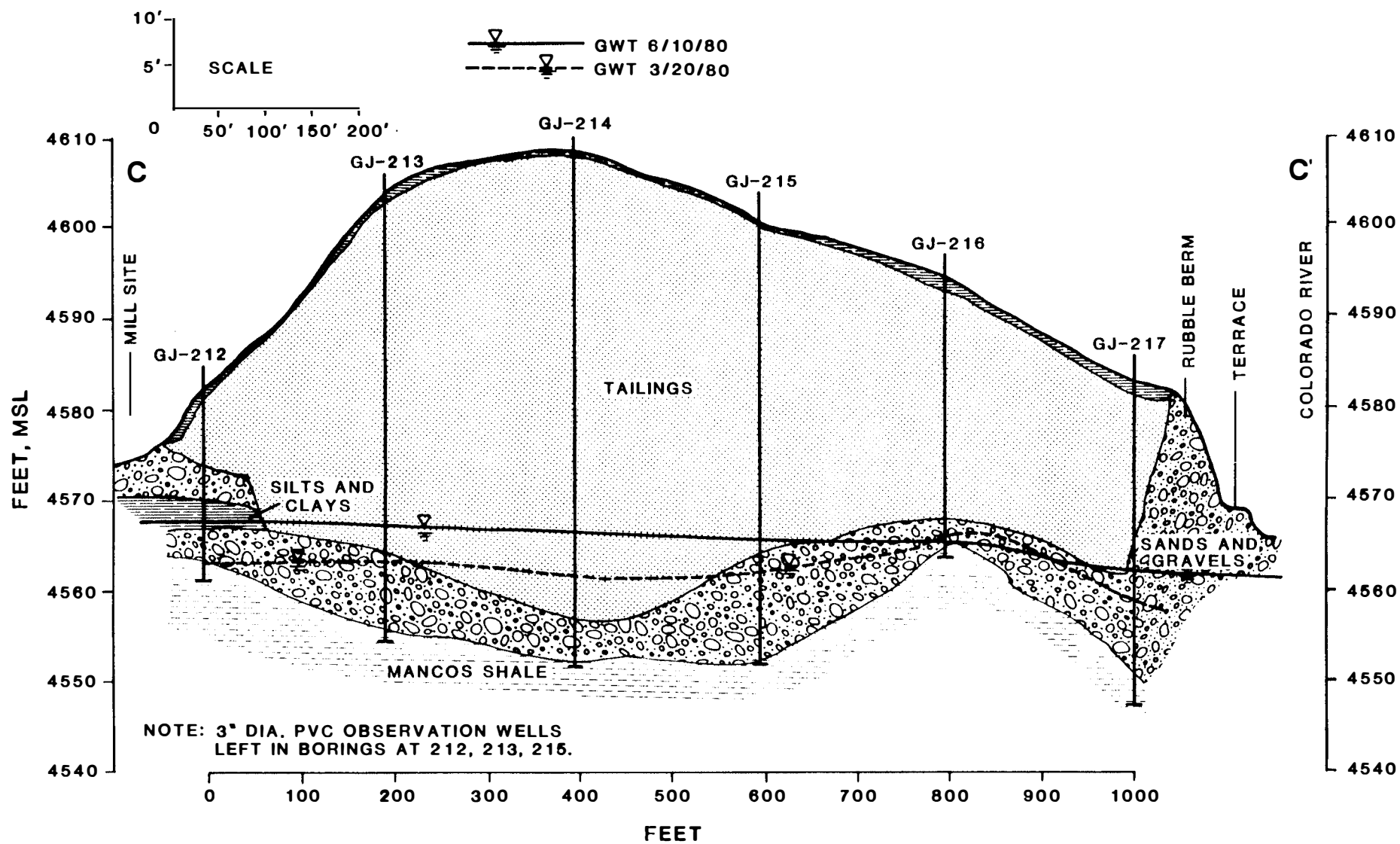


FIGURE F.3.5
GEOLOGIC PROFILE: SECTION C-C'

REFERENCE: NELSON AND WARDWELL (1982)

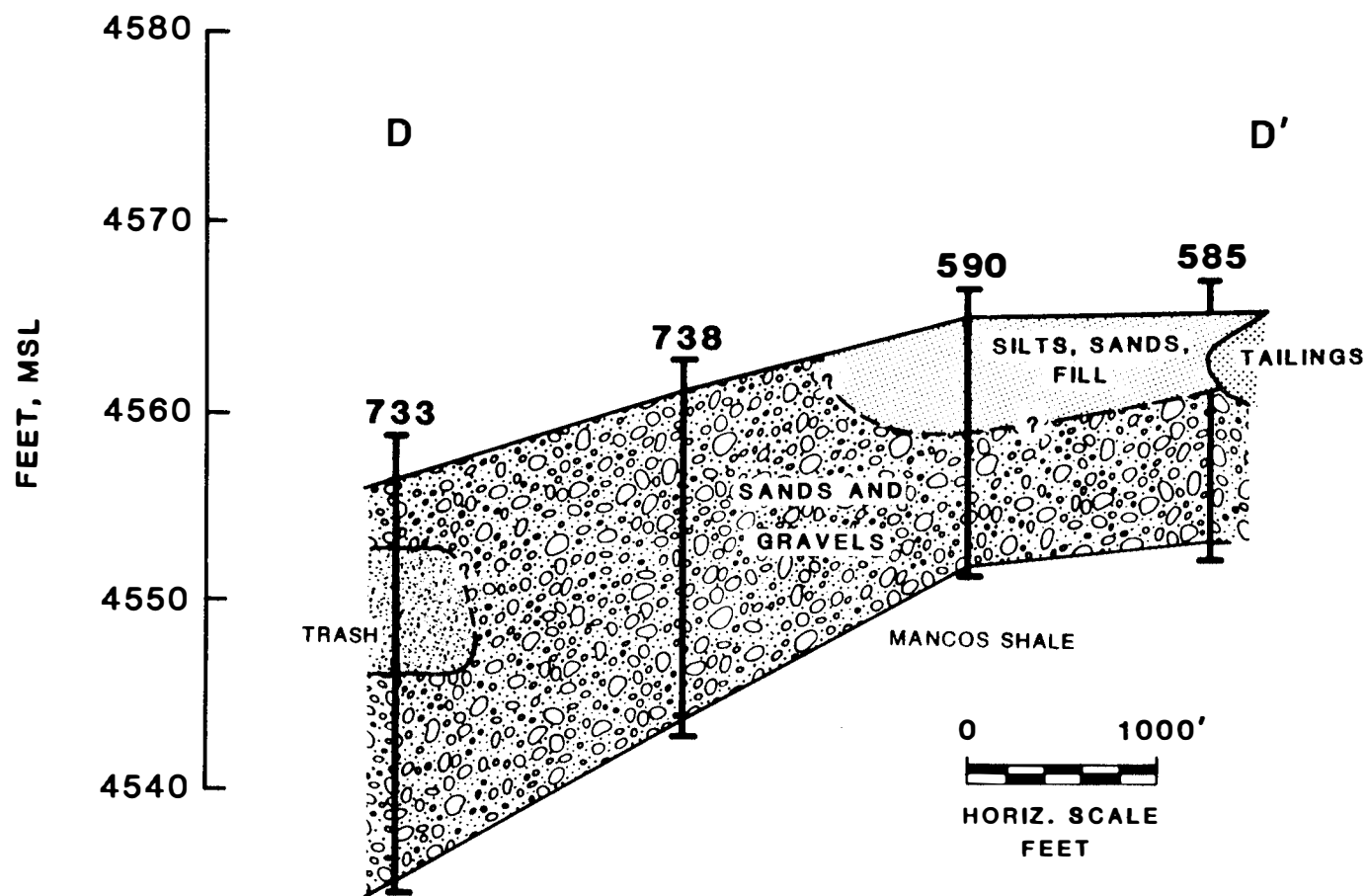


FIGURE F.3.6
GEOLOGIC CROSS SECTION D-D'

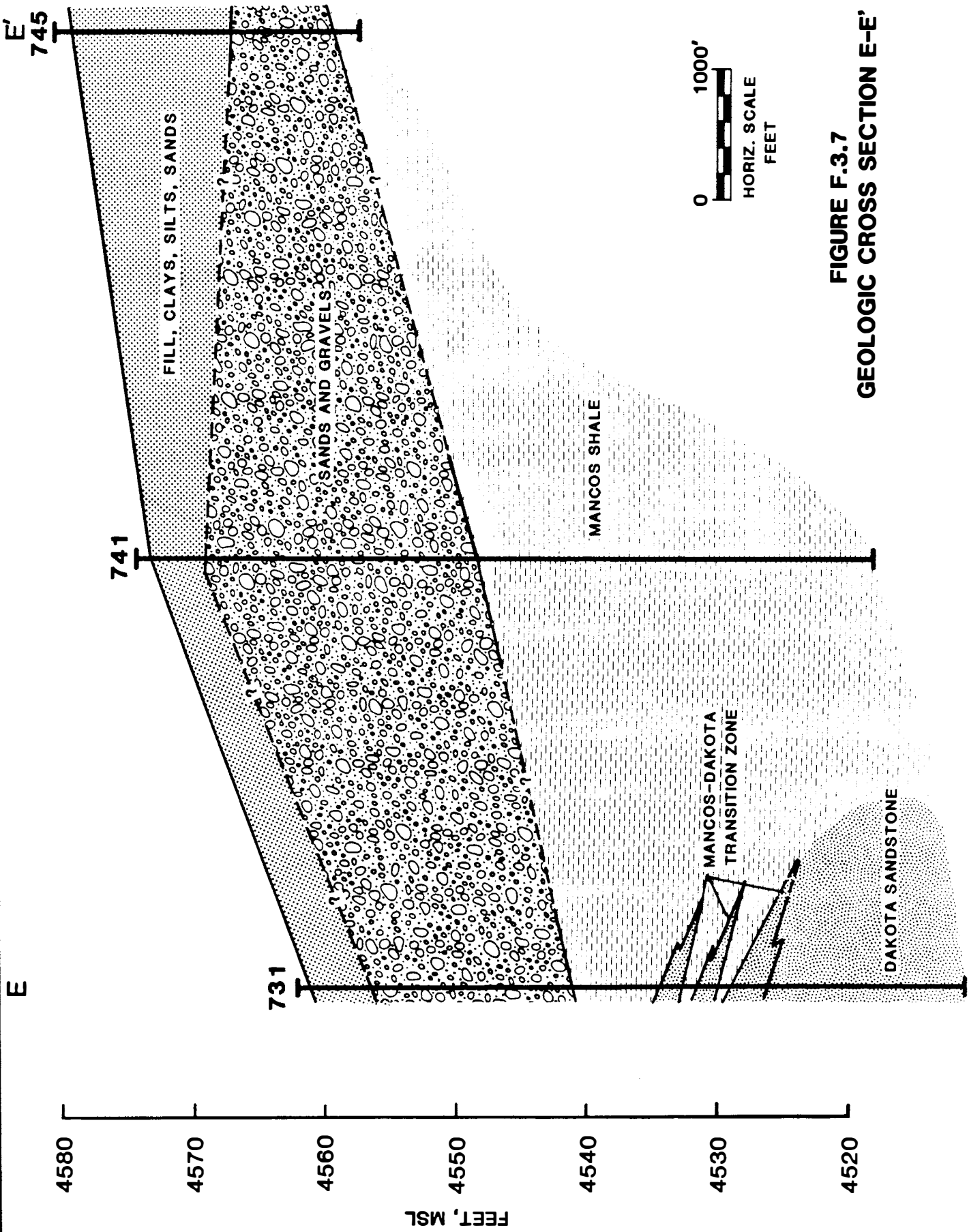


FIGURE F.3.7
GEOLOGIC CROSS SECTION E-E'

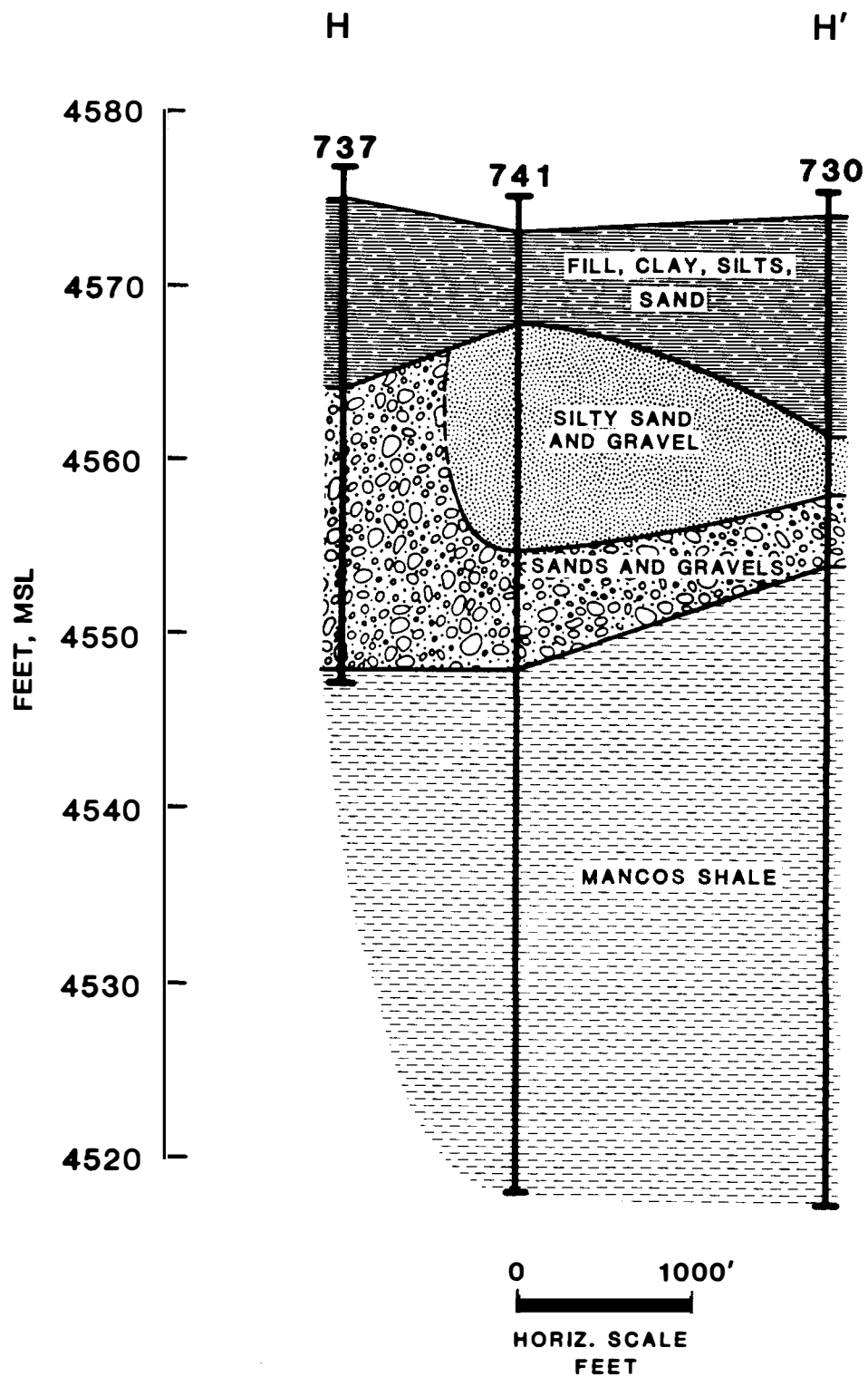


FIGURE F.3.8
GEOLOGIC CROSS SECTION H-H'

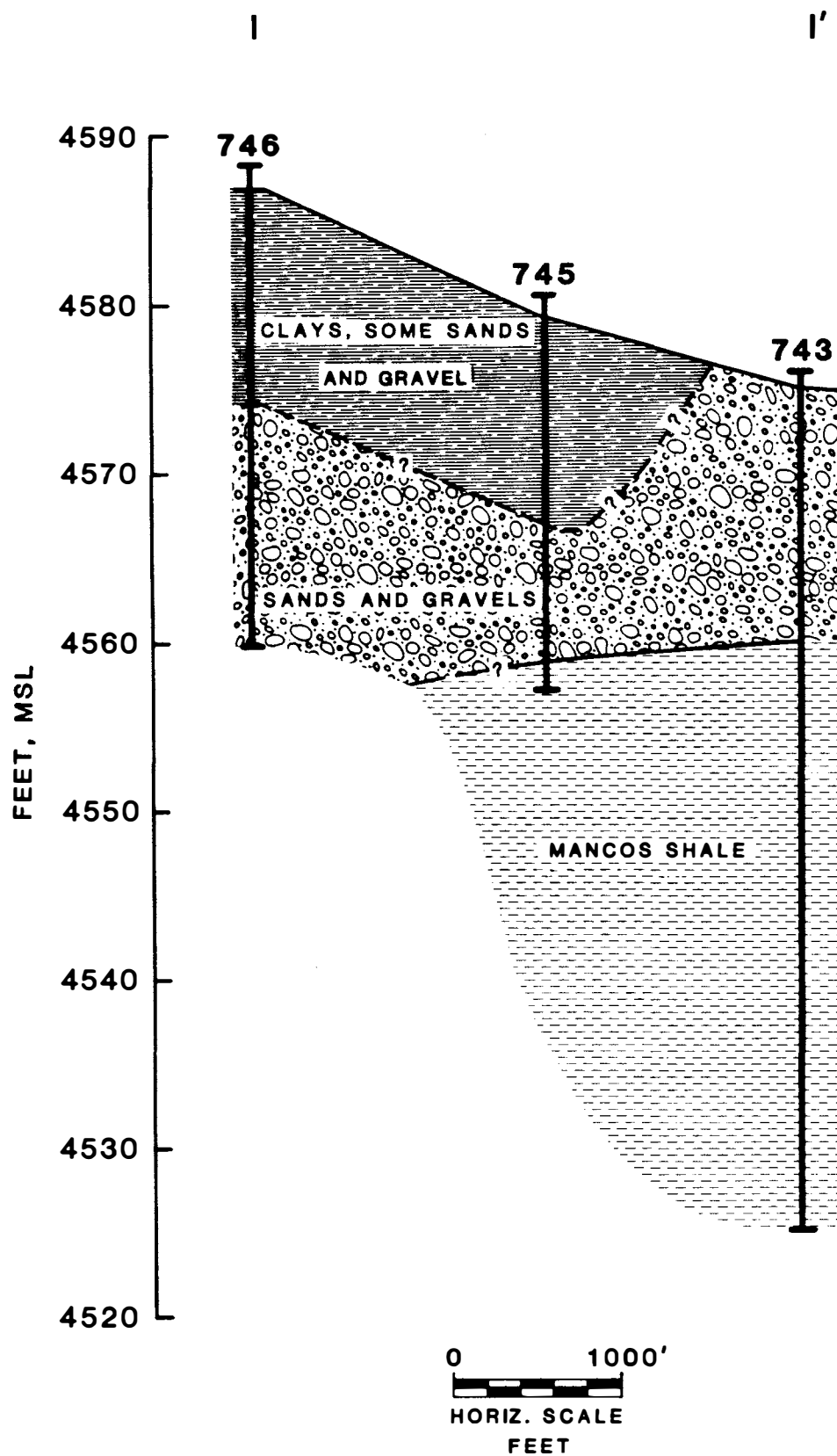


FIGURE F.3.9
GEOLOGIC CROSS SECTION I-I'

shallow stratigraphy near the Grand Junction site consists of three zones. From top to bottom these are:

- o A surficial disturbed zone.
- o A zone of unconsolidated alluvial sediments.
- o A sequence of consolidated sedimentary formations.

The surficial zone includes a variety of soil classifications and material types which have been deposited or altered through the action of man. It varies in depth from less than one to more than 50 feet. These include the tailings, which are shown in cross-section on Figures F.3.3 through F.3.5; trash, shown on Figure F.3.6; and fill, shown on Figures F.3.6 through F.3.8. The tailings consist of a series of interbedded sands and slimes which have been described in more detail by other investigators (Nelson and Wardwell, 1982).

Underlying or adjacent to the surficial zone is a zone of alluvial deposits (Figures F.3.3 through F.3.9). In the vicinity of the tailings this includes zones of mixed gravel, sand, and silty layers ranging in depth from less than seven to more than 21 feet. In general, the alluvium in this portion of the Grand Valley can be categorized into two types, as described below:

"In deeper sections of the Colorado River paleochannel is a stratum of gravel and cobbles overlying the Mancos Shale referred to as the cobble aquifer. Overlying the cobble aquifer is a layer of alluvium that extends over the entire Grand Valley." (U.S. Bureau of Reclamation, 1978)

In this report these two types of alluvial deposits will be grouped together and referred to as "alluvium."

The "cobble aquifer" borders the Colorado River in a strip two to three miles wide from Palisade to Loma, with a northern boundary approximately 0.5 mile south of the Government Highline Canal shown in Figure F.3.10.

The bottom of the cobble aquifer is formed by the erosional surface of the Mancos Shale which slopes gently (about five feet per mile) to the north where it abuts the base of the Book Cliffs (U.S. Bureau of Reclamation, no date).

Underlying the alluvial deposits is a sequence of consolidated sedimentary rocks, which are, in descending order, (Lohman, 1965):

Mancos Shale *
Dakota Sandstone *
Burro Canyon Formation *
Morrison Formation (Salt Wash
and Brushy Basin Members)

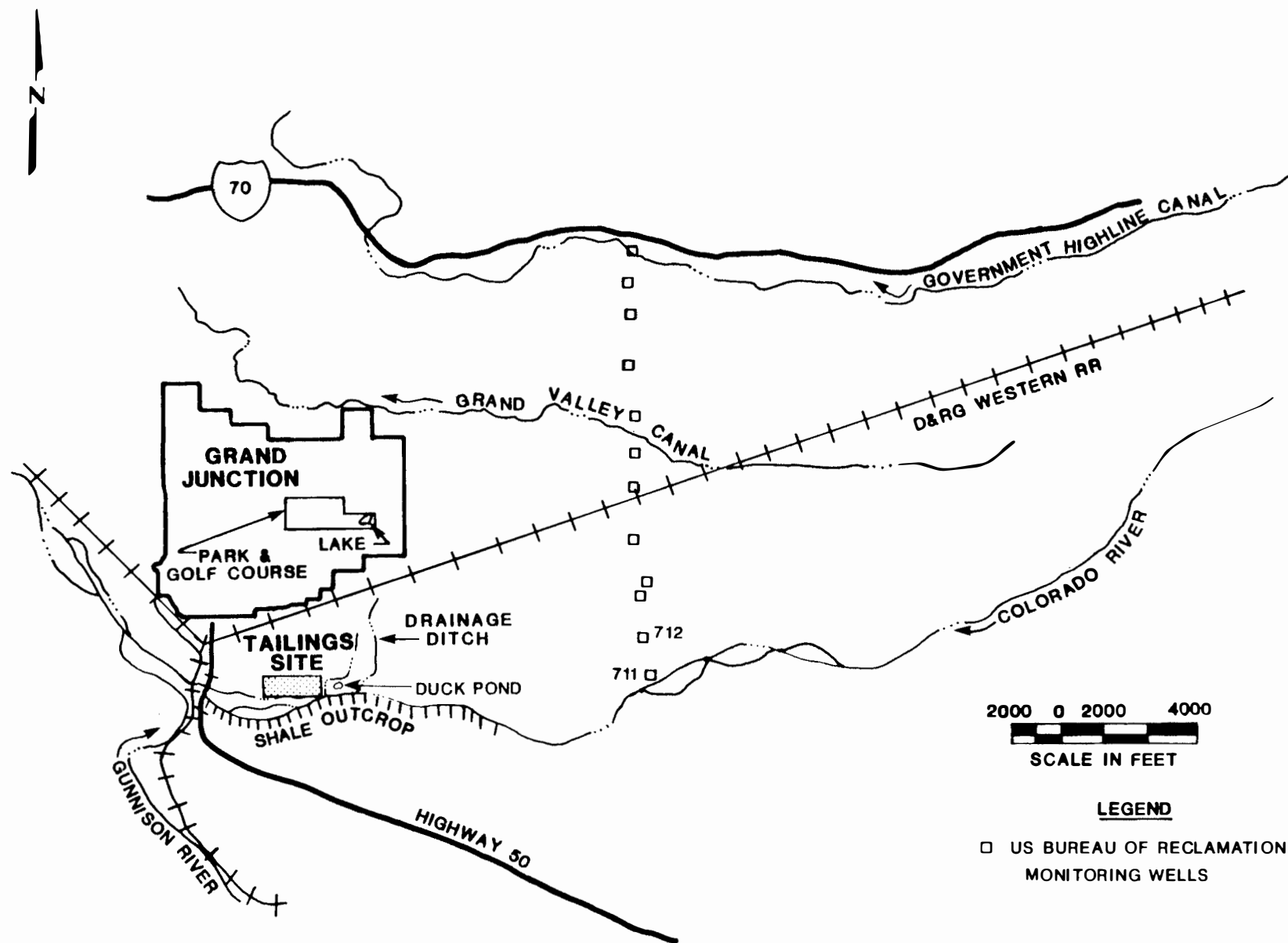


FIGURE F.3.10
HYDROLOGIC SETTING GRAND JUNCTION SITE

Summerville Formation
Entrada Sandstone
Kayenta Formation*
Wingate Sandstone
Chinle Formation

The formations shown with an asterisk above are tapped as aquifers in the Grand Junction area. The Dakota Sandstone and Burro Canyon Formation are grouped together as one water-bearing unit (Lohman, 1965).

Among the consolidated sedimentary formations, only the Mancos Shale and the Dakota Sandstone are of interest with respect to the tailings. The Mancos Shale is of interest because it is a low-permeability unit which can provide a barrier to downward migration of contamination. The Dakota Sandstone is of interest because it is the uppermost known bedrock aquifer and potentially could be impacted by the tailings.

The Mancos Shale is a thick sequence of shale which includes some sandy layers and thin sandstone beds. It not only underlies all of the Grand Valley but forms most of the Book Cliffs to the north. The Mancos Shale and the Dakota Sandstone intertongue and the contact between the two appears to be conformable and gradational (Lohman, 1965).

The thickness of the Mancos Shale underlying the tailings exceeds 50 feet (boring #729), while 0.5 mile west of the site at the Highway 50 bridge, it appears to thin to the extent that the Dakota Sandstone locally subcrops to the alluvium (Colorado Department of Highways, 1964). The Mancos Shale dips to the northeast, so that at a well approximately 1.5 miles northeast of the tailings it is 638 feet thick (Lohman, 1965).

The Dakota Sandstone consists of beds of sandstone, conglomeratic sandstone, shale, and coal. It is generally grouped with the underlying Burro Canyon Formation as one hydrogeologic unit, and is the least important of the four artesian aquifers in the Grand Junction area (Lohman, 1965). "The sandstone beds of the Burro Canyon Formation and Dakota Sandstone are tightly cemented, lenticular, and generally thin, hence they yield only small amounts of water, generally under insufficient head to flow at the surface." Below the tailings it is more than 65 feet below land surface (boring 729). The log of a well in the NE 1/4 SW 1/4 of section 24, a location approximately the same as the east end of the tailings, reported the top of the Dakota at 168 feet below land surface (Lohman, 1965).

Faulting. A seismic risk evaluation of the Grand Junction site has concluded that the probability of active faulting near or under the site cannot be quantified. Regardless, the effects of possible faults (if present) on the

existing hydrogeologic regime appear to be minimal. The differences in water quality between the contaminated alluvial system and the Dakota Sandstone (Section F.3.1.6), and the presence of entrapped oil in the Dakota Sandstone (boring #725) indicate minimal communication between the two systems near the processing site. The presence of oil shows that the overlying rock is so low in permeability as to trap the oil, whereas a fault zone could be a more permeable area along which oil could escape. A more detailed discussion of seismic risk is presented in Appendix E, Soils, Geologic, and Seismic Information.

F.3.1.4 Unsaturated zone hydraulics

The Grand Junction tailings have been extensively characterized in terms of hydraulic properties. The data produced by the characterizations are too many to report, but have been reported or summarized elsewhere (Veyera, 1980; Martin et al., 1980; Veyera and Nelson, 1981).

After cessation of operations (milling) the tailings are expected to have drained relatively rapidly (Veyera and Nelson, 1981). Based on this conclusion and the periodic flux of ground water through the tailings during seasonally high water levels, the importance of the unsaturated zone in the existing hydrologic regime is relatively minor. The main driving force for migration of contaminants in the existing environment is flow of ground water through those portions of the tailings which are below the water table.

F.3.1.5 Saturated zone hydraulics

Dakota Sandstone. No known published quantitative data are available for the Dakota Sandstone in the vicinity of the tailings. An extensive study of the hydrogeology of the Grand Junction area produced no quantitative data (Lohman, 1965).

Results from two slug tests of the upper Dakota Sandstone near the processing site show that it has relatively low permeability, comparable to the Mancos Shale (Table F.3.2). In addition to the slug test data, qualitative observations regarding the hydraulic properties of the Dakota Sandstone indicate that it has a relatively low yield. For example:

- o A four-inch diameter well (30-foot screen) installed during the 1985 field program yielded insufficient water (less than one gpm) to conduct a pump test.
- o "The sandstone beds of the Burro Canyon Formation and Dakota Sandstone are tightly cemented, lenticular, and generally thin, hence they yield only small amounts of water. . ." (Lohman, 1965).

Table F.3.2 Slug testing results for the Grand Junction site

Well ID ^b	Hydraulic conductivity ^a by methods			Storage coefficient ^c
	CBP ^c	F-K ^d	Skibitzke ^e	
724	--	--	4.6×10^{-5}	--
725	2.6×10^{-5} 4.4×10^{-5}	7.9×10^{-6}	--	10^{-3} 10^{-5}
727	5.5×10^{-6}	7.3×10^{-7}	7.7×10^{-7}	10^{-5}
729	--	--	1.9×10^{-7}	--
731	--	--	9.4×10^{-7}	--
735	--	--	3.9×10^{-7}	--
741	5.8×10^{-5}	1.4×10^{-5}	2.4×10^{-5}	10^{-4}
743	4.9×10^{-4}	1.35×10^{-4}	--	10^{-3}

^aIn cm/sec converted from transmissivity by assuming effective thickness of aquifer equal to thickness of gravel pack.

^bAll wells except 724 and 725 completed in Mancos Shale. 724 and 725 are completed in Dakota Sandstone.

^cCooper-Bredehoeft-Papadopoulos; Ref. Lohman, 1972.

^dFerris-Knowles; Ref. Ferris and Knowles, 1963.

^eRef. Skibitzke, 1963.

Mancos Shale. As reported by various authors, the Mancos Shale on a regional basis is generally accepted as a low-permeability formation which is "not water bearing" or transmits only very limited quantities of water (Lohman, 1965; Cooley et al., 1969). One boring into the Mancos Shale (location #735) encountered artesian flow which lasted for 10 minutes. The U.S. Bureau of Reclamation, at a site approximately 20 miles west of the tailings, characterized an artesian zone in the Mancos Shale with a thickness of 1.5 feet, hydraulic conductivity of 210 to 650 feet/day (0.074 to 0.23 cm/sec), and a storage coefficient of 10^{-5} (U.S. Bureau of Reclamation, 1978).

Slug-withdrawal tests of hydraulic conductivity confirm the low permeability of the Mancos Shale (Table F.3.2.). The calculated storage coefficients for Mancos Shale appear to be consistent within an order of magnitude of that reported by the U.S. Bureau of Reclamation, although the determination of storage coefficient by this method has questionable reliability (Cooper et al., 1967).

Packer-permeability tests, analyzed using methods of the U.S. Bureau of Reclamation (U.S. Bureau of Reclamation, 1981), for the Mancos Shale (Table F.3.3) indicate a generally higher permeability than do the slug tests (Table F.3.2). Only one value of hydraulic conductivity is available for a location, 729, at which packer testing was completed. The differing results between slug- and packer-testing can be attributed to the following factors:

- o Packer tests are described as semi-quantitative (U.S. Bureau of Reclamation, 1981).
- o Based on later water-level measurements, some of the packer tests may have been completed in a partially-saturated zone of the Mancos Shale. Permeabilities in Table F.3.3 were calculated assuming the test section was below the water table. Inaccuracies are associated with the application of U.S. Bureau of Reclamation methods to tests above the water table (Stephens and Neuman, 1982).

Despite the drawbacks associated with the packer-permeability tests, they can be used semi-quantitatively to conclude that:

- o The Mancos Shale appears to be relatively uniform with respect to horizontal permeability in the area of the site.
- o There is a small decrease in the horizontal permeability of the shale with increasing depth. This is confirmed by the results of the slug tests, which show decreasing hydraulic conductivity with increasing depth (Tables F.3.1 and F.3.2).

Table F.3.3 Packer-testing results^a for the Grand Junction site

Borehole	Permeability $\times 10^{-6}$ cm/sec for different test pressures ^b			
	Test Interval ^c (feet)	P1	P2	P3
726 ^e	28-33	107	163	480
	33-38	46	50	53
	38-43	61	63	53
	43-48	61	50	53
	48-53	61	63	53
	53-58	76	63	53
	58-63	61	75	80
	63-68	46 ^d	50 ^d	63
	68-73	0 ^d	0 ^d	32
729 ^f	26-31	244	265	315
	31-36	305	265	290
	36-41	285	265	164
	42-47	122	125	151
	47-52	163	171	87
	52-57	- unable to set packers-		
	57-62	51	93	126
730	29-34	113	147	---
	34-39	132	103	144
	39-44	169	117	108
	44-49	188	235	216
	49-54	123	161	156
	54-59	188	103	84
	59-64	75	88	96

^aDouble-packer tests of open boreholes completed March, 1985.

^bNet test pressure, at packers in feet of water;

for borehole 726: P1 = 52.5 P2 = 64.0 P3 = 75.5

for borehole 729: P1 = 37.5 P2 = 49.0 P3 = 60.5

for borehole 730: P1 = 40.5 P2 = 52.0 P3 = 63.5

^cTests analyzed using methods of the U.S. Bureau of Reclamation (1981).

^c729 and 730 entirely in Mancos Shale. Lower tests in 726 are in Mancos-Dakota transition zone or Dakota Sandstone.

^dFlow-meter reset after tests; may have been inoperational during tests.

^eStatic water level, May, 1985: 10.5 feet.

^fStatic water level, May, 1985: 34 feet.

Water levels in the Mancos Shale are generally within a few tenths of a foot of water levels in adjacent alluvial wells. Flow direction in the shallow Mancos Shale is essentially parallel to flow in the overlying alluvium.

Alluvium. Results of hydraulic testing in the saturated alluvium are reported in Table F.3.4. In general, it can be concluded that the alluvium has a relatively high permeability compared to the underlying shale. Water level iso-contour maps are presented in Figures F.3.11 through F.3.13. A contour of the saturated thickness of the alluvium is presented in Figure F.3.14.

The quantity of ground-water flux through the alluvium and tailings at the site can be calculated using Darcy's law (Davis and DeWiest, 1966):

$$Q = KA \frac{h_1 - h_2}{dl}$$

where

Q = flow rate (l^3/t)

K = hydraulic conductivity (l/t)

h_1, h_2 = hydraulic head at two points

dl = length of the flow path between points at which the head is given

The rate of ground-water flux varies seasonally. Flux calculations for water levels measured in March, 1985, (Figure F.3.12) and May, 1985, (Figure F.3.13) are summarized in Table F.3.4.

The average velocity of the ground water can be used to estimate migration rates of contaminants, or the time needed to flush contaminants from a ground-water system. It can be calculated as follows (Bear, 1979):

$$V = Q/n_{ef} A$$

where

V = average velocity (l/t)

Q = flow rate (l^3/t)

n_{ef} = effective porosity

A = cross-sectional area (l^2)

Table F.3.4 Well-development and hydrologic-test methods for the Grand Junction site

Well	Development method	Hydrologic-test method	Analytical method	Hydraulic conductivity (cm/sec) ^a
581	Air lift and bailing	--	--	--
582	Air lift and river water circulation	--	--	--
583	Bailing	--	--	--
584	Bailing	--	--	--
585	Bailing inside steel casing and suction pump	Stable drawdown with probe	Steady state	2.5×10^{-2}
586	Suction pump	Stable drawdown with probe	Steady state	2.3×10^{-2}
587	Submersible pump	Transient drawdown with transducer	Transient	4.2×10^{-2}
588	Submersible pump	Transient drawdown with transducer	Transient	1.5×10^{-2}
589	Submersible pump	Transient drawdown with transducer	Transient	2.0×10^{-2}
590	Submersible pump	Stable flow, assumed drawdown	Steady state	$>3.3 \times 10^{-2}$

^aCentimeters per second.

Ref. NUS, 1983.

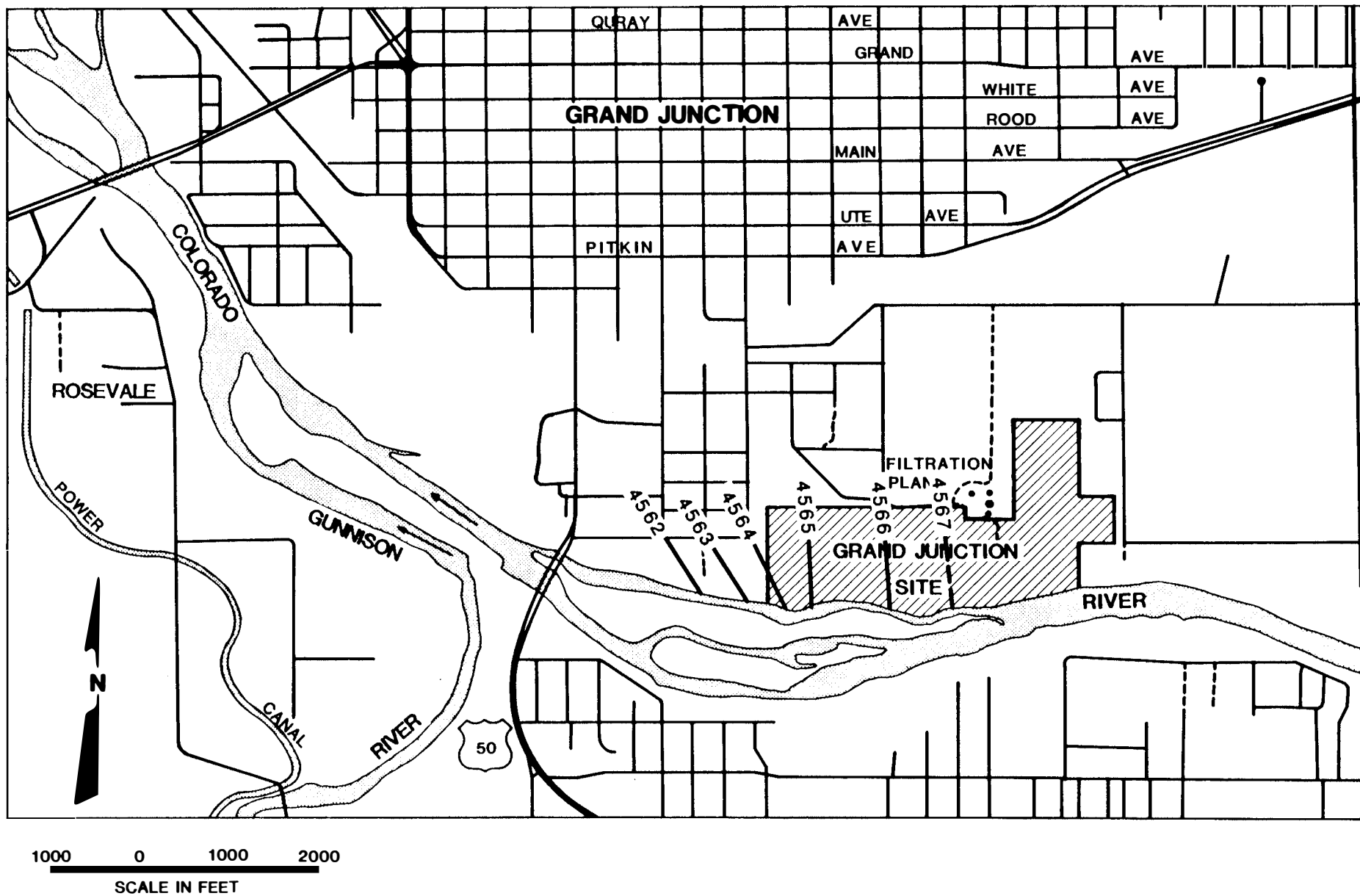


FIGURE F.3.11
JUNE, 1983 WATER LEVELS IN THE ALLUVIAL SYSTEM

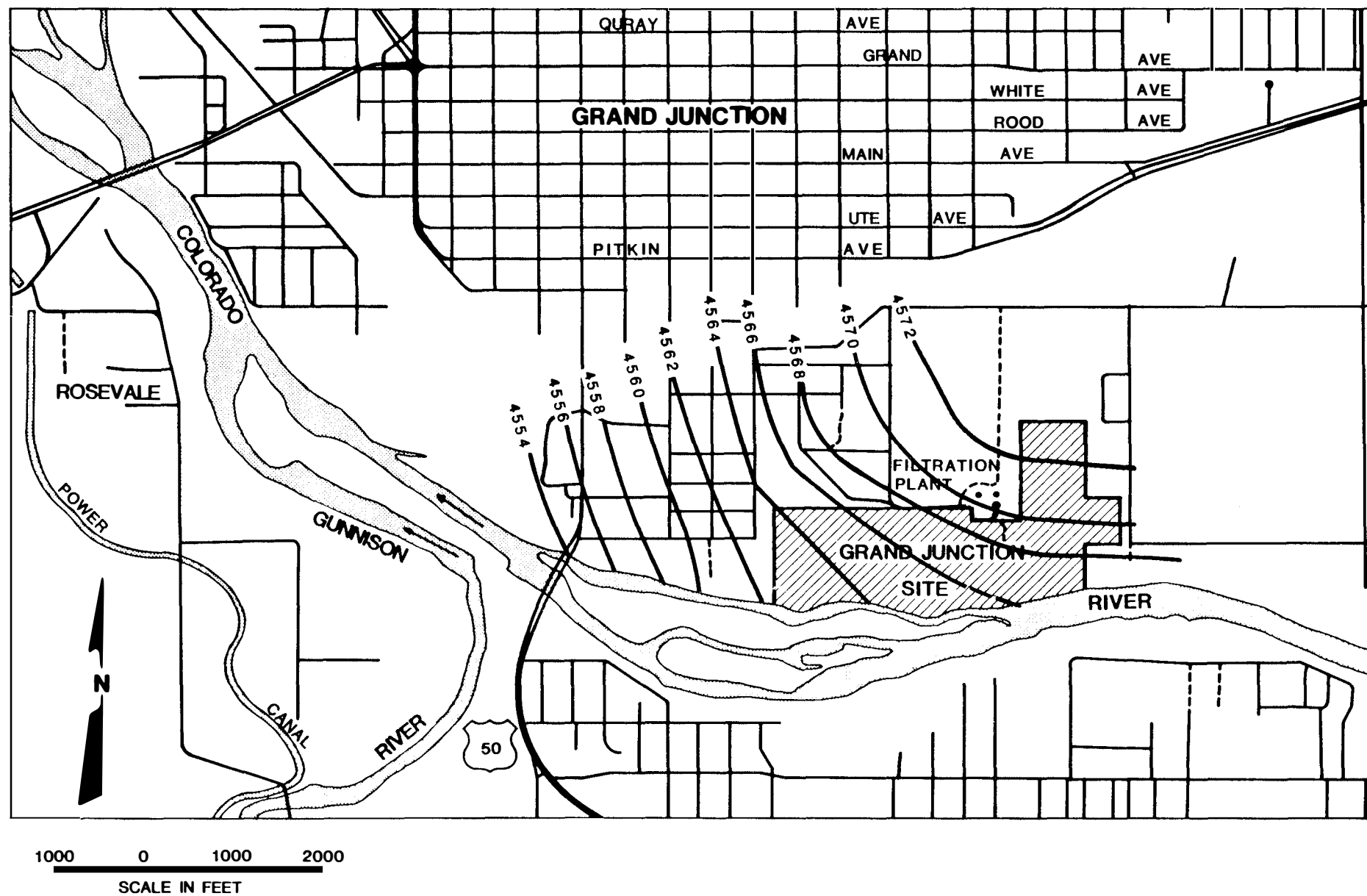


FIGURE F.3.12
MARCH, 1985 WATER LEVELS IN THE ALLUVIAL SYSTEM

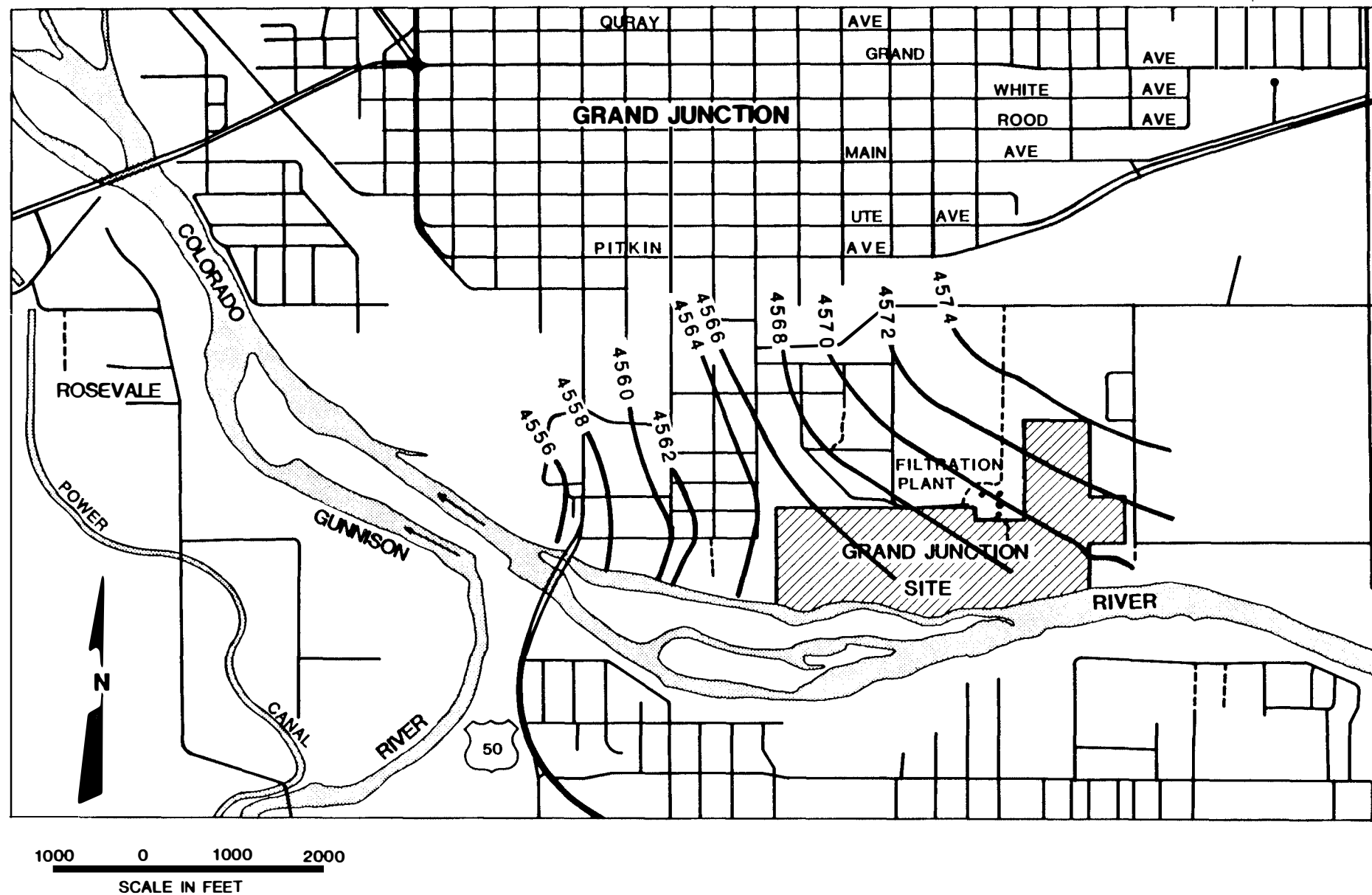
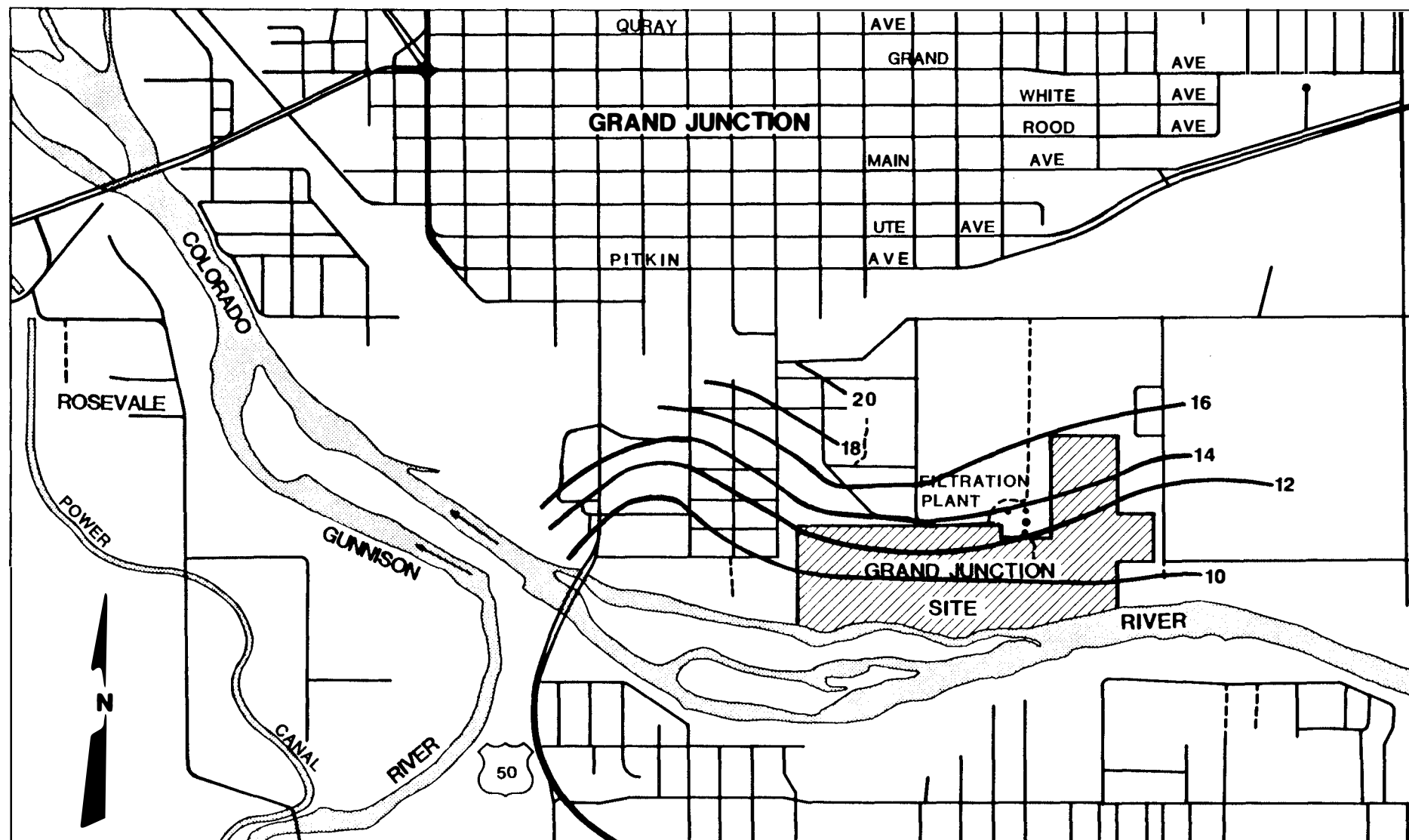


FIGURE F.3.13
MAY, 1985 WATER LEVELS IN THE ALLUVIAL SYSTEM



NOTE: THICKNESS IN FEET

FIGURE F.3.14
SATURATED THICKNESS OF ALLUVIUM MARCH, 1985

No measurements of effective porosity were available, so calculations were made assuming that effective porosity is equal to the specific yield. Calculations of average velocity are summarized in Table F.3.5.

The volume of alluvial ground water directly below the tailings can be calculated using the formula

$$V = A \times b \times S_y$$

where

$$V = \text{volume (l}^3\text{)}$$

$$A = \text{horizontal area (l}^2\text{)}$$

$$b = \text{average thickness of the saturated zone (l)}$$

$$S_y = \text{specific yield (ft}^3\text{/ft}^3\text{)}$$

Volume calculations are summarized in Table F.3.6, and will be used in the assessment of impacts on ground water of various remedial action alternatives.

Tailings. The tailings are saturated in the lower portions of the pile. Laboratory permeability tests have been reported by other investigators (see Section F.3.1.1). These are in the range of $>10^{-5}$ to $>10^{-3}$ cm/sec, depending on the composition of the tailings samples (Nelson and Wardwell, 1982).

Vertical hydraulic gradients. Measured water levels in the shallow Mancos Shale for March and May, 1985, were generally within 0.1 foot to one foot of water levels in adjacent alluvial wells. Calculated gradients (where "+" indicates a downward gradient) in March were slightly upward and ranged from -0.030 to +0.104 ft/ft. Calculated gradients in May were downward, in the range +0.021 to +0.201 ft/ft. Anomalous gradients of +2.0 ft/ft were calculated (wells 735 and 736), but this may reflect slow recovery of a well completed in the shale, consequent to well development and water sampling. Studies elsewhere have shown that wells completed in the Mancos Shale may require several months to recover after being developed (Dames and Moore, 1984) or sampled (DOE, 1985). It can be concluded that the gradient between the bedrock and the alluvium is slight, however definite conclusions about the absolute rate and direction of vertical ground-water movement would require additional water-level measurements in wells undisturbed by sampling.

In summary, it has been concluded that:

- o Based on qualitative evidence, the low permeability of the Dakota Sandstone limits its utility as an aquifer.

Table F.3.5 Ground-water flux rate

Date	3/85	6/83	6/83
K (cm/sec):	4.2×10^{-2}	4.2×10^{-2}	1.5×10^{-2}
A (ft ²)	20,000	10,000	10,000
h ₁	4570	4567	4567
h ₂	4564	4565	4565
d1 (ft)	1450	1550	1550
Q (ft ³ /yr)	3.6×10^6	5.6×10^5	2.00×10^5
Q (liters/yr)	1×10^8	1.6×10^7	5.67×10^6
V ^a (n _{ef} = 0.10)	1800	560	200
V ^a (n _{ef} = 0.20)	900	280	100
V ^a (n _{ef} = 0.35)	514	160	57

^aft/yr.

Table F.3.6 Volume of alluvial ground water below the tailings

Area (acres)	b(ft) ^a	Sy(ft ³ /ft ³) ^b	Volume(ft ³)	Volume (liters)
57	10	0.10	2.48×10^6	7×10^7
57	10	0.20	4.96×10^6	1.4×10^8
57	10	0.35	8.69×10^6	2.5×10^8

^aFrom Figure F.3.14.

^bRange of values for alluvium selected from Todd, 1980; Davis and DeWiest, 1966.

- o The Mancos Shale is generally acknowledged as a formation which inhibits the movement of water. Upper weathered portions and very localized zones transmit moderate quantities of water, relative to the alluvium.
- o The alluvium in the vicinity of the site and the tailings can transmit large quantities of water, relative to the Mancos Shale.

F.3.1.6 Water quality

Data on ground-water chemistry for samples collected on various dates are presented in Table F.3.7. Maps of iso-concentrations for those constituents for which a "plume" could be defined are presented in Figures F.3.15 through F.3.17.

Background water quality. Background water quality in the alluvium varies both seasonally and with distance from the Colorado River (U.S. Bureau of Reclamation, no date). Several wells were used to characterize background water quality in the alluvium. Two U.S. Bureau of Reclamation wells, 711 and 712 (Figure F.3.10) exhibit the decreasing quality moving away from the river (Table F.3.7).

The use of Bureau of Reclamation wells 711 and 712 as representative of background water quality in the alluvium is based on the following reasons:

- o The wells are approximately 2.5 miles from the tailings where ground-water levels are more than 20 feet above the levels near the tailings.
- o The wells penetrate a ground-water system that is known to be continuous through the Grand Valley (U.S. Bureau of Reclamation, 1978).

Two wells installed near the site during recent investigations are also used as representative of background. The use of data for wells 588 and 744 is justified based on the following reasons:

- o The wells are relatively close (750 to 2000 feet) to the tailings in the same hydrogeologic unit that the tailings are within.
- o The wells are hydraulically upgradient from the ground water immediately under the tailings.

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	581 02/07/83	581 06/09/83	581 09/22/83	581 03/26/85	581 06/07/85
ALKALINITY	MG/L CAC03		485.000	450.000	490.000	568.000	521.000
ALUMINUM	MG/L		-----	-----	0.004	< 0.100	< 0.100
AMMONIA	MG/L		-----	88.330	-----	-----	-----
AMMONIUM	MG/L		-----	-----	232.000	166.000	205.000
ANTIMONY	MG/L		-----	-----	< 0.005	< 0.003	< 0.003
ARSENIC	MG/L		< 0.001	< 0.001	0.008	0.016	0.010
BARIUM	MG/L		< 0.020	0.030	0.062	< 0.100	< 0.100
BORON	MG/L		-----	-----	-----	0.340	0.400
CADMIUM	MG/L		-----	-----	0.001	< 0.002	< 0.001
CALCIUM	MG/L		360.000	654.000	420.000	550.000	483.000
CHLORIDE	MG/L		515.000	640.000	530.000	490.000	563.000
CHROMIUM	MG/L		0.001	0.005	0.002	0.020	-----
COBALT	MG/L		< 0.001	0.053	0.001	< 0.010	< 0.050
COND, IN-SITU	UMHO/CM		4180.000	5200.000	-----	-----	-----
CONDUCTANCE	UMHO/CM		-----	-----	-----	6300.000	6000.000
COPPER	MG/L		0.011	< 0.000	< 0.000	0.050	< 0.020
CYANIDE	MG/L		-----	-----	-----	< 0.010	< 0.010
FLUORIDE	MG/L		-----	-----	4.400	4.700	4.300
GROSS ALPHA	PCI/L		-----	-----	-----	160.000	-----
GROSS BETA	PCI/L		-----	-----	-----	70.000	-----
HYD. SULFIDE	MG/L		-----	-----	-----	< 0.200	-----
IRON	MG/L		3.240	1.310	3.720	12.000	11.200
LEAD	MG/L		-----	-----	0.010	< 0.010	< 0.010
MAGNESIUM	MG/L		189.000	210.000	310.000	200.000	202.000
MANGANESE	MG/L		2.720	2.850	4.500	5.000	4.590
MERCURY	MG/L		-----	-----	< 0.000	< 0.000	< 0.000
MOLYBDENUM	MG/L		0.310	0.250	0.078	0.130	0.120
NICKEL	MG/L		-----	-----	-----	< 0.040	0.080
NITRATE	MG/L		0.120	-----	0.190	< 1.000	< 1.000
NITROGEN, KJL	MG/L		188.000	-----	-----	-----	-----
ORG. CARBON	MG/L		96.300	88.200	113.000	10.500	10.000
PB-210	PCI/L		-----	-----	-----	< 1.500	1.800
PH	SU		7.300	7.300	7.200	6.900	7.100
PHOSPHATE	MG/L		-----	-----	-----	< 0.100	< 0.100
PHOSPHORUS	MG/L		-----	-----	< 0.040	-----	-----
PO-210	PCI/L		-----	-----	-----	< 1.000	< 1.000
POTASSIUM	MG/L		66.400	56.000	52.000	57.000	61.200
RA-226	PCI/L		-----	-----	-----	1.400	1.000
RA-228	PCI/L		-----	-----	-----	< 1.000	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	581 02/07/83	581 06/09/83	581 09/22/83	581 03/26/85	581 06/07/85
SELENIUM	MG/L		0.020	< 0.002	< 0.002	< 0.005	< 0.005
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		-----	-----	22.000	12.400	11.900
SILVER	MG/L		-----	-----	< 0.002	< 0.010	< 0.010
SODIUM	MG/L		819.000	870.000	520.000	720.000	664.000
STRONTIUM	MG/L		-----	-----	-----	6.700	6.490
SULFATE	MG/L		3215.000	3800.000	2800.000	2900.000	2810.000
SULFIDE	MG/L		-----	-----	-----	-----	< 0.100
TEMP, IN-SITU	C-DEGREE		10.000	17.500	-----	-----	-----
TEMPERATURE	C - DEGREE		-----	-----	-----	14.000	16.000
TH-230	PCI/L		-----	-----	-----	< 1.000	< 1.000
TIN	MG/L		-----	-----	-----	0.008	< 0.005
TOTAL SOLIDS	MG/L		5260.000	5610.000	5200.000	5394.000	5464.000
TOTAL U	PPM		0.189	0.096	0.112	-----	-----
TOX	MG/L		-----	-----	-----	0.300	0.200
U-234	PCI/L		-----	-----	-----	-----	23.000
U-238	PCI/L		-----	-----	-----	-----	23.000
URANIUM	MG/L		-----	-----	-----	0.056	-----
VANADIUM	MG/L		0.074	0.078	0.018	0.020	0.020
ZINC	MG/L		0.030	0.040	0.040	0.100	< 0.005

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	581 06/07/85	581 06/07/85	581 06/07/85	581 06/07/85	582 02/08/83
ALKALINITY	MG/L CAC03		521.000	521.000	521.000	521.000	412.000
ALUMINUM	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	-----
AMMONIA	MG/L		-----	-----	-----	-----	-----
AMMONIUM	MG/L		206.000	199.000	202.000	201.000	-----
ANTIMONY	MG/L		< 0.003	< 0.003	< 0.003	< 0.003	-----
ARSENIC	MG/L		0.010	0.010	0.010	0.010	< 0.001
BARIUM	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	0.140
BORON	MG/L		0.450	0.440	0.450	0.430	-----
CADMIUM	MG/L		< 0.001	< 0.001	< 0.001	< 0.001	-----
CALCIUM	MG/L		481.000	474.000	477.000	474.000	106.000
CHLORIDE	MG/L		573.000	564.000	576.000	579.000	496.000
CHROMIUM	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.001
COBALT	MG/L		< 0.050	< 0.050	< 0.050	< 0.050	< 0.001
COND, IN-SITU	UMHO/CM		-----	-----	-----	-----	-----
CONDUCTANCE	UMHO/CM		6000.000	6000.000	6000.000	6000.000	-----
COPPER	MG/L		< 0.020	< 0.020	< 0.020	< 0.020	< 0.000
CYANIDE	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	-----
FLUORIDE	MG/L		4.200	4.300	4.300	4.100	-----
GROSS ALPHA	PCI/L		-----	-----	-----	-----	-----
GROSS BETA	PCI/L		-----	-----	-----	-----	-----
HYD. SULFIDE	MG/L		-----	-----	-----	-----	-----
IRON	MG/L		11.100	11.500	11.100	11.400	0.500
LEAD	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	-----
MAGNESIUM	MG/L		221.000	226.000	190.000	229.000	23.000
MANGANESE	MG/L		4.560	4.610	4.580	4.540	0.160
MERCURY	MG/L		< 0.000	< 0.000	< 0.000	< 0.000	-----
MOLYBDENUM	MG/L		0.080	0.080	0.100	0.090	.140
NICKEL	MG/L		0.090	0.080	0.030	0.080	-----
NITRATE	MG/L		< 1.000	< 1.000	< 1.000	< 1.000	< 0.100
NITROGEN, KJL	MG/L		-----	-----	-----	-----	10.000
ORG. CARBON	MG/L		10.000	9.900	9.600	10.200	71.800
PB-210	PCI/L		-----	-----	-----	-----	-----
PH	SU		7.100	7.100	7.100	7.100	7.500
PHOSPHATE	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	-----
PHOSPHORUS	MG/L		-----	-----	-----	-----	-----
PO-210	PCI/L		-----	-----	-----	-----	-----
POTASSIUM	MG/L		61.200	60.800	60.000	60.400	13.200
RA-226	PCI/L		-----	-----	-----	-----	-----
RA-228	PCI/L		-----	-----	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	581 06/07/85	581 06/07/85	581 06/07/85	581 06/07/85	582 02/08/83
SELENIUM	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	0.017
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		12.500	12.800	11.600	12.800	-----
SILVER	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	-----
SODIUM	MG/L		654.000	658.000	669.000	662.000	1090.000
STRONTIUM	MG/L		6.500	6.030	6.570	5.740	-----
SULFATE	MG/L		2810.000	2900.000	2960.000	2920.000	1665.000
SULFIDE	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	-----
TEMP, IN-SITU	C-DEGREE		-----	-----	-----	-----	-----
TEMPERATURE	C - DEGREE		16.000	16.000	16.000	16.000	-----
TH-230	PCI/L		-----	-----	-----	-----	-----
TIN	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	-----
TOTAL SOLIDS	MG/L		5498.000	5482.000	5460.000	5482.000	3320.000
TOTAL U	PPM		-----	-----	-----	-----	0.072
70X	MG/L		0.140	0.200	< 0.100	< 0.100	-----
U-234	PCI/L		-----	-----	-----	-----	-----
U-238	PCI/L		-----	-----	-----	-----	-----
URANIUM	MG/L		-----	-----	-----	-----	-----
VANADIUM	MG/L		0.030	0.010	0.020	0.030	0.032
ZINC	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	0.050

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	582 03/30/85	582 06/07/85	583 02/07/83	583 06/07/83	583 09/21/83
ALKALINITY	MG/L CAC03		477.000	542.000	504.000	360.000	570.000
ALUMINUM	MG/L		< 0.100	< 0.100	-----	-----	0.170
AMMONIA	MG/L		-----	-----	-----	254.100	-----
AMMONIUM	MG/L		18.000	27.200	-----	-----	335.000
ALUMINUM	MG/L		< 0.100	< 0.100	-----	-----	0.170
AMMONIA	MG/L		-----	-----	-----	254.100	-----
AMMONIUM	MG/L		18.000	27.200	-----	-----	335.000
ANTIMONY	MG/L		< 0.003	0.047	-----	-----	< 0.005
ARSENIC	MG/L		< 0.010	< 0.010	0.006	0.011	0.077
BARIUM	MG/L		< 0.100	< 0.100	0.050	0.002	0.170
BORON	MG/L		0.760	0.100	-----	-----	-----
CADMIUM	MG/L		< 0.002	< 0.001	-----	-----	0.072
CALCIUM	MG/L		190.000	143.000	555.000	475.000	520.000
CHLORIDE	MG/L		590.000	698.000	760.000	770.000	790.000
CHROMIUM	MG/L		0.050	< 0.010	< 0.001	0.010	0.004
COBALT	MG/L		< 0.010	< 0.050	0.030	0.049	0.530
COND, IN -SITU	UMHO/CM		-----	-----	6800.000	6100.000	-----
CONDUCTANCE	UMHO/CM		7300.000	6100.000	-----	-----	-----
COPPER	MG/L		0.060	< 0.020	0.044	0.008	0.067
CYANIDE	MG/L		< 0.010	< 0.010	-----	-----	-----
FLUORIDE	MG/L		1.200	1.300	-----	-----	4.400
GROSS ALPHA	PCI/L		200.000	-----	-----	-----	-----
GROSS BETA	PCI/L		< 50.000	-----	-----	-----	-----
HYD. SULFIDE	MG/L		< 0.200	-----	-----	-----	-----
IRON	MG/L		0.060	0.190	0.490	0.018	0.071
LEAD	MG/L		< 0.010	< 0.010	-----	-----	< 0.001
MAGNESIUM	MG/L		59.000	53.400	334.000	178.000	450.000
MANGANESE	MG/L		0.300	0.130	3.100	1.750	10.000
MERCURY	MG/L		< 0.000	< 0.000	-----	-----	< 0.000
MOLYBDENUM	MG/L		0.130	< 0.010	0.530	0.400	0.190
NICKEL	MG/L		0.060	0.100	-----	-----	-----
NITRATE	MG/L		< 1.000	< 1.000	0.190	-----	50.000
NITROGEN, KJL	MG/L		-----	-----	346.000	-----	-----
ORG. CARBON	MG/L		8.900	20.400	111.000	84.200	129.000
PB-210	PCI/L		< 1.500	< 1.500	-----	-----	-----
PH	SU		7.300	7.300	7.200	7.000	6.900
PHOSPHATE	MG/L		< 0.100	< 0.100	-----	-----	-----
PHOSPHORUS	MG/L		-----	-----	-----	-----	0.100
PO-210	PCI/L		< 1.000	< 1.000	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	582 03/30/85	582 06/07/85	583 02/07/83	583 06/07/83	583 09/21/83
POTASSIUM	MG/L		14.000	18.400	104.000	49.000	96.000
RA-226	PCI/L		< 1.000	< 1.000	-----	-----	29.000
RA-228	PCI/L		< 1.000	-----	-----	-----	-----
SELENIUM	MG/L		< 0.005	0.005	0.092	0.013	0.120
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		6.200	5.300	-----	-----	23.000
SILVER	MG/L		< 0.010	< 0.010	-----	-----	0.002
SODIUM	MG/L		1590.000	1450.000	890.000	1090.000	980.000
STRONTIUM	MG/L		10.200	8.040	-----	-----	-----
SULFATE	MG/L		2700.000	2440.000	4200.000	3100.000	4900.000
SULFIDE	MG/L		-----	< 0.100	-----	-----	-----
TEMP, IN -SITU	C-DEGREE		-----	-----	13.000	19.000	-----
TEMPERATURE	C - DEGREE		11.000	15.000	-----	-----	-----
TH-230	PCI/L		< 1.000	< 1.000	-----	-----	< 1.100
TIN	MG/L		< 0.005	< 0.005	-----	-----	-----
TOTAL SOLIDS	MG/L		5510.000	5180.000	6420.000	5830.000	8000.000
TOTAL U	PPM		-----	-----	0.229	0.524	0.075
TOX	MG/L		0.400	0.140	-----	-----	-----
U-234	PCI/L		-----	3.000	-----	-----	-----
U-238	PCI/L		-----	2.000	-----	-----	-----
URANIUM	MG/L		0.036	-----	-----	-----	-----
VANADIUM	MG/L		0.030	0.050	1.600	1.700	7.600
ZINC	MG/L		0.200	0.010	0.870	0.510	23.000

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	583 03/26/85	583 06/07/85	584 02/08/83	584 06/08/83	584 09/21/83
ALKALINITY	MG/L CACO3		517.000	464.000	286.000	530.000	560.000
ALUMINUM	MG/L		< 0.100	< 0.100	-----	-----	0.510
AMMONIA	MG/L		-----	-----	-----	544.500	-----
AMMONIUM	MG/L		357.000	274.000	-----	-----	374.000
ANTIMONY	MG/L		< 0.003	< 0.003	-----	-----	< 0.005
ARSENIC	MG/L		0.019	0.020	0.007	0.045	0.070
BARIUM	MG/L		< 0.100	< 0.100	-----	< 0.020	0.083
BORON	MG/L		0.570	0.660	-----	-----	-----
CADMIUM	MG/L		0.010	0.008	-----	-----	0.420
CALCIUM	MG/L		520.000	492.000	556.000	585.000	470.000
CHLORIDE	MG/L		660.000	787.000	822.000	970.000	790.000
CHROMIUM	MG/L		0.010	< 0.010	0.001	0.007	0.074
COBALT	MG/L		0.020	0.050	0.160	0.150	0.660
COND, IN-SITU	UMHO/CM		-----	-----	7000.000	6200.000	-----
CONDUCTANCE	UMHO/CM		8600.000	7320.000	-----	-----	-----
COPPER	MG/L		0.110	< 0.020	0.120	0.049	0.200
CYANIDE	MG/L		< 0.010	< 0.010	-----	-----	-----
FLUORIDE	MG/L		4.200	3.000	-----	-----	4.300
GROSS ALPHA	PCI/L		255.000	-----	-----	-----	-----
GROSS BETA	PCI/L		140.000	-----	-----	-----	-----
HYD. SULFIDE	MG/L		< 0.200	-----	-----	-----	-----
IRON	MG/L		1.800	1.080	0.189	0.019	0.066
LEAD	MG/L		< 0.010	< 0.010	-----	-----	< 0.001
MAGNESIUM	MG/L		230.000	185.000	25.100	220.000	470.000
MANGANESE	MG/L		4.300	2.560	4.220	3.040	8.100
MERCURY	MG/L		0.000	< 0.000	-----	-----	< 0.000
MOLYBDENUM	MG/L		0.300	0.130	0.420	0.380	0.170
NICKEL	MG/L		0.180	0.180	-----	-----	-----
NITRATE	MG/L		< 1.000	< 1.000	0.300	-----	41.000
NITROGEN, KJL	MG/L		-----	-----	388.000	-----	-----
ORG. CARBON	MG/L		11.700	10.500	120.000	84.600	139.000
PB-210	PCI/L		< 1.500	< 1.500	-----	-----	-----
PH	SU		6.800	7.100	7.200	7.200	6.800
PHOSPHATE	MG/L		< 0.100	< 0.100	-----	-----	-----
PHOSPHORUS	MG/L		-----	-----	-----	-----	0.080
PO-210	PCI/L		< 1.000	< 1.000	-----	-----	-----
POTASSIUM	MG/L		96.000	69.200	113.000	97.000	99.000
RA-226	PCI/L		4.500	5.000	-----	-----	15.000
RA-228	PCI/L		1.600	-----	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	583 03/26/85	583 06/07/85	584 02/08/83	584 06/08/83	584 09/21/83
SELENIUM	MG/L		< 0.005	0.005	0.051	0.027	0.220
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		11.700	8.800	-----	-----	29.000
SILVER	MG/L		< 0.010	< 0.010	-----	-----	0.002
SODIUM	MG/L		920.000	1130.000	1210.000	930.000	950.000
STRONTIUM	MG/L		4.300	3.550	-----	-----	-----
SULFATE	MG/L		3700.000	3390.000	4440.000	4200.000	4900.000
SULFIDE	MG/L		-----	< 0.100	-----	-----	-----
TEMP, IN-SITU	C-DEGREE		-----	-----	13.000	15.500	-----
TEMPERATURE	C - DEGREE		13.000	15.000	-----	-----	-----
TH-230	PCI/L		< 1.000	< 1.000	-----	-----	0.950
TIN	MG/L		< 0.005	< 0.005	-----	-----	-----
TOTAL SOLIDS	MG/L		6606.000	6150.000	6350.000	6380.000	8100.000
TOTAL U	PPM		-----	-----	0.148	0.913	0.181
TOX	MG/L		0.300	0.330	-----	-----	-----
U-234	PCI/L		-----	41.000	-----	-----	-----
U-238	PCI/L		-----	42.000	-----	-----	-----
URANIUM	MG/L		0.185	-----	-----	-----	-----
VANADIUM	MG/L		0.600	0.280	6.000	5.200	9.000
ZINC	MG/L		0.600	0.267	6.700	4.900	37.000

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	584 03/26/85	584 06/07/85	585 02/03/83	585 06/09/83	585 09/20/83
ALKALINITY	MG/L CAC03		582.000	540.000	510.000	540.000	520.000
ALUMINUM	MG/L		< 0.100	< 0.100	-----	-----	0.012
AMMONIA	MG/L		-----	-----	-----	471.900	-----
AMMONIUM	MG/L		439.000	440.000	-----	-----	335.000
ANTIMONY	MG/L		< 0.003	< 0.003	-----	-----	< 0.005
ARSENIC	MG/L		< 0.180	0.090	0.008	< 0.001	0.018
BARIUM	MG/L		< 0.100	-----	< 0.020	0.030	0.051
BORON	MG/L		0.500	0.630	-----	-----	-----
CADMIUM	MG/L		0.097	0.073	-----	-----	< 0.000
CALCIUM	MG/L		530.000	605.000	556.000	584.000	540.000
CHLORIDE	MG/L		720.000	791.000	790.000	800.000	810.000
CHROMIUM	MG/L		0.030	< 0.010	0.001	0.007	0.003
COBALT	MG/L		0.050	0.070	0.004	0.082	0.005
COND, IN-SITU	UMHO/CM		-----	-----	5900.000	7200.000	-----
CONDUCTANCE	UMHO/CM		7600.000	7564.000	-----	-----	-----
COPPER	MG/L		0.150	0.076	0.008	< 0.000	0.009
CYANIDE	MG/L		< 0.010	< 0.010	-----	-----	-----
FLUORIDE	MG/L		3.700	3.700	-----	-----	3.200
GROSS ALPHA	PCI/L		230.000	-----	-----	-----	-----
GROSS BETA	PCI/L		155.000	-----	-----	-----	-----
HYD. SULFIDE	MG/L		< 0.200	-----	-----	-----	-----
IRON	MG/L		< 0.050	0.060	4.030	2.640	2.710
LEAD	MG/L		< 0.010	< 0.010	-----	-----	< 0.001
MAGNESIUM	MG/L		260.000	220.000	620.000	280.000	310.000
MANGANESE	MG/L		4.000	3.400	3.420	3.380	4.800
MERCURY	MG/L		< 0.000	< 0.000	-----	-----	< 0.000
MOLYBDENUM	MG/L		0.280	0.220	0.440	0.290	0.210
NICKEL	MG/L		0.290	0.280	-----	-----	-----
NITRATE	MG/L		< 1.000	< 1.000	0.100	-----	< 0.010
NITROGEN, KJL	MG/L		-----	-----	340.000	-----	-----
ORG. CARBON	MG/L		10.400	11.600	64.700	103.000	99.100
PB-210	PCI/L		2.800	2.700	-----	-----	-----
PH	SU		6.800	7.100	7.600	7.300	7.200
PHOSPHATE	MG/L		< 0.100	< 0.100	-----	-----	-----
PHOSPHORUS	MG/L		-----	-----	-----	-----	< 0.040
PO-210	PCI/L		1.100	< 1.000	-----	-----	-----
POTASSIUM	MG/L		106.000	99.600	99.500	97.000	100.000
RA-226	PCI/L		7.500	6.000	-----	-----	18.000
RA-228	PCI/L		< 1.000	-----	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	584 03/26/85	584 06/07/85	585 02/03/83	585 06/09/83	585 09/20/83
SELENIUM	MG/L		0.240	0.178	0.004	< 0.002	< 0.002
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		13.300	12.600	-----	-----	21.000
SILVER	MG/L		< 0.010	< 0.010	-----	-----	0.004
SODIUM	MG/L		970.000	860.000	1020.000	960.000	990.000
STRONTIUM	MG/L		4.600	3.870	-----	-----	-----
SULFATE	MG/L		4100.000	3960.000	4320.000	4500.000	3800.000
SULFIDE	MG/L		-----	0.100	-----	-----	-----
TEMP, IN-SITU	C-DEGREE		-----	-----	10.000	18.500	-----
TEMPERATURE	C - DEGREE		14.000	15.000	-----	-----	-----
TH-230	PCI/L		< 1.000	< 1.000	-----	-----	5.400
TIN	MG/L		0.005	< 0.005	-----	-----	-----
TOTAL SOLIDS	MG/L		7186.000	6716.000	6440.000	6520.000	6640.000
TOTAL U	PPM		-----	-----	0.240	0.225	0.193
TOX	MG/L		0.600	0.140	-----	-----	-----
U-234	PCI/L		-----	47.000	-----	-----	-----
U-238	PCI/L		-----	49.000	-----	-----	-----
URANIUM	MG/L		0.165	-----	-----	-----	-----
VANADIUM	MG/L		7.480	6.750	0.027	0.141	0.097
ZINC	MG/L		4.100	2.560	0.030	0.030	0.010

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	585 03/25/85	585 06/07/85	586 02/02/83	586 06/09/83	586 09/20/83
ALKALINITY	MG/L CAC03		592.000	585.000	562.000	570.000	610.000
ALUMINUM	MG/L		< 0.100	< 0.100	-----	-----	0.011
AMMONIA	MG/L		-----	-----	-----	484.000	-----
AMMONIUM	MG/L		383.000	369.000	-----	-----	310.000
ANTIMONY	MG/L		< 0.003	< 0.003	-----	-----	< 0.005
ARSENIC	MG/L		0.015	< 0.010	0.004	0.027	0.110
BARIUM	MG/L		< 0.100	< 0.100	0.074	0.303	0.099
BORON	MG/L		0.620	0.660	-----	-----	-----
CADMIUM	MG/L		< 0.002	< 0.001	-----	-----	0.000
CALCIUM	MG/L		540.000	625.000	487.000	589.000	570.000
CHLORIDE	MG/L		850.000	868.000	805.000	860.000	820.000
CHROMIUM	MG/L		0.030	< 0.010	0.002	0.011	0.003
COBALT	MG/L		< 0.010	< 0.050	0.001	0.017	0.003
COND, IN-SITU	UMHO/CM		-----	-----	6200.000	5900.000	-----
CONDUCTANCE	UMHO/CM		5300.000	8296.000	-----	-----	-----
COPPER	MG/L		0.040	< 0.020	0.009	< 0.000	0.004
CYANIDE	MG/L		< 0.010	< 0.010	-----	-----	-----
FLUORIDE	MG/L		3.100	3.200	-----	-----	3.400
GROSS ALPHA	PCI/L		380.000	-----	-----	-----	-----
GROSS BETA	PCI/L		200.000	-----	-----	-----	-----
HYD. SULFIDE	MG/L		< 0.200	-----	-----	-----	-----
IRON	MG/L		13.000	11.200	13.500	6.090	4.770
LEAD	MG/L		< 0.010	< 0.010	-----	-----	< 0.001
MAGNESIUM	MG/L		310.000	354.000	323.000	270.000	290.000
MANGANESE	MG/L		4.800	4.050	4.070	334.000	4.600
MERCURY	MG/L		< 0.000	< 0.000	-----	-----	< 0.000
MOLYBDENUM	MG/L		0.270	0.180	0.470	0.360	0.360
NICKEL	MG/L		0.150	0.050	-----	-----	-----
NITRATE	MG/L		< 1.000	< 1.000	0.190	-----	< 0.100
NITROGEN, KJL	MG/L		-----	-----	389.000	-----	-----
ORG. CARBON	MG/L		9.800	-----	118.000	96.900	78.600
PB-210	PCI/L		< 1.500	< 1.500	-----	-----	-----
PH	SU		6.900	7.100	7.300	7.300	7.100
PHOSPHATE	MG/L		< 0.100	< 0.100	-----	-----	-----
PHOSPHORUS	MG/L		-----	-----	-----	-----	0.140
PO-210	PCI/L		< 1.000	< 1.000	-----	-----	-----
POTASSIUM	MG/L		95.000	98.400	110.000	94.000	120.000
RA-226	PCI/L		< 1.000	< 1.000	-----	-----	18.000
RA-228	PCI/L		4.500	-----	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	585 03/25/85	585 06/07/85	586 02/02/83	586 06/09/83	586 09/20/83
SELENIUM	MG/L		< 0.005	< 0.005	< 0.005	< 0.002	< 0.002
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		11.600	10.600	-----	-----	23.000
SILVER	MG/L		< 0.010	< 0.010	-----	-----	0.002
SODIUM	MG/L		970.000	916.000	1020.000	940.000	1000.000
STRONTIUM	MG/L		4.700	5.220	-----	-----	-----
SULFATE	MG/L		3600.000	3780.000	4320.000	4400.000	3800.000
SULFIDE	MG/L		-----	< 0.100	-----	-----	-----
TEMP, IN-SITU	C-DEGREE		-----	-----	10.000	17.000	-----
TEMPERATURE	C - DEGREE		12.500	15.000	-----	-----	-----
TH-230	PCI/L		< 1.000	< 1.000	-----	-----	4.200
TIN	MG/L		0.005	< 0.005	-----	-----	-----
TOTAL SOLIDS	MG/L		7198.000	7310.000	6760.000	6620.000	6530.000
TOTAL U	PPM		-----	-----	0.386	0.147	0.229
TOX	MG/L		0.900	-----	-----	-----	-----
U-234	PCI/L		-----	84.000	-----	-----	-----
U-238	PCI/L		-----	84.000	-----	-----	-----
URANIUM	MG/L		0.310	-----	-----	-----	-----
VANADIUM	MG/L		0.110	0.090	0.140	0.400	0.250
ZINC	MG/L		0.050	< 0.005	0.300	0.050	0.010

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	586 03/25/85	586 06/07/85	587 01/31/83	587 06/08/83	587 09/21/83
ALKALINITY	MG/L CAC03		618.000	609.000	381.000	340.000	400.000
ALUMINUM	MG/L		< 0.100	< 0.100	-----	-----	0.011
AMMONIA	MG/L		-----	-----	-----	37.510	-----
AMMONIUM	MG/L		393.000	384.000	-----	-----	32.300
ANTIMONY	MG/L		0.012	0.003	-----	-----	< 0.005
ARSENIC	MG/L		0.018	0.040	< 0.001	0.007	< 0.001
BARIUM	MG/L		< 0.100	< 0.100	0.026	0.030	0.036
BORON	MG/L		0.560	0.670	-----	-----	-----
CADMIUM	MG/L		< 0.002	< 0.001	-----	-----	0.004
CALCIUM	MG/L		550.000	630.000	454.000	505.000	410.000
CHLORIDE	MG/L		740.000	860.000	375.000	520.000	400.000
CHROMIUM	MG/L		0.020	< 0.010	0.002	0.001	0.001
COBALT	MG/L		< 0.010	< 0.050	< 0.001	0.038	0.001
COND, IN-SITU	UMHO/CM		-----	-----	2800.000	3800.000	-----
CONDUCTANCE	UMHO/CM		8900.000	7320.000	-----	-----	-----
COPPER	MG/L		0.070	< 0.020	0.011	< 0.000	< 0.002
CYANIDE	MG/L		< 0.010	< 0.010	-----	-----	-----
FLUORIDE	MG/L		3.100	3.300	-----	-----	1.000
GROSS ALPHA	PCI/L		490.000	-----	-----	-----	-----
GROSS BETA	PCI/L		180.000	-----	-----	-----	-----
HYD. SULFIDE	MG/L		< 0.200	-----	-----	-----	-----
IRON	MG/L		16.000	12.800	0.370	0.015	0.064
LEAD	MG/L		< 0.010	< 0.010	-----	-----	< 0.001
MAGNESIUM	MG/L		310.000	364.000	292.000	330.000	350.000
MANGANESE	MG/L		4.800	4.020	0.460	7.100	1.910
MERCURY	MG/L		< 0.000	< 0.000	-----	-----	< 0.000
MOLYBDENUM	MG/L		0.230	0.200	0.140	0.128	0.076
NICKEL	MG/L		0.120	0.140	-----	-----	-----
NITRATE	MG/L		< 1.000	< 1.000	0.640	-----	< 0.100
NITROGEN, KJL	MG/L		-----	-----	24.000	-----	-----
ORG. CARBON	MG/L		10.100	-----	99.900	63.500	87.400
PB-210	PCI/L		< 1.500	2.700	-----	-----	-----
PH	SU		7.000	7.000	7.000	7.200	7.100
PHOSPHATE	MG/L		< 0.100	< 0.100	-----	-----	-----
PHOSPHORUS	MG/L		-----	-----	-----	-----	< 0.040
PO-210	PCI/L		< 1.000	< 1.000	-----	-----	-----
POTASSIUM	MG/L		94.000	101.000	12.900	14.400	15.000
RA-226	PCI/L		1.100	2.000	-----	-----	-----
RA-228	PCI/L		2.500	-----	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	586 03/25/85	586 06/07/85	587 01/31/83	587 06/08/83	587 09/21/83
SELENIUM	MG/L		< 0.005	< 0.005	< 0.002	< 0.002	0.002
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		12.600	11.800	-----	-----	22.000
SILVER	MG/L		< 0.010	< 0.010	-----	-----	< 0.002
SODIUM	MG/L		990.000	914.000	419.000	490.000	490.000
STRONTIUM	MG/L		4.700	4.630	-----	-----	-----
SULFATE	MG/L		3700.000	3740.000	2370.000	2700.000	2000.000
SULFIDE	MG/L		-----	0.200	-----	-----	-----
TEMP, IN-SITU	C-DEGREE		-----	-----	11.000	18.500	-----
TEMPERATURE	C - DEGREE		12.500	15.000	-----	-----	-----
TH-230	PCI/L		< 1.000	< 1.000	-----	-----	-----
TIN	MG/L		< 0.005	< 0.005	-----	-----	-----
TOTAL SOLIDS	MG/L		7276.000	7186.000	4220.000	4570.000	4790.000
TOTAL U	PPM		-----	-----	0.081	0.076	0.085
TOX	MG/L		0.500	-----	-----	-----	-----
U-234	PCI/L		-----	118.000	-----	-----	-----
U-238	PCI/L		-----	116.000	-----	-----	-----
URANIUM	MG/L		0.445	-----	-----	-----	-----
VANADIUM	MG/L		0.130	0.270	0.049	0.062	0.030
ZINC	MG/L		0.050	< 0.005	0.020	0.060	0.110

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	588 02/01/83	588 06/07/85	589 02/01/83	589 06/08/83	589 09/22/83
ALKALINITY	MG/L CAC03		281.000	265.000	479.000	570.000	510.000
ALUMINUM	MG/L		-----	< 0.100	-----	-----	0.190
AMMONIA	MG/L		-----	-----	-----	118.580	-----
AMMONIUM	MG/L		-----	9.870	-----	-----	10.400
ANTIMONY	MG/L		-----	< 0.003	-----	-----	< 0.005
ARSENIC	MG/L		0.004	0.010	< 0.001	< 0.001	0.022
BARIUM	MG/L		0.040	< 0.100	0.080	.060	0.130
BORON	MG/L		-----	0.070	-----	-----	-----
CADMIUM	MG/L		-----	< 0.001	-----	-----	0.003
CALCIUM	MG/L		118.000	94.000	574.000	581.000	480.000
CHLORIDE	MG/L		167.000	143.000	749.000	840.000	860.000
CHROMIUM	MG/L		0.002	< 0.010	0.001	.005	0.004
COBALT	MG/L		< 0.001	< 0.050	< 0.001	.071	< 0.001
COND, IN-SITU	UMHO/CM		-----	-----	4600.000	6100.000	-----
CONDUCTANCE	UMHO/CM		-----	910.000	-----	-----	-----
COPPER	MG/L		0.011	< 0.020	0.116	.007	0.003
CYANIDE	MG/L		-----	< 0.010	-----	-----	-----
FLUORIDE	MG/L		-----	0.400	-----	-----	0.540
GROSS ALPHA	PCI/L		-----	-----	-----	-----	-----
GROSS BETA	PCI/L		-----	-----	-----	-----	-----
HYD. SULFIDE	MG/L		-----	-----	-----	-----	-----
IRON	MG/L		2.300	0.330	2.720	.080	3.420
LEAD	MG/L		-----	< 0.010	-----	-----	0.010
MAGNESIUM	MG/L		42.800	35.000	303.000	260.000	360.000
MANGANESE	MG/L		0.160	0.150	1.200	1.110	1.610
MERCURY	MG/L		-----	< 0.000	-----	-----	< 0.000
MOLYBDENUM	MG/L		< 0.030	< 0.010	0.200	.093	0.012
NICKEL	MG/L		-----	< 0.040	-----	-----	-----
NITRATE	MG/L		< 0.100	< 1.000	0.980	-----	< 0.100
NITROGEN, KJL	MG/L		7.700	-----	58.000	-----	-----
ORG. CARBON	MG/L		64.500	4.600	116.000	92.000	118.000
PB-210	PCI/L		-----	< 1.500	-----	-----	-----
PH	SU		7.100	7.800	7.000	7.400	7.300
PHOSPHATE	MG/L		-----	< 0.100	-----	-----	-----
PHOSPHORUS	MG/L		-----	-----	-----	-----	< 0.040
PO-210	PCI/L		-----	< 1.000	-----	-----	-----
POTASSIUM	MG/L		9.000	12.400	52.500	53.000	53.000
RA-226	PCI/L		-----	< 1.000	-----	-----	-----
RA-228	PCI/L		-----	-----	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	588 02/01/83	588 06/07/85	589 02/01/83	589 06/08/83	589 09/22/83
SELENIUM	MG/L		< 0.002	< 0.005	0.012	< 0.002	< 0.002
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		-----	6.200	-----	-----	17.000
SILVER	MG/L		-----	< 0.010	-----	-----	0.004
SODIUM	MG/L		141.000	111.000	1090.000	1000.000	1300.000
STRONTIUM	MG/L		-----	0.750	-----	-----	-----
SULFATE	MG/L		184.000	142.000	3630.000	3200.000	2900.000
SULFIDE	MG/L		-----	< 0.100	-----	-----	-----
TEMP, IN-SITU	C-DEGREE		-----	-----	13.000	18.500	-----
TEMPERATURE	C - DEGREE		-----	18.000	-----	-----	-----
TH-230	PCI/L		-----	< 1.000	-----	-----	-----
TIN	MG/L		-----	< 0.005	-----	-----	-----
TOTAL SOLIDS	MG/L		878.000	656.000	6400.000	6030.000	6150.000
TOTAL U	PPM		0.010	-----	0.277	0.147	0.302
TOX	MG/L		-----	0.100	-----	-----	-----
U-234	PCI/L		-----	1.000	-----	-----	-----
U-238	PCI/L		-----	1.000	-----	-----	-----
URANIUM	MG/L		-----	-----	-----	-----	-----
VANADIUM	MG/L		0.006	< 0.010	0.027	0.058	0.110
ZINC	MG/L		< 0.010	< 0.005	0.050	0.080	0.390

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	589 03/25/85	589 06/07/85	590 02/02/83	590 06/07/83	590 09/22/83
ALKALINITY	MG/L CAC03		522.000	633.000	449.000	390.000	460.000
ALUMINUM	MG/L		< 0.100	< 0.100	-----	-----	0.018
AMMONIA	MG/L		-----	-----	-----	12.100	-----
AMMONIUM	MG/L		124.000	148.000	-----	-----	18.100
ANTIMONY	MG/L		< 0.003	< 0.003	-----	-----	< 0.005
ARSENIC	MG/L		< 0.010	< 0.010	< 0.001	< 0.001	< 0.001
BARIUM	MG/L		< 0.100	< 0.100	0.019	0.030	0.070
BORON	MG/L		0.600	0.600	-----	-----	-----
CADMIUM	MG/L		< 0.002	< 0.001	-----	-----	0.001
CALCIUM	MG/L		590.000	665.000	500.000	493.000	480.000
CHLORIDE	MG/L		930.000	1100.000	736.000	990.000	670.000
CHROMIUM	MG/L		0.020	< 0.010	0.002	0.003	0.002
COBALT	MG/L		< 0.010	< 0.050	< 0.001	0.052	< 0.001
COND, IN-SITU	UMHO/CM		-----	-----	4810.000	3480.000	-----
CONDUCTANCE	UMHO/CM		7200.000	7800.000	-----	-----	-----
COPPER	MG/L		0.050	< 0.020	0.012	< 0.000	0.005
CYANIDE	MG/L		< 0.010	< 0.010	-----	-----	-----
FLUORIDE	MG/L		0.300	0.400	-----	-----	0.530
GROSS ALPHA	PCI/L		260.000	-----	-----	-----	-----
GROSS BETA	PCI/L		130.000	-----	-----	-----	-----
HYD. SULFIDE	MG/L		< 0.200	-----	-----	-----	-----
IRON	MG/L		1.100	3.790	0.018	0.056	0.062
LEAD	MG/L		< 0.010	< 0.010	-----	-----	0.020
MAGNESIUM	MG/L		310.000	360.000	407.000	254.000	420.000
MANGANESE	MG/L		2.000	2.180	0.360	0.380	1.230
MERCURY	MG/L		< 0.000	< 0.000	-----	-----	< 0.000
MOLYBDENUM	MG/L		0.060	0.010	0.130	0.101	0.015
NICKEL	MG/L		< 0.040	0.110	-----	-----	-----
NITRATE	MG/L		39.000	< 1.000	3.600	-----	0.110
NITROGEN, KJL	MG/L		-----	-----	8.500	-----	-----
ORG. CARBON	MG/L		16.000	13.700	81.900	79.700	98.100
PB-210	PCI/L		< 1.500	< 1.500	-----	-----	-----
PH	SU		6.900	7.000	7.100	7.100	7.100
PHOSPHATE	MG/L		< 0.100	0.100	-----	-----	-----
PHOSPHORUS	MG/L		-----	-----	-----	-----	0.100
PO-210	PCI/L		< 1.000	< 1.000	-----	-----	-----
POTASSIUM	MG/L		52.000	66.400	22.200	17.200	19.100
RA-226	PCI/L		< 1.000	< 1.000	-----	-----	< 0.600
RA-228	PCI/L		< 1.000	-----	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	589 03/25/85	589 06/07/85	590 02/02/83	590 06/07/83	590 09/22/83
SELENIUM	MG/L		< 0.005	< 0.005	< 0.002	< 0.002	< 0.002
SILICON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		7.100	7.200	-----	-----	20.000
SILVER	MG/L		< 0.010	< 0.010	-----	-----	< 0.002
SODIUM	MG/L		1120.000	1060.000	1030.000	700.000	830.000
STRONTIUM	MG/L		6.100	5.940	-----	-----	-----
SULFATE	MG/L		3400.000	3350.000	3410.000	2100.000	2500.000
SULFIDE	MG/L		-----	< 0.100	-----	-----	-----
TEMP, IN-SITU	C-DEGREE		-----	-----	10.000	15.500	-----
TEMPERATURE	C - DEGREE		13.000	13.000	-----	-----	-----
TH-230	PCI/L		< 1.000	< 1.000	-----	-----	-----
TIN	MG/L		0.010	< 0.005	-----	-----	-----
TOTAL SOLIDS	MG/L		7302.000	7184.000	6560.000	4670.000	5600.000
TOTAL U	PPM		-----	-----	0.376	0.135	0.162
TOX	MG/L		0.600	0.220	-----	-----	-----
U-234	PCI/L		-----	99.000	-----	-----	-----
U-238	PCI/L		-----	89.000	-----	-----	-----
URANIUM	MG/L		0.270	-----	-----	-----	-----
VANADIUM	MG/L		< 0.010	0.010	< 0.010	0.055	0.004
ZINC	MG/L		0.100	0.031	0.020	0.040	0.070

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	590 03/25/85	590 06/07/85
ALKALINITY	MG/L CAC03		522.000	498.000
ALUMINUM	MG/L		< 0.100	< 0.100
AMMONIA	MG/L		-----	-----
AMMONIUM	MG/L		17.400	8.360
ANTIMONY	MG/L		0.004	< 0.003
ARSENIC	MG/L		< 0.010	< 0.010
BARIUM	MG/L		< 0.100	< 0.100
BORON	MG/L		0.560	0.410
CADMIUM	MG/L		< 0.002	< 0.001
CALCIUM	MG/L		580.000	316.000
CHLORIDE	MG/L		830.000	459.000
CHROMIUM	MG/L		0.020	< 0.010
COBALT	MG/L		< 0.010	< 0.050
COND, IN-SITU	UMHO/CM		-----	-----
CONDUCTANCE	UMHO/CM		6700.000	2700.000
COPPER	MG/L		0.010	< 0.020
CYANIDE	MG/L		< 0.010	< 0.010
FLUORIDE	MG/L		0.300	0.500
GROSS ALPHA	PCI/L		240.000	-----
GROSS BETA	PCI/L		110.000	-----
HYD. SULFIDE	MG/L		< 0.200	-----
IRON	MG/L		1.100	< 0.030
LEAD	MG/L		< 0.010	< 0.010
MAGNESIUM	MG/L		340.000	177.000
MANGANESE	MG/L		1.500	0.740
MERCURY	MG/L		< 0.000	< 0.000
MOLYBDENUM	MG/L		0.020	0.010
NICKEL	MG/L		< 0.040	< 0.040
NITRATE	MG/L		12.000	< 1.000
NITROGEN, KJL	MG/L		-----	-----
ORG. CARBON	MG/L		3.700	9.900
PB-210	PCI/L		< 1.500	< 1.500
PH	SU		6.700	7.000
PHOSPHATE	MG/L		< 0.100	-----
PHOSPHORUS	MG/L		-----	-----
PO-210	PCI/L		< 1.000	< 1.000
POTASSIUM	MG/L		20.000	15.700
RA-226	PCI/L		< 1.000	< 1.000
RA-228	PCI/L		< 1.000	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC:	590	590
		DATE:	03/25/85	06/07/85
SELENIUM	MG/L		< 0.005	< 0.005
SILCON	MG/L		8.500	-----
SILICA	MG/L		8.500	7.900
SILVER	MG/L		< 0.010	< 0.010
SODIUM	MG/L		940.000	498.000
STRONTIUM	MG/L		5.900	2.970
SULFATE	MG/L		3200.000	1370.000
SULFIDE	MG/L		-----	< 0.100
TEMP, IN-SITU	C-DEGREE		-----	-----
TEMPERATURE	C - DEGREE		13.000	13.000
TH-230	PCI/L		< 1.000	< 1.000
TIN	MG/L		< 0.005	< 0.005
TOTAL SOLIDS	MG/L		6566.000	3292.000
TOTAL U	PPM		-----	-----
TOX	MG/L		0.500	0.280
U-234	PCI/L		-----	31.
U-238	PCI/L		-----	28.000
URANIUM	MG/L		0.205	-----
VANADIUM	MG/L		< 0.100	0.020
ZINC	MG/L		0.050	< 0.005

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	581 02/07/83	581 06/09/83	581 09/22/83	581 03/26/85	581 06/07/85
ALKALINITY	MG/L CAC03		485.000	450.000	490.000	568.000	521.000
ALUMINUM	MG/L		-----	-----	0.004	< 0.100	< 0.100
AMMONIA	MG/L		-----	88.330	-----	-----	-----
AMMONIUM	MG/L		-----	-----	232.000	166.000	205.000
ANTIMONY	MG/L		-----	-----	< 0.005	< 0.003	< 0.003
ARSENIC	MG/L		< 0.001	< 0.001	0.008	0.016	0.010
BARIUM	MG/L		< 0.020	0.030	0.062	< 0.100	< 0.100
BORON	MG/L		-----	-----	-----	0.340	0.400
CADMIUM	MG/L		-----	-----	0.001	< 0.002	< 0.001
CALCIUM	MG/L		360.000	654.000	420.000	550.000	483.000
CHLORIDE	MG/L		515.000	640.000	530.000	490.000	563.000
CHROMIUM	MG/L		0.001	0.005	0.002	0.020	-----
COBALT	MG/L		< 0.001	0.053	0.001	< 0.010	< 0.050
COND, IN -SITU	UMHO/CM		4180.000	5200.000	-----	-----	-----
CONDUCTANCE	UMHO/CM		-----	-----	-----	6300.000	6000.000
COPPER	MG/L		0.011	< 0.000	< 0.000	0.050	< 0.020
CYANIDE	MG/L		-----	-----	-----	< 0.010	< 0.010
FLUORIDE	MG/L		-----	-----	4.400	4.700	4.300
GROSS ALPHA	PCI/L		-----	-----	-----	160.000	-----
GROSS BETA	PCI/L		-----	-----	-----	70.000	-----
HYD. SULFIDE	MG/L		-----	-----	-----	< 0.200	-----
IRON	MG/L		3.240	1.310	3.720	12.000	11.200
LEAD	MG/L		-----	-----	0.010	< 0.010	< 0.010
MAGNESIUM	MG/L		189.000	210.000	310.000	200.000	202.000
MANGANESE	MG/L		2.720	2.850	4.500	5.000	4.590
MERCURY	MG/L		-----	-----	< 0.000	< 0.000	< 0.000
MOLYBDENUM	MG/L		0.310	0.250	0.078	0.130	0.120
NICKEL	MG/L		-----	-----	-----	< 0.040	0.080
NITRATE	MG/L		0.120	-----	0.190	< 1.000	< 1.000
NITROGEN, K JL	MG/L		188.000	-----	-----	-----	-----
ORG. CARBON	MG/L		96.300	88.200	113.000	10.500	10.000
PB-210	PCI/L		-----	-----	-----	< 1.500	1.800
PH	SU		7.300	7.300	7.200	6.900	7.100
PHOSPHATE	MG/L		-----	-----	-----	< 0.100	< 0.100
PHOSPHORUS	MG/L		-----	-----	< 0.040	-----	-----
PO-210	PCI/L		-----	-----	-----	< 1.000	< 1.000
POTASSIUM	MG/L		66.400	56.000	52.000	57.000	61.200
RA-226	PCI/L		-----	-----	-----	1.400	1.000
RA-228	PCI/L		-----	-----	-----	< 1.000	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	581 02/07/83	581 06/09/83	581 09/22/83	581 03/26/85	581 06/07/85
SELENIUM	MG/L		0.020	< 0.002	< 0.002	< 0.005	< 0.005
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		-----	-----	22.000	12.400	11.900
SILVER	MG/L		-----	-----	< 0.002	< 0.010	< 0.010
SODIUM	MG/L		819.000	870.000	520.000	720.000	664.000
STRONTIUM	MG/L		-----	-----	-----	6.700	6.490
SULFATE	MG/L		3215.000	3800.000	2800.000	2900.000	2810.000
SULFIDE	MG/L		-----	-----	-----	-----	< 0.100
TEMP, IN-SITU	C-DEGREE		10.000	17.500	-----	-----	-----
TEMPERATURE	C - DEGREE		-----	-----	-----	14.000	16.000
TH-230	PCI/L		-----	-----	-----	< 1.000	< 1.000
TIN	MG/L		-----	-----	-----	0.008	< 0.005
TOTAL SOLIDS	MG/L		5260.000	5610.000	5200.000	5394.000	5464.000
TOTAL U	PPM		0.189	0.096	0.112	-----	-----
TOX	MG/L		-----	-----	-----	0.300	0.200
U-234	PCI/L		-----	-----	-----	-----	23.000
U-238	PCI/L		-----	-----	-----	-----	23.000
URANIUM	MG/L		-----	-----	-----	0.056	-----
VANADIUM	MG/L		0.074	0.078	0.018	0.020	0.020
ZINC	MG/L		0.030	0.040	0.040	0.100	< 0.005

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	581 06/07/85	581 06/07/85	581 06/07/85	581 06/07/85	582 02/08/83
ALKALINITY	MG/L CAC03		521.000	521.000	521.000	521.000	412.000
ALUMINUM	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	-----
AMMONIA	MG/L		-----	-----	-----	-----	-----
AMMONIUM	MG/L		206.000	199.000	202.000	201.000	-----
ANTIMONY	MG/L		< 0.003	< 0.003	< 0.003	< 0.003	-----
ARSENIC	MG/L		0.010	0.010	0.010	0.010	< 0.001
BARIUM	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	0.140
BORON	MG/L		0.450	0.440	0.450	0.430	-----
CADMIUM	MG/L		< 0.001	< 0.001	< 0.001	< 0.001	-----
CALCIUM	MG/L		481.000	474.000	477.000	474.000	106.000
CHLORIDE	MG/L		573.000	564.000	576.000	579.000	496.000
CHROMIUM	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.001
COBALT	MG/L		< 0.050	< 0.050	< 0.050	< 0.050	< 0.001
COND, IN-SITU	UMHO/CM		-----	-----	-----	-----	-----
CONDUCTANCE	UMHO/CM		6000.000	6000.000	6000.000	6000.000	-----
COPPER	MG/L		< 0.020	< 0.020	< 0.020	< 0.020	< 0.000
CYANIDE	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	-----
FLUORIDE	MG/L		4.200	4.300	4.300	4.100	-----
GROSS ALPHA	PCI/L		-----	-----	-----	-----	-----
GROSS BETA	PCI/L		-----	-----	-----	-----	-----
HYD. SULFIDE	MG/L		-----	-----	-----	-----	-----
IRON	MG/L		11.100	11.500	11.100	11.400	0.500
LEAD	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	-----
MAGNESIUM	MG/L		221.000	226.000	190.000	229.000	23.000
MANGANESE	MG/L		4.560	4.610	4.580	4.540	0.160
MERCURY	MG/L		< 0.000	< 0.000	< 0.000	< 0.000	-----
MOLYBDENUM	MG/L		0.080	0.080	0.100	0.090	.140
NICKEL	MG/L		0.090	0.080	0.030	0.080	-----
NITRATE	MG/L		< 1.000	< 1.000	< 1.000	< 1.000	< 0.100
NITROGEN, KJL	MG/L		-----	-----	-----	-----	10.000
ORG. CARBON	MG/L		10.000	9.900	9.600	10.200	71.800
PB-210	PCI/L		-----	-----	-----	-----	-----
PH	SU		7.100	7.100	7.100	7.100	7.500
PHOSPHATE	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	-----
PHOSPHORUS	MG/L		-----	-----	-----	-----	-----
PO-210	PCI/L		-----	-----	-----	-----	-----
POTASSIUM	MG/L		61.200	60.800	60.000	60.400	13.200
RA-226	PCI/L		-----	-----	-----	-----	-----
RA-228	PCI/L		-----	-----	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	581 06/07/85	581 06/07/85	581 06/07/85	581 06/07/85	582 02/08/83
SELENIUM	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	0.017
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		12.500	12.800	11.600	12.800	-----
SILVER	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	-----
SODIUM	MG/L		654.000	658.000	669.000	662.000	1090.000
STRONTIUM	MG/L		6.500	6.030	6.570	5.740	-----
SULFATE	MG/L		2810.000	2900.000	2960.000	2920.000	1665.000
SULFIDE	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	-----
TEMP, IN-SITU	C-DEGREE		-----	-----	-----	-----	-----
TEMPERATURE	C - DEGREE		16.000	16.000	16.000	16.000	-----
TH-230	PCI/L		-----	-----	-----	-----	-----
TIN	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	-----
TOTAL SOLIDS	MG/L		5498.000	5482.000	5460.000	5482.000	3320.000
TOTAL U	PPM		-----	-----	-----	-----	0.072
70X	MG/L		0.140	0.200	< 0.100	< 0.100	-----
U-234	PCI/L		-----	-----	-----	-----	-----
U-238	PCI/L		-----	-----	-----	-----	-----
URANIUM	MG/L		-----	-----	-----	-----	-----
VANADIUM	MG/L		0.030	0.010	0.020	0.030	0.032
ZINC	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	0.050

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	582 03/30/85	582 06/07/85	583 02/07/83	583 06/07/83	583 09/21/83
ALKALINITY	MG/L CAC03		477.000	542.000	504.000	360.000	570.000
ALUMINUM	MG/L		< 0.100	< 0.100	-----	-----	0.170
AMMONIA	MG/L		-----	-----	-----	254.100	-----
AMMONIUM	MG/L		18.000	27.200	-----	-----	335.000
ALUMINUM	MG/L		< 0.100	< 0.100	-----	-----	0.170
AMMONIA	MG/L		-----	-----	-----	254.100	-----
AMMONIUM	MG/L		18.000	27.200	-----	-----	335.000
ANTIMONY	MG/L		< 0.003	0.047	-----	-----	< 0.005
ARSENIC	MG/L		< 0.010	< 0.010	0.006	0.011	0.077
BARIUM	MG/L		< 0.100	< 0.100	0.050	0.002	0.170
BORON	MG/L		0.760	0.100	-----	-----	-----
CADMIUM	MG/L		< 0.002	< 0.001	-----	-----	0.072
CALCIUM	MG/L		190.000	143.000	555.000	475.000	520.000
CHLORIDE	MG/L		590.000	698.000	760.000	770.000	790.000
CHROMIUM	MG/L		0.050	< 0.010	< 0.001	0.010	0.004
COBALT	MG/L		< 0.010	< 0.050	0.030	0.049	0.530
COND., IN-SITU	UMHO/CM		-----	-----	6800.000	6100.000	-----
CONDUCTANCE	UMHO/CM		7300.000	6100.000	-----	-----	-----
COPPER	MG/L		0.060	< 0.020	0.044	0.008	0.067
CYANIDE	MG/L		< 0.010	< 0.010	-----	-----	-----
FLUORIDE	MG/L		1.200	1.300	-----	-----	4.400
GROSS ALPHA	PCI/L		200.000	-----	-----	-----	-----
GROSS BETA	PCI/L		< 50.000	-----	-----	-----	-----
HYD. SULFIDE	MG/L		< 0.200	-----	-----	-----	-----
IRON	MG/L		0.060	0.190	0.490	0.018	0.071
LEAD	MG/L		< 0.010	< 0.010	-----	-----	< 0.001
MAGNESIUM	MG/L		59.000	53.400	334.000	178.000	450.000
MANGANESE	MG/L		0.300	0.130	3.100	1.750	10.000
MERCURY	MG/L		< 0.000	< 0.000	-----	-----	< 0.000
MOLYBDENUM	MG/L		0.130	< 0.010	0.530	0.400	0.190
NICKEL	MG/L		0.060	0.100	-----	-----	-----
NITRATE	MG/L		< 1.000	< 1.000	0.190	-----	50.000
NITROGEN, KJL	MG/L		-----	-----	346.000	-----	-----
ORG. CARBON	MG/L		8.900	20.400	111.000	84.200	129.000
PB-210	PCI/L		< 1.500	< 1.500	-----	-----	-----
PH	SU		7.300	7.300	7.200	7.000	6.900
PHOSPHATE	MG/L		< 0.100	< 0.100	-----	-----	-----
PHOSPHORUS	MG/L		-----	-----	-----	-----	0.100
PO-210	PCI/L		< 1.000	< 1.000	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	582 03/30/85	582 06/07/85	583 02/07/83	583 06/07/83	583 09/21/83
POTASSIUM	MG/L		14.000	18.400	104.000	49.000	96.000
RA-226	PCI/L		< 1.000	< 1.000	-----	-----	29.000
RA-228	PCI/L		< 1.000	-----	-----	-----	-----
SELENIUM	MG/L		< 0.005	0.005	0.092	0.013	0.120
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		6.200	5.300	-----	-----	23.000
SILVER	MG/L		< 0.010	< 0.010	-----	-----	0.002
SODIUM	MG/L		1590.000	1450.000	890.000	1090.000	980.000
STRONTIUM	MG/L		10.200	8.040	-----	-----	-----
SULFATE	MG/L		2700.000	2440.000	4200.000	3100.000	4900.000
SULFIDE	MG/L		-----	< 0.100	-----	-----	-----
TEMP, IN-SITU	C-DEGREE		-----	-----	13.000	19.000	-----
TEMPERATURE	C - DEGREE		11.000	15.000	-----	-----	-----
TH-230	PCI/L		< 1.000	< 1.000	-----	-----	< 1.100
TIN	MG/L		< 0.005	< 0.005	-----	-----	-----
TOTAL SOLIDS	MG/L		5510.000	5180.000	6420.000	5830.000	8000.000
TOTAL U	PPM		-----	-----	0.229	0.524	0.075
TOX	MG/L		0.400	0.140	-----	-----	-----
U-234	PCI/L		-----	3.000	-----	-----	-----
U-238	PCI/L		-----	2.000	-----	-----	-----
URANIUM	MG/L		0.036	-----	-----	-----	-----
VANADIUM	MG/L		0.030	0.050	1.600	1.700	7.600
ZINC	MG/L		0.200	0.010	0.870	0.510	23.000

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	583 03/26/85	583 06/07/85	584 02/08/83	584 06/08/83	584 09/21/83
ALKALINITY	MG/L CAC03		517.000	464.000	286.000	530.000	560.000
ALUMINUM	MG/L		< 0.100	< 0.100	-----	-----	0.510
AMMONIA	MG/L		-----	-----	-----	544.500	-----
AMMONIUM	MG/L		357.000	274.000	-----	-----	374.000
ANTIMONY	MG/L		< 0.003	< 0.003	-----	-----	< 0.005
ARSENIC	MG/L		0.019	0.020	0.007	0.045	0.070
BARIUM	MG/L		< 0.100	< 0.100	-----	< 0.020	0.083
BORON	MG/L		0.570	0.660	-----	-----	-----
CADMIUM	MG/L		0.010	0.008	-----	-----	0.420
CALCIUM	MG/L		520.000	492.000	556.000	585.000	470.000
CHLORIDE	MG/L		660.000	787.000	822.000	970.000	790.000
CHROMIUM	MG/L		0.010	< 0.010	0.001	0.007	0.074
COBALT	MG/L		0.020	0.050	0.160	0.150	0.660
COND, IN-SITU	UMHO/CM		-----	-----	7000.000	6200.000	-----
CONDUCTANCE	UMHO/CM		8600.000	7320.000	-----	-----	-----
COPPER	MG/L		0.110	< 0.020	0.120	0.049	0.200
CYANIDE	MG/L		< 0.010	< 0.010	-----	-----	-----
FLUORIDE	MG/L		4.200	3.000	-----	-----	4.300
GROSS ALPHA	PCI/L		255.000	-----	-----	-----	-----
GROSS BETA	PCI/L		140.000	-----	-----	-----	-----
HYD. SULFIDE	MG/L		< 0.200	-----	-----	-----	-----
IRON	MG/L		1.800	1.080	0.189	0.019	0.066
LEAD	MG/L		< 0.010	< 0.010	-----	-----	< 0.001
MAGNESIUM	MG/L		230.000	185.000	25.100	220.000	470.000
MANGANESE	MG/L		4.300	2.560	4.220	3.040	8.100
MERCURY	MG/L		0.000	< 0.000	-----	-----	< 0.000
MOLYBDENUM	MG/L		0.300	0.130	0.420	0.380	0.170
NICKEL	MG/L		0.180	0.180	-----	-----	-----
NITRATE	MG/L		< 1.000	< 1.000	0.300	-----	41.000
NITROGEN, KJL	MG/L		-----	-----	388.000	-----	-----
ORG. CARBON	MG/L		11.700	10.500	120.000	84.600	139.000
PB-210	PCI/L		< 1.500	< 1.500	-----	-----	-----
PH	SU		6.800	7.100	7.200	7.200	6.800
PHOSPHATE	MG/L		< 0.100	< 0.100	-----	-----	-----
PHOSPHORUS	MG/L		-----	-----	-----	-----	0.080
PO-210	PCI/L		< 1.000	< 1.000	-----	-----	-----
POTASSIUM	MG/L		96.000	69.200	113.000	97.000	99.000
RA-226	PCI/L		4.500	5.000	-----	-----	15.000
RA-228	PCI/L		1.600	-----	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	583 03/26/85	583 06/07/85	584 02/08/83	584 06/08/83	584 09/21/83
SELENIUM	MG/L		< 0.005	0.005	0.051	0.027	0.220
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		11.700	8.800	-----	-----	29.000
SILVER	MG/L		< 0.010	< 0.010	-----	-----	0.002
SODIUM	MG/L		920.000	1130.000	1210.000	930.000	950.000
STRONTIUM	MG/L		4.300	3.550	-----	-----	-----
SULFATE	MG/L		3700.000	3390.000	4440.000	4200.000	4900.000
SULFIDE	MG/L		-----	< 0.100	-----	-----	-----
TEMP, IN-SITU	C-DEGREE		-----	-----	13.000	15.500	-----
TEMPERATURE	C - DEGREE		13.000	15.000	-----	-----	-----
TH-230	PCI/L		< 1.000	< 1.000	-----	-----	0.950
TIN	MG/L		< 0.005	< 0.005	-----	-----	-----
TOTAL SOLIDS	MG/L		6606.000	6150.000	6350.000	6380.000	8100.000
TOTAL U	PPM		-----	-----	0.148	0.913	0.181
TOX	MG/L		0.300	0.330	-----	-----	-----
U-234	PCI/L		-----	41.000	-----	-----	-----
U-238	PCI/L		-----	42.000	-----	-----	-----
URANIUM	MG/L		0.185	-----	-----	-----	-----
VANADIUM	MG/L		0.600	0.280	6.000	5.200	9.000
ZINC	MG/L		0.600	0.267	6.700	4.900	37.000

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	584 03/26/85	584 06/07/85	585 02/03/83	585 06/09/83	585 09/20/83
ALKALINITY	MG/L CAC03		582.000	540.000	510.000	540.000	520.000
ALUMINUM	MG/L		< 0.100	< 0.100	-----	-----	0.012
AMMONIA	MG/L		-----	-----	-----	471.900	-----
AMMONIUM	MG/L		439.000	440.000	-----	-----	335.000
ANTIMONY	MG/L		< 0.003	< 0.003	-----	-----	< 0.005
ARSENIC	MG/L		< 0.180	0.090	0.008	< 0.001	0.018
BARIUM	MG/L		< 0.100	-----	< 0.020	0.030	0.051
BORON	MG/L		0.500	0.630	-----	-----	-----
CADMIUM	MG/L		0.097	0.073	-----	-----	< 0.000
CALCIUM	MG/L		530.000	605.000	556.000	584.000	540.000
CHLORIDE	MG/L		720.000	791.000	790.000	800.000	810.000
CHROMIUM	MG/L		0.030	< 0.010	0.001	0.007	0.003
COBALT	MG/L		0.050	0.070	0.004	0.082	0.005
COND, IN -SITU	UMHO/CM		-----	-----	5900.000	7200.000	-----
CONDUCTANCE	UMHO/CM		7600.000	7564.000	-----	-----	-----
COPPER	MG/L		0.150	0.076	0.008	< 0.000	0.009
CYANIDE	MG/L		< 0.010	< 0.010	-----	-----	-----
FLUORIDE	MG/L		3.700	3.700	-----	-----	3.200
GROSS ALPHA	PCI/L		230.000	-----	-----	-----	-----
GROSS BETA	PCI/L		155.000	-----	-----	-----	-----
HYD. SULFIDE	MG/L		< 0.200	-----	-----	-----	-----
IRON	MG/L		< 0.050	0.060	4.030	2.640	2.710
LEAD	MG/L		< 0.010	< 0.010	-----	-----	< 0.001
MAGNESIUM	MG/L		260.000	220.000	620.000	280.000	310.000
MANGANESE	MG/L		4.000	3.400	3.420	3.380	4.800
MERCURY	MG/L		< 0.000	< 0.000	-----	-----	< 0.000
MOLYBDENUM	MG/L		0.280	0.220	0.440	0.290	0.210
NICKEL	MG/L		0.290	0.280	-----	-----	-----
NITRATE	MG/L		< 1.000	< 1.000	0.100	-----	< 0.010
NITROGEN, KJL	MG/L		-----	-----	340.000	-----	-----
ORG. CARBON	MG/L		10.400	11.600	64.700	103.000	99.100
PB-210	PCI/L		2.800	2.700	-----	-----	-----
PH	SU		6.800	7.100	7.600	7.300	7.200
PHOSPHATE	MG/L		< 0.100	< 0.100	-----	-----	-----
PHOSPHORUS	MG/L		-----	-----	-----	-----	< 0.040
PO-210	PCI/L		1.100	< 1.000	-----	-----	-----
POTASSIUM	MG/L		106.000	99.600	99.500	97.000	100.000
RA-226	PCI/L		7.500	6.000	-----	-----	18.000
RA-228	PCI/L		< 1.000	-----	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	584 03/26/85	584 06/07/85	585 02/03/83	585 06/09/83	585 09/20/83
SELENIUM	MG/L		0.240	0.178	0.004	< 0.002	< 0.002
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		13.300	12.600	-----	-----	21.000
SILVER	MG/L		< 0.010	< 0.010	-----	-----	0.004
SODIUM	MG/L		970.000	860.000	1020.000	960.000	990.000
STRONTIUM	MG/L		4.600	3.870	-----	-----	-----
SULFATE	MG/L		4100.000	3960.000	4320.000	4500.000	3800.000
SULFIDE	MG/L		-----	0.100	-----	-----	-----
TEMP, IN-SITU	C-DEGREE		-----	-----	10.000	18.500	-----
TEMPERATURE	C - DEGREE		14.000	15.000	-----	-----	-----
TH-230	PCI/L		< 1.000	< 1.000	-----	-----	5.400
TIN	MG/L		0.005	< 0.005	-----	-----	-----
TOTAL SOLIDS	MG/L		7186.000	6716.000	6440.000	6520.000	6640.000
TOTAL U	PPM		-----	-----	0.240	0.225	0.193
TOX	MG/L		0.600	0.140	-----	-----	-----
U-234	PCI/L		-----	47.000	-----	-----	-----
U-238	PCI/L		-----	49.000	-----	-----	-----
URANIUM	MG/L		0.165	-----	-----	-----	-----
VANADIUM	MG/L		7.480	6.750	0.027	0.141	0.097
ZINC	MG/L		4.100	2.560	0.030	0.030	0.010

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	585 03/25/85	585 06/07/85	586 02/02/83	586 06/09/83	586 09/20/83
ALKALINITY	MG/L CAC03		592.000	585.000	562.000	570.000	610.000
ALUMINUM	MG/L		< 0.100	< 0.100	-----	-----	0.011
AMMONIA	MG/L		-----	-----	-----	484.000	-----
AMMONIUM	MG/L		383.000	369.000	-----	-----	310.000
ANTIMONY	MG/L		< 0.003	< 0.003	-----	-----	< 0.005
ARSENIC	MG/L		0.015	< 0.010	0.004	0.027	0.110
BARIUM	MG/L		< 0.100	< 0.100	0.074	0.303	0.099
BORON	MG/L		0.620	0.660	-----	-----	-----
CADMIUM	MG/L		< 0.002	< 0.001	-----	-----	0.000
CALCIUM	MG/L		540.000	625.000	487.000	589.000	570.000
CHLORIDE	MG/L		850.000	868.000	805.000	860.000	820.000
CHROMIUM	MG/L		0.030	< 0.010	0.002	0.011	0.003
COBALT	MG/L		< 0.010	< 0.050	0.001	0.017	0.003
COND, IN-SITU	UMHO/CM		-----	-----	6200.000	5900.000	-----
CONDUCTANCE	UMHO/CM		5300.000	8296.000	-----	-----	-----
COPPER	MG/L		0.040	< 0.020	0.009	< 0.000	0.004
CYANIDE	MG/L		< 0.010	< 0.010	-----	-----	-----
FLUORIDE	MG/L		3.100	3.200	-----	-----	3.400
GROSS ALPHA	PCI/L		380.000	-----	-----	-----	-----
GROSS BETA	PCI/L		200.000	-----	-----	-----	-----
HYD. SULFIDE	MG/L		< 0.200	-----	-----	-----	-----
IRON	MG/L		13.000	11.200	13.500	6.090	4.770
LEAD	MG/L		< 0.010	< 0.010	-----	-----	< 0.001
MAGNESIUM	MG/L		310.000	354.000	323.000	270.000	290.000
MANGANESE	MG/L		4.800	4.050	4.070	334.000	4.600
MERCURY	MG/L		< 0.000	< 0.000	-----	-----	< 0.000
MOLYBDENUM	MG/L		0.270	0.180	0.470	0.360	0.360
NICKEL	MG/L		0.150	0.050	-----	-----	-----
NITRATE	MG/L		< 1.000	< 1.000	0.190	-----	< 0.100
NITROGEN, KJL	MG/L		-----	-----	389.000	-----	-----
ORG. CARBON	MG/L		9.800	-----	118.000	96.900	78.600
PB-210	PCI/L		< 1.500	< 1.500	-----	-----	-----
PH	SU		6.900	7.100	7.300	7.300	7.100
PHOSPHATE	MG/L		< 0.100	< 0.100	-----	-----	-----
PHOSPHORUS	MG/L		-----	-----	-----	-----	0.140
PO-210	PCI/L		< 1.000	< 1.000	-----	-----	-----
POTASSIUM	MG/L		95.000	98.400	110.000	94.000	120.000
RA-226	PCI/L		< 1.000	< 1.000	-----	-----	18.000
RA-228	PCI/L		4.500	-----	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	585 03/25/85	585 06/07/85	586 02/02/83	586 06/09/83	586 09/20/83
SELENIUM	MG/L		< 0.005	< 0.005	< 0.005	< 0.002	< 0.002
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		11.600	10.600	-----	-----	23.000
SILVER	MG/L		< 0.010	< 0.010	-----	-----	0.002
SODIUM	MG/L		970.000	916.000	1020.000	940.000	1000.000
STRONTIUM	MG/L		4.700	5.220	-----	-----	-----
SULFATE	MG/L		3600.000	3780.000	4320.000	4400.000	3800.000
SULFIDE	MG/L		-----	< 0.100	-----	-----	-----
TEMP, IN-SITU	C-DEGREE		-----	-----	10.000	17.000	-----
TEMPERATURE	C - DEGREE		12.500	15.000	-----	-----	-----
TH-230	PCI/L		< 1.000	< 1.000	-----	-----	4.200
TIN	MG/L		0.005	< 0.005	-----	-----	-----
TOTAL SOLIDS	MG/L		7198.000	7310.000	6760.000	6620.000	6530.000
TOTAL U	PPM		-----	-----	0.386	0.147	0.229
TOX	MG/L		0.900	-----	-----	-----	-----
U-234	PCI/L		-----	84.000	-----	-----	-----
U-238	PCI/L		-----	84.000	-----	-----	-----
URANIUM	MG/L		0.310	-----	-----	-----	-----
VANADIUM	MG/L		0.110	0.090	0.140	0.400	0.250
ZINC	MG/L		0.050	< 0.005	0.300	0.050	0.010

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	586 03/25/85	586 06/07/85	587 01/31/83	587 06/08/83	587 09/21/83
ALKALINITY	MG/L CAC03		618.000	609.000	381.000	340.000	400.000
ALUMINUM	MG/L		< 0.100	< 0.100	-----	-----	0.011
AMMONIA	MG/L		-----	-----	-----	37.510	-----
AMMONIUM	MG/L		393.000	384.000	-----	-----	32.300
ANTIMONY	MG/L		0.012	0.003	-----	-----	< 0.005
ARSENIC	MG/L		0.018	0.040	< 0.001	0.007	< 0.001
BARIUM	MG/L		< 0.100	< 0.100	0.026	0.030	0.036
BORON	MG/L		0.560	0.670	-----	-----	-----
CADMIUM	MG/L		< 0.002	< 0.001	-----	-----	0.004
CALCIUM	MG/L		550.000	630.000	454.000	505.000	410.000
CHLORIDE	MG/L		740.000	860.000	375.000	520.000	400.000
CHROMIUM	MG/L		0.020	< 0.010	0.002	0.001	0.001
COBALT	MG/L		< 0.010	< 0.050	< 0.001	0.038	0.001
COND, IN-SITU	UMHO/CM		-----	-----	2800.000	3800.000	-----
CONDUCTANCE	UMHO/CM		8900.000	7320.000	-----	-----	-----
COPPER	MG/L		0.070	< 0.020	0.011	< 0.000	< 0.002
CYANIDE	MG/L		< 0.010	< 0.010	-----	-----	-----
FLUORIDE	MG/L		3.100	3.300	-----	-----	1.000
GROSS ALPHA	PCI/L		490.000	-----	-----	-----	-----
GROSS BETA	PCI/L		180.000	-----	-----	-----	-----
HYD. SULFIDE	MG/L		< 0.200	-----	-----	-----	-----
IRON	MG/L		16.000	12.800	0.370	0.015	0.064
LEAD	MG/L		< 0.010	< 0.010	-----	-----	< 0.001
MAGNESIUM	MG/L		310.000	364.000	292.000	330.000	350.000
MANGANESE	MG/L		4.800	4.020	0.460	7.100	1.910
MERCURY	MG/L		< 0.000	< 0.000	-----	-----	< 0.000
MOLYBDENUM	MG/L		0.230	0.200	0.140	0.128	0.076
NICKEL	MG/L		0.120	0.140	-----	-----	-----
NITRATE	MG/L		< 1.000	< 1.000	0.640	-----	< 0.100
NITROGEN, KJL	MG/L		-----	-----	24.000	-----	-----
ORG. CARBON	MG/L		10.100	-----	99.900	63.500	87.400
PB-210	PCI/L		< 1.500	2.700	-----	-----	-----
PH	SU		7.000	7.000	7.000	7.200	7.100
PHOSPHATE	MG/L		< 0.100	< 0.100	-----	-----	-----
PHOSPHORUS	MG/L		-----	-----	-----	-----	< 0.040
PO-210	PCI/L		< 1.000	< 1.000	-----	-----	-----
POTASSIUM	MG/L		94.000	101.000	12.900	14.400	15.000
RA-226	PCI/L		1.100	2.000	-----	-----	-----
RA-228	PCI/L		2.500	-----	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	586 03/25/85	586 06/07/85	587 01/31/83	587 06/08/83	587 09/21/83
SELENIUM	MG/L		< 0.005	< 0.005	< 0.002	< 0.002	0.002
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		12.600	11.800	-----	-----	22.000
SILVER	MG/L		< 0.010	< 0.010	-----	-----	< 0.002
SODIUM	MG/L		990.000	914.000	419.000	490.000	490.000
STRONTIUM	MG/L		4.700	4.630	-----	-----	-----
SULFATE	MG/L		3700.000	3740.000	2370.000	2700.000	2000.000
SULFIDE	MG/L		-----	0.200	-----	-----	-----
TEMP, IN -SITU	C-DEGREE		-----	-----	11.000	18.500	-----
TEMPERATURE	C - DEGREE		12.500	15.000	-----	-----	-----
TH-230	PCI/L		< 1.000	< 1.000	-----	-----	-----
TIN	MG/L		< 0.005	< 0.005	-----	-----	-----
TOTAL SOLIDS	MG/L		7276.000	7186.000	4220.000	4570.000	4790.000
TOTAL U	PPM		-----	-----	0.081	0.076	0.085
TOX	MG/L		0.500	-----	-----	-----	-----
U-234	PCI/L		-----	118.000	-----	-----	-----
U-238	PCI/L		-----	116.000	-----	-----	-----
URANIUM	MG/L		0.445	-----	-----	-----	-----
VANADIUM	MG/L		0.130	0.270	0.049	0.062	0.030
ZINC	MG/L		0.050	< 0.005	0.020	0.060	0.110

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	588 02/01/83	588 06/07/85	589 02/01/83	589 06/08/83	589 09/22/83
ALKALINITY	MG/L CAC03		281.000	265.000	479.000	570.000	510.000
ALUMINUM	MG/L		-----	< 0.100	-----	-----	0.190
AMMONIA	MG/L		-----	-----	-----	118.580	-----
AMMONIUM	MG/L		-----	9.870	-----	-----	10.400
ANTIMONY	MG/L		-----	< 0.003	-----	-----	< 0.005
ARSENIC	MG/L		0.004	0.010	< 0.001	< 0.001	0.022
BARIUM	MG/L		0.040	< 0.100	0.080	.060	0.130
BORON	MG/L		-----	0.070	-----	-----	-----
CADMIUM	MG/L		-----	< 0.001	-----	-----	0.003
CALCIUM	MG/L		118.000	94.000	574.000	581.000	480.000
CHLORIDE	MG/L		167.000	143.000	749.000	840.000	860.000
CHROMIUM	MG/L		0.002	< 0.010	0.001	.005	0.004
COBALT	MG/L		< 0.001	< 0.050	< 0.001	.071	< 0.001
COND, IN-SITU	UMHO/CM		-----	-----	4600.000	6100.000	-----
CONDUCTANCE	UMHO/CM		-----	910.000	-----	-----	-----
COPPER	MG/L		0.011	< 0.020	0.116	.007	0.003
CYANIDE	MG/L		-----	< 0.010	-----	-----	-----
FLUORIDE	MG/L		-----	0.400	-----	-----	0.540
GROSS ALPHA	PCI/L		-----	-----	-----	-----	-----
GROSS BETA	PCI/L		-----	-----	-----	-----	-----
HYD. SULFIDE	MG/L		-----	-----	-----	-----	-----
IRON	MG/L		2.300	0.330	2.720	.080	3.420
LEAD	MG/L		-----	< 0.010	-----	-----	0.010
MAGNESIUM	MG/L		42.800	35.000	303.000	260.000	360.000
MANGANESE	MG/L		0.160	0.150	1.200	1.110	1.610
MERCURY	MG/L		-----	< 0.000	-----	-----	< 0.000
MOLYBDENUM	MG/L		< 0.030	< 0.010	0.200	.093	0.012
NICKEL	MG/L		-----	< 0.040	-----	-----	-----
NITRATE	MG/L		< 0.100	< 1.000	0.980	-----	< 0.100
NITROGEN, KJL	MG/L		7.700	-----	58.000	-----	-----
ORG. CARBON	MG/L		64.500	4.600	116.000	92.000	118.000
PB-210	PCI/L		-----	< 1.500	-----	-----	-----
PH	SU		7.100	7.800	7.000	7.400	7.300
PHOSPHATE	MG/L		-----	< 0.100	-----	-----	-----
PHOSPHORUS	MG/L		-----	-----	-----	-----	< 0.040
PO-210	PCI/L		-----	< 1.000	-----	-----	-----
POTASSIUM	MG/L		9.000	12.400	52.500	53.000	53.000
RA-226	PCI/L		-----	< 1.000	-----	-----	-----
RA-228	PCI/L		-----	-----	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	588 02/01/83	588 06/07/85	589 02/01/83	589 06/08/83	589 09/22/83
SELENIUM	MG/L		< 0.002	< 0.005	0.012	< 0.002	< 0.002
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		-----	6.200	-----	-----	17.000
SILVER	MG/L		-----	< 0.010	-----	-----	0.004
SODIUM	MG/L		141.000	111.000	1090.000	1000.000	1300.000
STRONTIUM	MG/L		-----	0.750	-----	-----	-----
SULFATE	MG/L		184.000	142.000	3630.000	3200.000	2900.000
SULF IDE	MG/L		-----	< 0.100	-----	-----	-----
TEMP, IN-SITU	C-DEGREE		-----	-----	13.000	18.500	-----
TEMPERATURE	C - DEGREE		-----	18.000	-----	-----	-----
TH-230	PCI/L		-----	< 1.000	-----	-----	-----
TIN	MG/L		-----	< 0.005	-----	-----	-----
TOTAL SOLIDS	MG/L		878.000	656.000	6400.000	6030.000	6150.000
TOTAL U	PPM		0.010	-----	0.277	0.147	0.302
TOX	MG/L		-----	0.100	-----	-----	-----
U-234	PCI/L		-----	1.000	-----	-----	-----
U-238	PCI/L		-----	1.000	-----	-----	-----
URANIUM	MG/L		-----	-----	-----	-----	-----
VANADIUM	MG/L		0.006	< 0.010	0.027	0.058	0.110
ZINC	MG/L		< 0.010	< 0.005	0.050	0.080	0.390

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	589 03/25/85	589 06/07/85	590 02/02/83	590 06/07/83	590 09/22/83
ALKALINITY	MG/L CAC03		522.000	633.000	449.000	390.000	460.000
ALUMINUM	MG/L		< 0.100	< 0.100	-----	-----	0.018
AMMONIA	MG/L		-----	-----	-----	12.100	-----
AMMONIUM	MG/L		124.000	148.000	-----	-----	18.100
ANTIMONY	MG/L		< 0.003	< 0.003	-----	-----	< 0.005
ARSENIC	MG/L		< 0.010	< 0.010	< 0.001	< 0.001	< 0.001
BARIUM	MG/L		< 0.100	< 0.100	0.019	0.030	0.070
BORON	MG/L		0.600	0.600	-----	-----	-----
CADMIUM	MG/L		< 0.002	< 0.001	-----	-----	0.001
CALCIUM	MG/L		590.000	665.000	500.000	493.000	480.000
CHLORIDE	MG/L		930.000	1100.000	736.000	990.000	670.000
CHROMIUM	MG/L		0.020	< 0.010	0.002	0.003	0.002
COBALT	MG/L		< 0.010	< 0.050	< 0.001	0.052	< 0.001
COND, IN-SITU	UMHO/CM		-----	-----	4810.000	3480.000	-----
CONDUCTANCE	UMHO/CM		7200.000	7800.000	-----	-----	-----
COPPER	MG/L		0.050	< 0.020	0.012	< 0.000	0.005
CYANIDE	MG/L		< 0.010	< 0.010	-----	-----	-----
FLUORIDE	MG/L		0.300	0.400	-----	-----	0.530
GROSS ALPHA	PCI/L		260.000	-----	-----	-----	-----
GROSS BETA	PCI/L		130.000	-----	-----	-----	-----
HYD. SULFIDE	MG/L		< 0.200	-----	-----	-----	-----
IRON	MG/L		1.100	3.790	0.018	0.056	0.062
LEAD	MG/L		< 0.010	< 0.010	-----	-----	0.020
MAGNESIUM	MG/L		310.000	360.000	407.000	254.000	420.000
MANGANESE	MG/L		2.000	2.180	0.360	0.380	1.230
MERCURY	MG/L		< 0.000	< 0.000	-----	-----	< 0.000
MOLYBDENUM	MG/L		0.060	0.010	0.130	0.101	0.015
NICKEL	MG/L		< 0.040	0.110	-----	-----	-----
NITRATE	MG/L		39.000	< 1.000	3.600	-----	0.110
NITROGEN, KJL	MG/L		-----	-----	8.500	-----	-----
ORG. CARBON	MG/L		16.000	13.700	81.900	79.700	98.100
PB-210	PCI/L		< 1.500	< 1.500	-----	-----	-----
PH	SU		6.900	7.000	7.100	7.100	7.100
PHOSPHATE	MG/L		< 0.100	0.100	-----	-----	-----
PHOSPHORUS	MG/L		-----	-----	-----	-----	0.100
PO-210	PCI/L		< 1.000	< 1.000	-----	-----	-----
POTASSIUM	MG/L		52.000	66.400	22.200	17.200	19.100
RA-226	PCI/L		< 1.000	< 1.000	-----	-----	< 0.600
RA-228	PCI/L		< 1.000	-----	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	589 03/25/85	589 06/07/85	590 02/02/83	590 06/07/83	590 09/22/83
SELENIUM	MG/L		< 0.005	< 0.005	< 0.002	< 0.002	< 0.002
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		7.100	7.200	-----	-----	20.000
SILVER	MG/L		< 0.010	< 0.010	-----	-----	< 0.002
SODIUM	MG/L		1120.000	1060.000	1030.000	700.000	830.000
STRONTIUM	MG/L		6.100	5.940	-----	-----	-----
SULFATE	MG/L		3400.000	3350.000	3410.000	2100.000	2500.000
SULFIDE	MG/L		-----	< 0.100	-----	-----	-----
TEMP, IN-SITU	C-DEGREE		-----	-----	10.000	15.500	-----
TEMPERATURE	C - DEGREE		13.000	13.000	-----	-----	-----
TH-230	PCI/L		< 1.000	< 1.000	-----	-----	-----
TIN	MG/L		0.010	< 0.005	-----	-----	-----
TOTAL SOLIDS	MG/L		7302.000	7184.000	6560.000	4670.000	5600.000
TOTAL U	PPM		-----	-----	0.376	0.135	0.162
TOX	MG/L		0.600	0.220	-----	-----	-----
U-234	PCI/L		-----	99.000	-----	-----	-----
U-238	PCI/L		-----	89.000	-----	-----	-----
URANIUM	MG/L		0.270	-----	-----	-----	-----
VANADIUM	MG/L		< 0.010	0.010	< 0.010	0.055	0.004
ZINC	MG/L		0.100	0.031	0.020	0.040	0.070

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	590 03/25/85	590 06/07/85
ALKALINITY	MG/L CAC03		522.000	498.000
ALUMINUM	MG/L		< 0.100	< 0.100
AMMONIA	MG/L		-----	-----
AMMONIUM	MG/L		17.400	8.360
ANTIMONY	MG/L		0.004	< 0.003
ARSENIC	MG/L		< 0.010	< 0.010
BARIUM	MG/L		< 0.100	< 0.100
BORON	MG/L		0.560	0.410
CADMIUM	MG/L		< 0.002	< 0.001
CALCIUM	MG/L		580.000	316.000
CHLORIDE	MG/L		830.000	459.000
CHROMIUM	MG/L		0.020	< 0.010
COBALT	MG/L		< 0.010	< 0.050
COND, IN-SITU	UMHO/CM		-----	-----
CONDUCTANCE	UMHO/CM		6700.000	2700.000
COPPER	MG/L		0.010	< 0.020
CYANIDE	MG/L		< 0.010	< 0.010
FLUORIDE	MG/L		0.300	0.500
GROSS ALPHA	PCI/L		240.000	-----
GROSS BETA	PCI/L		110.000	-----
HYD. SULFIDE	MG/L		< 0.200	-----
IRON	MG/L		1.100	< 0.030
LEAD	MG/L		< 0.010	< 0.010
MAGNESIUM	MG/L		340.000	177.000
MANGANESE	MG/L		1.500	0.740
MERCURY	MG/L		< 0.000	< 0.000
MOLYBDENUM	MG/L		0.020	0.010
NICKEL	MG/L		< 0.040	< 0.040
NITRATE	MG/L		12.000	< 1.000
NITROGEN, KJL	MG/L		-----	-----
ORG. CARBON	MG/L		3.700	9.900
PB-210	PCI/L		< 1.500	< 1.500
PH	SU		6.700	7.000
PHOSPHATE	MG/L		< 0.100	-----
PHOSPHORUS	MG/L		-----	-----
PO-210	PCI/L		< 1.000	< 1.000
POTASSIUM	MG/L		20.000	15.700
RA-226	PCI/L		< 1.000	< 1.000
RA-228	PCI/L		< 1.000	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	590 03/25/85	590 06/07/85
SELENIUM	MG/L		< 0.005	< 0.005
SILCON	MG/L		8.500	-----
SILICA	MG/L		8.500	7.900
SILVER	MG/L		< 0.010	< 0.010
SODIUM	MG/L		940.000	498.000
STRONTIUM	MG/L		5.900	2.970
SULFATE	MG/L		3200.000	1370.000
SULFIDE	MG/L		-----	< 0.100
TEMP, IN-SITU	C-DEGREE		-----	-----
TEMPERATURE	C - DEGREE		13.000	13.000
TH-230	PCI/L		< 1.000	< 1.000
TIN	MG/L		< 0.005	< 0.005
TOTAL SOLIDS	MG/L		6566.000	3292.000
TOTAL U	PPM		-----	-----
TOX	MG/L		0.500	0.280
U-234	PCI/L		-----	31.
U-238	PCI/L		-----	28.000
URANIUM	MG/L		0.205	-----
VANADIUM	MG/L		< 0.100	0.020
ZINC	MG/L		0.050	< 0.005

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	710 03/21/85	710 06/07/85
ALKALINITY	MG/L CAC03		535.000	507.000
ALUMINUM	MG/L		< 0.100	< 0.100
AMMONIUM	MG/L		45.000	24.900
ANTIMONY	MG/L		< 0.003	< 0.003
ARSENIC	MG/L		< 0.010	< 0.010
BARIUM	MG/L		< 0.100	< 0.100
BICARBONATE	MG/L		-----	-----
BORON	MG/L		0.310	0.370
CADMIUM	MG/L		< 0.002	< 0.001
CALCIUM	MG/L		590.000	524.000
CHLORIDE	MG/L		770.000	607.000
CHROMIUM	MG/L		0.020	< 0.010
COBALT	MG/L		< 0.010	< 0.050
CONDUCTANCE	UMHO/CM		6700.000	4300.000
COPPER	MG/L		0.020	< 0.020
CYANIDE	MG/L		< 0.010	< 0.010
FLUORIDE	MG/L		1.000	1.100
GROSS ALPHA	PCI/L		< 70.000	-----
GROSS BETA	PCI/L		100.000	-----
4YD. SULFIDE	MG/L		< 0.200	-----
IRON	MG/L		0.100	0.110
LEAD	MG/L		< 0.010	< 0.010
MAGNESIUM	MG/L		330.000	327.000
MANGANESE	MG/L		2.700	2.910
MERCURY	MG/L		0.000	< 0.000
MOLYBDENUM	MG/L		0.080	0.070
NICKEL	MG/L		< 0.040	< 0.040
NITRATE	MG/L		3.000	< 1.000
ORG. CARBON	MG/L		7.200	8.900
PB-210	PCI/L		< 1.500	< 1.5
PH	SU		7.100	6.850
PHOSPHATE	MG/L		< 0.100	< 0.100
PO-210	PCI/L		< 1.000	< 1.000
POTASSIUM	MG/L		24.000	23.600
RA-226	PCI/L		< 1.000	< 1.000
RA-228	PCI/L		1.000	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC:	710	710
		DATE:	03/21/85	06/07/85
SELENIUM	MG/L		< 0.005	< 0.005
SILCON	MG/L		-----	-----
SILICA	MG/L		7.800	8.200
SILVER	MG/L		< 0.010	< 0.010
SODIUM	MG/L		780.000	665.000
STRONTIUM	MG/L		6.100	5.810
SULFATE	MG/L		3000.000	2430.000
SULFIDE	MG/L		-----	< 0.100
TEMPERATURE	C - DEGREE		11.500	16.000
TH-230	PCI/L		< 1.000	< 1.000
TIN	MG/L		< 0.005	< 0.005
TOTAL SOLIDS	MG/L		6204.000	5658.000
TOX	MG/L		0.200	0.210
U-234	PCI/L		29.000	36.000
U-238	PCI/L		23.000	30.700
VANADIUM	MG/L		< 0.010	< 0.010
ZINC	MG/L		0.050	< 0.005

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	711 03/27/85	711 06/07/85
ALKALINITY	MG/L CAC03		385.000	737.000
ALUMINUM	MG/L		< 0.100	< 0.100
AMMONIUM	MG/L		2.100	0.340
ANTIMONY	MG/L		< 0.003	0.008
ARSENIC	MG/L		< 0.010	< 0.010
BARIUM	MG/L		< 0.100	< 0.100
BICARBONATE	MG/L		-----	-----
BORON	MG/L		0.070	0.810
CADMIUM	MG/L		< 0.002	< 0.001
CALCIUM	MG/L		390.000	313.000
CHLORIDE	MG/L		300.000	316.000
CHROMIUM	MG/L		< 0.010	< 0.010
COBALT	MG/L		< 0.010	< 0.050
CONDUCTANCE	UMHO/CM		3400.000	4880.000
COPPER	MG/L		0.010	< 0.020
CYANIDE	MG/L		< 0.010	< 0.010
FLUORIDE	MG/L		0.400	0.800
GROSS ALPHA	PCI/L		90.000	-----
GROSS BETA	PCI/L		< 50.000	-----
HYD. SULFIDE	MG/L		< 0.200	-----
IRON	MG/L		0.100	0.760
LEAD	MG/L		< 0.010	< 0.010
MAGNESIUM	MG/L		140.000	420.000
MANGANESE	MG/L		1.400	1.550
MERCURY	MG/L		0.000	< 0.000
MOLYBDENUM	MG/L		0.010	0.050
NICKEL	MG/L		< 0.040	< 0.040
NITRATE	MG/L		2.000	< 1.000
ORG. CARBON	MG/L		5.400	26.100
PB-210	PCI/L		2.300	< 1.500
PH	SU		6.700	7.100
PHOSPHATE	MG/L		< 0.100	< 0.100
PO-210	PCI/L		< 1.000	< 1.000
POTASSIUM	MG/L		12.000	13.100
RA-226	PCI/L		< 1.000	< 1.000
RA-228	PCI/L		< 1.000	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	711 03/27/85	711 06/07/85
SELENIUM	MG/L		< 0.005	0.014
SILCON	MG/L		-----	-----
SILICA	MG/L		9.000	9.800
SILVER	MG/L		< 0.010	< 0.010
SODIUM	MG/L		340.000	662.000
STRONTIUM	MG/L		3.200	3.410
SULFATE	MG/L		1500.000	2780.000
SULFIDE	MG/L		-----	< 0.100
TEMPERATURE	C - DEGREE		11.500	15.000
TH-230	PCI/L		< 1.000	< 1.000
TIN	MG/L		< 0.005	< 0.005
TOTAL SOLIDS	MG/L		3008.000	5486.000
TOX	MG/L		< 0.100	0.200
U-234	PCI/L		9.000	25.000
U-238	PCI/L		8.000	16.000
VANADIUM	MG/L		< 0.010	0.020
ZINC	MG/L		0.060	0.018

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	712 03/26/85	712 06/07/85	724 03/30/85	724 06/07/85	724 06/07/85
ALKALINITY	MG/L CACO3		1016.000	494.000	2014.000	1785.000	1785.000
ALUMINUM	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
AMMONIUM	MG/L		0.290	15.700	1.200	1.000	1.700
ANTIMONY	MG/L		< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
ARSENIC	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
BARIUM	MG/L		< 0.100	< 0.100	5.100	5.540	5.290
BICARBONATE	MG/L		-----	-----	-----	-----	-----
BORON	MG/L		0.580	0.640	0.760	0.910	0.850
CADMIUM	MG/L		< 0.002	< 0.001	< 0.002	< 0.001	< 0.001
CALCIUM	MG/L		350.000	241.000	26.000	22.400	20.800
CHLORIDE	MG/L		350.000	208.000	1600.000	1520.000	1510.000
CHROMIUM	MG/L		0.020	< 0.010	< 0.010	< 0.010	< 0.010
COBALT	MG/L		< 0.010	< 0.050	< 0.010	< 0.050	< 0.050
CONDUCTANCE	UMHO/CM		5400.000	2379.000	6900.000	5300.000	5300.000
COPPER	MG/L		< 0.010	< 0.020	0.020	< 0.020	< 0.020
CYANIDE	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
FLUORIDE	MG/L		0.900	0.400	2.600	2.100	2.100
GROSS ALPHA	PCI/L		50.000	-----	< 60.000	-----	-----
GROSS BETA	PCI/L		< 50.000	-----	< 50.000	-----	-----
HYD. SULFIDE	MG/L		< 0.200	-----	< 0.200	-----	-----
IRON	MG/L		1.200	0.890	0.200	0.152	0.161
LEAD	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
MAGNESIUM	MG/L		360.000	97.100	7.800	7.330	7.340
MANGANESE	MG/L		1.100	8.740	< 0.050	< 0.010	< 0.010
MERCURY	MG/L		< 0.000	< 0.000	< 0.000	< 0.000	< 0.000
MOLYBDENUM	MG/L		0.060	< 0.010	< 0.010	< 0.010	< 0.010
NICKEL	MG/L		< 0.040	0.050	< 0.040	< 0.040	< 0.040
NITRATE	MG/L		8.000	< 1.000	< 1.000	< 1.000	< 1.000
ORG. CARBON	MG/L		53.600	17.700	38.200	16.600	17.000
PB-210	PCI/L		< 1.500	< 1.500	< 1.500	< 1.500	-----
PH	SU		7.100	7.100	7.500	7.700	7.700
PHOSPHATE	MG/L		< 0.100	2.040	< 0.100	< 0.100	< 0.100
PO-210	PCI/L		< 1.000	< 1.000	< 1.000	< 1.	-----
POTASSIUM	MG/L		12.000	15.300	7.000	31.100	18.200
RA-226	PCI/L		< 1.000	< 1.000	1.600	3.000	-----
RA-228	PCI/L		< 1.000	-----	1.200	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	712 03/26/85	712 06/07/85	724 03/30/85	724 06/07/85	724 06/07/85
SELENIUM	MG/L		0.009	0.005	< 0.005	0.006	0.006
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		8.100	7.700	4.500	4.700	4.400
SILVER	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
SODIUM	MG/L		730.000	231.000	1780.000	1700.000	1660.000
STRONTIUM	MG/L		3.800	2.100	3.700	3.640	3.490
SULFATE	MG/L		2700.000	831.000	6.000	20.300	10.400
SULFIDE	MG/L		-----	< 0.100	-----	< 0.100	< 0.100
TEMPERATURE	C - DEGREE		11.000	15.000	14.000	15.000	15.000
TH-230	PCI/L		< 1.000	< 1.000	< 1.000	< 1.000	-----
TIN	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
TOTAL SOLIDS	MG/L		5382.000	2072.000	4576.000	4438.000	4450.000
TOX	MG/L		< 0.100	< 0.010	0.100	< 0.100	0.180
U-234	PCI/L		23.000	9.000	5.000	< 1.000	-----
U-238	PCI/L		17.000	6.000	4.000	< 1.000	-----
VANADIUM	MG/L		< 0.010	< 0.010	< 0.010	0.010	< 0.010
ZINC	MG/L		< 0.050	< 0.005	0.080	< 0.005	< 0.005

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	724 06/07/85	724 06/07/85	724 06/07/85	725 03/29/85	725 03/29/85
ALKALINITY	MG/L CAC03		1785.000	1785.000	1785.000	2000.000	2000.000
ALUMINUM	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
AMMONIUM	MG/L		1.700	1.700	1.400	2.300	2.200
ANTIMONY	MG/L		< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
ARSENIC	MG/L		< 0.010	0.010	< 0.010	< 0.010	< 0.010
BARIUM	MG/L		5.320	5.490	5.930	1.800	1.800
BICARBONATE	MG/L		-----	-----	-----	-----	-----
BORON	MG/L		0.850	0.860	0.860	0.070	0.080
CADMIUM	MG/L		< 0.001	< 0.001	< 0.001	< 0.002	< 0.002
CALCIUM	MG/L		21.100	21.800	22.900	540.000	574.000
CHLORIDE	MG/L		1560.000	1500.000	1600.000	2400.000	2300.000
CHROMIUM	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
COBALT	MG/L		< 0.050	< 0.050	< 0.050	< 0.010	< 0.010
CONDUCTANCE	UMHO/CM		5300.000	5300.000	5300.000	17000.000	17000.000
COPPER	MG/L		< 0.020	< 0.020	< 0.020	< 0.010	< 0.010
CYANIDE	MG/L		< 0.010	< 0.010	< 0.010	< 0.000	< 0.010
FLUORIDE	MG/L		2.200	2.100	2.000	0.800	0.800
GROSS ALPHA	PCI/L		-----	-----	-----	220.000	100.000
GROSS BETA	PCI/L		-----	-----	-----	90.000	< 50.000
HYD. SULFIDE	MG/L		-----	-----	-----	4.700	3.400
IRON	MG/L		0.152	0.148	< 0.030	< 0.050	< 0.050
LEAD	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
MAGNESIUM	MG/L		7.100	7.370	6.400	0.040	4.200
MANGANESE	MG/L		< 0.010	< 0.010	< 0.010	< 0.050	< 0.050
MERCURY	MG/L		< 0.000	< 0.000	< 0.000	< 0.000	0.000
MOLYBDENUM	MG/L		< 0.010	< 0.010	< 0.010	0.080	0.900
NICKEL	MG/L		< 0.040	< 0.040	< 0.040	< 0.040	< 0.040
NITRATE	MG/L		< 1.000	< 1.000	< 1.000	< 1.000	< 1.000
ORG. CARBON	MG/L		17.200	17.000	16.500	7.100	7.000
PB-210	PCI/L		-----	-----	-----	< 1.500	< 1.500
PH	SU		7.700	7.700	7.700	12.600	12.600
PHOSPHATE	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
PO-210	PCI/L		-----	-----	-----	< 1.000	< 1.000
POTASSIUM	MG/L		30.000	21.600	31.100	59.000	57.200
RA-226	PCI/L		-----	-----	-----	5.000	4.000
RA-228	PCI/L		-----	-----	-----	< 1.000	1.300

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	724 06/07/85	724 06/07/85	724 06/07/85	725 03/29/85	725 03/29/85
SELENIUM	MG/L		0.005	0.007	0.007	< 0.005	< 0.005
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		4.400	4.600	4.400	1.800	1.800
SILVER	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
SODIUM	MG/L		1690.000	1690.000	1690.000	2080.000	1900.000
STRONTIUM	MG/L		3.460	3.540	3.720	11.000	10.600
SULFATE	MG/L		10.200	9.600	10.000	120.000	190.000
SULFIDE	MG/L		< 0.100	< 0.100	< 0.100	-----	-----
TEMPERATURE	C - DEGREE		15.000	15.000	15.000	12.000	12.000
TH-230	PCI/L		-----	-----	-----	< 1.000	< 1.000
TIN	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
TOTAL SOLIDS	MG/L		4428.000	4430.000	4468.000	6174.000	6178.000
TOX	MG/L		0.200	< 0.100	0.140	0.200	< 0.100
U-234	PCI/L		-----	-----	-----	< 1.000	< 1.000
U-238	PCI/L		-----	-----	-----	< 1.000	< 1.000
VANADIUM	MG/L		0.010	< 0.010	0.010	< 0.010	< 0.010
ZINC	MG/L		< 0.005	< 0.005	< 0.005	0.100	0.090

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	725 06/07/85
ALKALINITY	MG/L CAC03		835.000
ALUMINUM	MG/L		< 0.100
AMMONIUM	MG/L		2.000
ANTIMONY	MG/L		< 0.003
ARSENIC	MG/L		0.010
BARIUM	MG/L		1.050
BICARBONATE	MG/L		-----
BORON	MG/L		0.360
CADMIUM	MG/L		< 0.001
CALCIUM	MG/L		210.000
CHLORIDE	MG/L		3720.000
CHROMIUM	MG/L		< 0.010
COBALT	MG/L		< 0.050
CONDUCTANCE	UMHO/CM		13250.000
COPPER	MG/L		< 0.020
CYANIDE	MG/L		< 0.010
FLUORIDE	MG/L		0.500
GROSS ALPHA	PCI/L		-----
GROSS BETA	PCI/L		-----
HYD. SULFIDE	MG/L		-----
IRON	MG/L		111.000
LEAD	MG/L		< 0.010
MAGNESIUM	MG/L		< 0.010
MANGANESE	MG/L		< 0.010
MERCURY	MG/L		0.000
MOLYBDENUM	MG/L		0.030
NICKEL	MG/L		< 0.040
NITRATE	MG/L		< 1.000
ORG. CARBON	MG/L		4.400
PB-210	PCI/L		< 1.500
PH	SU		11.900
PHOSPHATE	MG/L		< 0.100
PO-210	PCI/L		< 1.000
POTASSIUM	MG/L		37.400
RA-226	PCI/L		2.000
RA-228	PCI/L		-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: 725 DATE: 06/07/85
SELENIUM	MG/L	0.016
SILCON	MG/L	-----
SILICA	MG/L	5.500
SILVER	MG/L	< 0.010
SODIUM	MG/L	2530.000
STRONTIUM	MG/L	4.470
SULFATE	MG/L	79.200
SULFIDE	MG/L	0.200
TEMPERATURE	C - DEGREE	14.000
TH-230	PCI/L	< 1.000
TIN	MG/L	< 0.005
TOTAL SOLIDS	MG/L	7164.000
TOX	MG/L	< 0.100
U-234	PCI/L	< 1.000
U-238	PCI/L	< 1.000
VANADIUM	MG/L	0.030
ZINC	MG/L	< 0.005

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	727 03/29/85	727 06/07/85	728 03/25/85	728 06/07/85	728 06/07/85
ALKALINITY	MG/L CAC03		1600.000	1468.000	441.000	558.000	558.000
ALUMINUM	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
AMMONIUM	MG/L		0.290	0.010	17.100	7.920	7.810
ANTIMONY	MG/L		< 0.003	< 0.003	0.003	< 0.003	< 0.003
ARSENIC	MG/L		< 0.010	< 0.010	< 0.010	< 0.510	< 0.010
BARIUM	MG/L		0.400	0.510	< 0.100	< 0.100	< 0.100
BORON	MG/L		0.600	0.640	0.510	-----	0.490
CADMIUM	MG/L		< 0.002	< 0.001	< 0.002	< 0.001	< 0.001
CALCIUM	MG/L		18.000	7.100	548.000	328.000	328.000
CHLORIDE	MG/L		360.000	312.000	800.000	436.000	436.000
CHROMIUM	MG/L		< 0.010	< 0.010	0.020	< 0.010	< 0.010
COBALT	MG/L		< 0.010	< 0.050	< 0.010	< 0.050	< 0.050
CONDUCTANCE	UMHO/CM		3200.000	3150.000	6300.000	2820.000	2820.000
COPPER	MG/L		< 0.010	< 0.020	0.010	< 0.020	< 0.020
CYANIDE	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
FLUORIDE	MG/L		2.800	2.400	0.400	0.500	0.500
GROSS ALPHA	PCI/L		45.000	-----	120.000	-----	-----
GROSS BETA	PCI/L		< 50.000	-----	90.000	-----	-----
HYD. SULFIDE	MG/L		< 0.200	-----	< 0.200	-----	-----
IRON	MG/L		< 0.050	0.060	2.500	1.580	1.580
LEAD	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
MAGNESIUM	MG/L		6.000	1.850	368.000	186.000	182.000
MANGANESE	MG/L		< 0.050	0.020	1.700	0.950	0.900
MERCURY	MG/L		0.000	< 0.000	< 0.000	< 0.000	< 0.000
MOLYBDENUM	MG/L		< 0.010	< 0.010	0.030	< 0.010	< 0.010
NICKEL	MG/L		0.050	< 0.040	< 0.040	< 0.040	0.040
NITRATE	MG/L		< 1.000	< 1.000	18.000	< 1.000	< 1.000
ORG. CARBON	MG/L		5.100	5.400	110.000	12.200	12.000
PB-210	PCI/L		< 1.500	< 1.500	< 1.500	< 1.500	-----
PH	SU		8.600	8.200	8.000	7.200	7.200
PHOSPHATE	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
PO-210	PCI/L		< 1.000	< 1.000	< 1.000	< 1.000	-----
POTASSIUM	MG/L		6.800	7.080	21.200	16.900	16.800
RA-226	PCI/L		< 1.000	< 1.000	< 1.000	< 1.000	-----
RA-228	PCI/L		< 1.000	-----	< 1.000	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	727 03/29/85	727 06/07/85	728 03/25/85	728 06/07/85	728 06/07/85
SELENIUM	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		5.800	5.000	8.900	8.700	8.300
SILVER	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
SODIUM	MG/L		880.000	840.000	960.000	536.000	531.000
STRONTIUM	MG/L		0.400	0.360	6.300	3.190	3.300
SULFATE	MG/L		9.000	12.700	3400.000	1430.000	1450.000
SULFIDE	MG/L		-----	0.200	-----	< 0.100	< 0.100
TEMPERATURE	C - DEGREE		7.000	14.000	11.000	12.000	12.000
TH-230	PCI/L		< 1.000	< 1.000	< 1.000	< 1.000	-----
TH-230	PCI/G		-----	-----	-----	-----	-----
TIN	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
TOTAL SOLIDS	MG/L		2098.000	2118.000	6600.000	3638.000	3684.000
TOX	MG/L		0.100	< 0.100	-----	0.240	0.290
U-234	PCI/L		2.900	3.000	61.000	33.000	-----
U-238	PCI/L		1.800	2.000	47.000	28.000	-----
VANADIUM	MG/L		< 0.010	0.050	< 0.010	0.020	< 0.010
ZINC	MG/L		< 0.050	< 0.005	< 0.050	< 0.005	< 0.005

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	728 06/07/85	728 06/07/85	728 06/07/85	729 04/01/85	729 06/07/85
ALKALINITY	MG/L CAC03		558.000	558.000	558.000	400.000	435.000
ALUMINUM	MG/L		< 0.100	< 0.100	< 0.100	0.200	< 0.100
AMMONIUM	MG/L		7.230	7.440	7.580	11.500	4.450
ANTIMONY	MG/L		< 0.003	< 0.003	< 0.003	0.003	< 0.004
ARSENIC	MG/L		< 0.010	< 0.010	< 0.010	0.013	0.010
BARIUM	MG/L		< 0.100	< 0.100	< 0.100	0.200	0.310
BORON	MG/L		0.490	0.480	0.500	0.320	0.530
CADMIUM	MG/L		< 0.001	< 0.001	< 0.001	< 0.002	< 0.001
CALCIUM	MG/L		324.000	320.000	311.000	110.000	37.600
CHLORIDE	MG/L		422.000	432.000	463.000	2300.000	3480.000
CHROMIUM	MG/L		< 0.010	< 0.010	< 0.010	0.030	< 0.010
COBALT	MG/L		< 0.050	< 0.050	< 0.050	< 0.010	< 0.050
CONDUCTANCE	UMHO/CM		2820.000	2820.000	2820.000	9000.000	8000.000
COPPER	MG/L		< 0.020	< 0.020	< 0.020	0.040	< 0.020
CYANIDE	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
FLUORIDE	MG/L		0.500	0.500	0.500	2.600	1.300
GROSS ALPHA	PCI/L		-----	-----	-----	70.000	-----
GROSS BETA	PCI/L		-----	-----	-----	< 50.000	-----
HYD. SULFIDE	MG/L		-----	-----	-----	3.200	-----
IRON	MG/L		1.450	1.530	1.510	< 0.050	< 0.030
LEAD	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
MAGNESIUM	MG/L		190.000	188.000	179.000	0.200	4.720
MANGANESE	MG/L		0.950	0.940	0.900	< 0.050	< 0.010
MERCURY	MG/L		< 0.000	< 0.000	< 0.000	0.000	< 0.000
MOLYBDENUM	MG/L		< 0.010	0.010	< 0.010	0.120	< 0.010
NICKEL	MG/L		< 0.040	0.040	< 0.040	< 0.040	< 0.040
NITRATE	MG/L		< 1.000	< 1.000	< 1.000	< 1.000	< 1.000
ORG. CARBON	MG/L		12.000	11.200	11.800	-----	3.600
PB-210	PCI/L		-----	-----	-----	< 1.500	< 1.500
PH	SU		7.200	7.200	7.200	11.500	9.200
PHOSPHATE	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
PO-210	PCI/L		-----	-----	-----	< 1.000	< 1.000
POTASSIUM	MG/L		17.000	16.700	16.900	22.000	15.400
RA-226	PCI/L		-----	-----	-----	< 1.000	< 1.000
RA-228	PCI/L		-----	-----	-----	< 1.000	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	728 06/07/85	728 06/07/85	728 06/07/85	729 04/01/85	729 06/07/85
SELENIUM	MG/L		< 0.005	< 0.005	< 0.005	0.011	0.008
SILICON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		8.900	8.700	8.100	12.300	5.300
SILVER	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
SODIUM	MG/L		526.000	531.000	522.000	1780.000	2280.000
STRONTIUM	MG/L		3.200	3.140	3.160	2.400	2.640
SULFATE	MG/L		1400.000	1430.000	1570.000	330.000	99.000
SULFIDE	MG/L		< 0.100	< 0.100	< 0.100	-----	< 0.100
TEMPERATURE	C - DEGREE		12.000	12.000	12.000	14.000	15.000
TH-230	PCI/L		-----	-----	-----	-----	< 1.000
TH-230	PCI/G		-----	-----	-----	< 1.000	-----
TIN	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
TOTAL SOLIDS	MG/L		3668.000	3638.000	3672.000	4842.000	6280.000
TOX	MG/L		< 0.100	0.130	0.140	-----	0.540
U-234	PCI/L		-----	-----	-----	< 1.000	7.000
U-238	PCI/L		-----	-----	-----	< 1.000	2.000
VANADIUM	MG/L		< 0.010	< 0.010	0.020	0.110	0.010
ZINC	MG/L		< 0.005	< 0.005	< 0.005	2.900	< 0.005

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	731 03/26/85	731 06/07/85	732 03/26/85	732 06/07/85	733 03/25/85
ALKALINITY	MG/L CAC03		1900.000	1505.000	466.000	509.000	690.000
ALUMINUM	MG/L		0.200	0.230	< 0.100	< 0.100	< 0.100
AMMONIUM	MG/L		3.680	5.390	0.290	0.510	0.860
ANTIMONY	MG/L		< 0.003	< 0.003	0.003	< 0.003	< 0.003
ARSENIC	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
BARIUM	MG/L		0.800	0.490	< 0.100	< 0.100	< 0.100
BORON	MG/L		0.020	< 0.010	0.510	0.700	0.810
CADMIUM	MG/L		< 0.002	< 0.001	< 0.002	< 0.001	< 0.002
CALCIUM	MG/L		320.000	194.000	540.000	665.000	510.000
CHLORIDE	MG/L		300.000	554.000	930.000	1130.000	1100.000
CHROMIUM	MG/L		< 0.010	< 0.010	0.020	< 0.010	0.030
COBALT	MG/L		< 0.010	< 0.050	< 0.010	< 0.050	< 0.010
CONDUCTANCE	UMHO/CM		9900.000	7000.000	7600.000	6000.000	-----
COPPER	MG/L		0.030	0.030	0.010	< 0.020	0.010
CYANIDE	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
FLUORIDE	MG/L		0.800	0.500	0.900	0.900	0.500
GROSS ALPHA	PCI/L		< 40.000	-----	105.000	-----	185.000
GROSS BETA	PCI/L		160.000	-----	60.000	-----	60.000
HYD. SULFIDE	MG/L		5.000	-----	< 0.200	-----	< 0.200
IRON	MG/L		< 0.050	< 0.030	0.200	0.080	4.200
LEAD	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
MAGNESIUM	MG/L		< 0.010	< 0.010	500.000	585.000	480.000
MANGANESE	MG/L		< 0.050	< 0.010	1.000	0.850	2.200
MERCURY	MG/L		< 0.000	< 0.000	< 0.000	< 0.000	< 0.000
MOLYBDENUM	MG/L		0.060	0.020	0.040	0.030	0.030
NICKEL	MG/L		< 0.040	< 0.040	< 0.040	< 0.040	< 0.040
NITRATE	MG/L		1.000	1.000	< 1.000	< 1.000	< 1.000
ORG. CARBON	MG/L		20.600	20.800	-----	12.000	522.000
PB-210	PCI/L		< 1.500	< 1.500	< 1.500	< 1.500	< 1.500
PH	SU		12.600	12.500	6.950	7.000	6.800
PHOSPHATE	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
PO-210	PCI/L		< 1.000	< 1.000	< 1.000	< 1.000	< 1.000
POTASSIUM	MG/L		169.000	96.800	9.500	12.200	12.000
RA-226	PCI/L		< 1.000	< 1.000	< 1.000	< 1.000	< 1.000
RA-228	PCI/L		< 1.000	-----	< 1.000	-----	< 1.000

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	731 03/26/85	731 06/07/85	732 03/26/85	732 06/07/85	733 03/25/85
SELENIUM	MG/L		< 0.005	0.007	< 0.005	0.007	< 0.005
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		1.600	1.200	6.700	6.800	9.200
SILVER	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
SODIUM	MG/L		790.000	824.000	980.000	1060.000	1230.000
STRONTIUM	MG/L		18.700	10.900	6.800	6.870	7.900
SULFATE	MG/L		240.000	107.000	3400.000	3790.000	3400.000
SULFIDE	MG/L		-----	0.300	-----	< 0.100	-----
TEMPERATURE	C - DEGREE		13.000	18.000	12.000	14.500	15.000
TH-230	PCI/L		< 1.000	< 1.000	< 1.000	< 1.000	< 1.000
TH-230	PCI/G		-----	-----	-----	-----	-----
TIN	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
TOTAL SOLIDS	MG/L		2994.000	2740.000	7504.000	7864.000	7922.000
TOX	MG/L		0.200	0.150	< 0.100	0.160	-----
U-234	PCI/L		< 1.000	< 1.000	53.000	58.000	39.000
U-238	PCI/L		< 1.000	< 1.000	36.000	38.000	25.000
VANADIUM	MG/L		0.010	< 0.010	< 0.010	< 0.010	< 0.010
ZINC	MG/L		< 0.050	0.005	< 0.050	< 0.005	0.050

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	733 06/07/85	735 03/29/85	735 06/07/85	736 03/22/85	736 06/07/85
ALKALINITY	MG/L CAC03		568.000	350.000	393.000	581.000	579.000
ALUMINUM	MG /L		< 0.100	0.700	< 0.100	< 0.100	< 0.100
AMMONIUM	MG /L		0.540	18.100	9.040	0.370	0.300
ANTIMONY	MG/L		< 0.003	< 0.003	0.008	< 0.003	< 0.003
ARSENIC	MG /L		< 0.010	0.011	0.020	< 0.010	< 0.010
BARIUM	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
BORON	MG/L		0.840	0.190	0.630	0.730	0.770
CADMIUM	MG/L		< 0.001	< 0.002	< 0.001	< 0.002	< 0.001
CALCIUM	MG/L		610.000	48.000	16.300	570.000	665.000
CHLORIDE	MG/L		1250.000	270.000	500.000	890.000	1060.000
CHROMIUM	MG/L		< 0.010	0.030	< 0.010	0.030	< 0.010
COBALT	MG/L		< 0.050	< 0.010	< 0.050	< 0.010	< 0.050
CONDUCTANCE	UMHO/CM		6800.000	2400.000	2415.000	9300.000	7930.000
COPPER	MG/L		< 0.020	0.220	< 0.020	0.020	< 0.020
CYANIDE	MG/L		< 0.010	< 0.010	-----	< 0.010	< 0.010
FLUORIDE	MG/L		0.700	2.100	3.400	0.500	0.800
GROSS ALPHA	PCI/L		-----	-----	-----	345.000	-----
GROSS BETA	PCI/L		-----	-----	-----	60.000	-----
HYD. SULFIDE	MG/L		-----	< 0.200	-----	< 0.200	-----
IRON	MG/L		2.040	0.100	< 0.030	0.500	0.090
LEAD	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
MAGNESIUM	MG/L		555.000	0.200	< 0.010	490.000	575.000
MANGANESE	MG/L		2.170	< 0.050	< 0.010	2.700	3.000
MERCURY	MG/L		< 0.000	0.000	< 0.000	0.000	< 0.000
MOLYBDENUM	MG/L		< 0.010	0.120	0.060	0.030	< 0.010
NICKEL	MG/L		0.060	< 0.040	0.050	0.100	0.040
NITRATE	MG/L		< 1.000	1.000	< 1.000	25.000	34.000
ORG. CARBON	MG/L		20.700	-----	-----	55.300	21.000
PB-210	PCI/L		< 1.500	-----	< 1.500	< 1.500	< 1.500
PH	SU		6.800	11.800	10.800	6.800	7.000
PHOSPHATE	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
PO-210	PCI/L		< 1.000	-----	< 1.000	< 1.000	< 1.000
POTASSIUM	MG/L		12.800	6.500	5.580	15.000	15.600
RA-226	PCI/L		< 1.000	-----	-----	< 1.000	< 1.000
RA-228	PCI/L		-----	-----	-----	< 1.000	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	733 06/07/85	735 03/29/85	735 06/07/85	736 03/22/85	736 06/07/85
SELENIUM	MG/L		< 0.005	0.024	0.016	< 0.005	< 0.005
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		7.800	20.400	21.600	10.300	11.200
SILVER	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
SODIUM	MG/L		1190.000	370.000	525.000	1370.000	1200.000
STRONTIUM	MG/L		7.100	0.700	0.300	6.500	7.490
SULFATE	MG/L		3490.000	210.000	312.000	4100.000	3890.000
SULFIDE	MG/L		< 0.100	-----	-----	-----	< 0.100
TEMPERATURE	C - DEGREE		18.000	13.000	17.000	10.000	15.000
TH-230	PCI/L		< 1.000	-----	< 1.000	< 1.000	< 1.000
TH-230	PCI/G		-----	-----	-----	-----	-----
TIN	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
TOTAL SOLIDS	MG/L		8092.000	-----	-----	8728.000	8792.000
TOX	MG/L		0.390	-----	-----	0.500	0.170
U-234	PCI/L		43.000	-----	< 1.000	66.000	60.000
U-238	PCI/L		29.000	-----	< 1.000	49.000	60.000
VANADIUM	MG/L		< 0.010	0.230	0.150	< 0.010	0.020
ZINC	MG/L		< 0.005	< 5.300	< 0.005	0.060	< 0.005

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	737 03/22/85	737 06/07/85	738 03/25/85	738 06/07/85	739 03/22/85
ALKALINITY	MG/L CAC03		470.000	463.000	603.000	643.000	486.000
ALUMINUM	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
AMMONIUM	MG/L		0.540	0.570	0.660	0.750	0.420
ANTIMONY	MG/L		< 0.003	< 0.003	0.004	< 0.003	0.004
ARSENIC	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
BARIUM	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
BORON	MG/L		0.690	0.830	0.760	0.920	0.770
CADMIUM	MG/L		< 0.002	< 0.001	< 0.002	< 0.001	< 0.002
CALCIUM	MG/L		550.000	640.000	470.000	422.000	540.000
CHLORIDE	MG/L		880.000	1080.000	670.000	944.000	970.000
CHROMIUM	MG/L		0.030	< 0.010	0.030	< 0.010	0.030
COBALT	MG/L		< 0.010	< 0.050	< 0.010	< 0.050	< 0.010
CONDUCTANCE	UMHO/CM		8900.000	7800.000	7000.000	5500.000	8300.000
COPPER	MG/L		0.020	< 0.020	0.040	< 0.020	0.010
CYANIDE	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
FLUORIDE	MG/L		1.000	1.100	0.400	0.600	0.900
GROSS ALPHA	PCI/L		185.000	-----	170.000	-----	< 90.000
GROSS BETA	PCI/L		60.000	-----	125.000	-----	< 50.000
HYD. SULFIDE	MG/L		< 0.200	-----	< 0.200	-----	< 0.200
IRON	MG/L		1.700	0.600	10.000	9.970	3.400
LEAD	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
MAGNESIUM	MG/L		540.000	625.000	330.000	415.000	520.000
MANGANESE	MG/L		2.600	2.420	1.600	1.400	1.800
MERCURY	MG/L		< 0.000	< 0.000	0.000	< 0.000	< 0.000
MOLYBDENUM	MG/L		0.110	0.080	0.020	< 0.010	0.110
NICKEL	MG/L		< 0.040	< 0.040	< 0.040	< 0.040	< 0.040
NITRATE	MG/L		< 1.000	< 1.000	< 1.000	< 1.000	< 1.000
ORG. CARBON	MG/L		18.000	13.300	11.300	10.800	14.200
PB-210	PCI/L		< 1.500	< 1.500	< 1.500	< 1.500	< 1.500
PH	SU		6.600	7.100	7.000	7.150	6.900
PHOSPHATE	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
PO-210	PCI/L		< 1.000	< 1.000	< 1.000	< 1.000	< 1.000
POTASSIUM	MG/L		12.000	15.100	18.000	21.600	11.000
RA-226	PCI/L		< 1.000	< 1.000	< 1.000	< 1.000	< 1.000
RA-228	PCI/L		< 1.000	-----	< 1.000	-----	< 1.000

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	737 03/22/85	737 06/07/85	738 03/25/85	738 06/07/85	739 03/22/85
SELENIUM	MG/L		< 0.005	< 0.005	< 0.005	0.005	< 0.005
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		8.700	8.500	12.300	11.400	10.000
SILVER	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
SODIUM	MG/L		1190.000	1070.000	1110.000	1200.000	1260.000
STRONTIUM	MG/L		7.300	7.190	5.800	5.560	7.400
SULFATE	MG/L		3800.000	3770.000	2900.000	3050.000	4000.000
SULFIDE	MG/L		-----	< 0.100	-----	0.100	-----
TEMPERATURE	C - DEGREE		12.000	16.000	13.000	15.000	14.000
TH-230	PCI/L		< 1.000	< 1.000	< 1.000	< 1.000	< 1.000
TH-230	PCI/G		-----	-----	-----	-----	-----
TIN	MG/L		0.005	< 0.005	< 0.005	< 0.005	< 0.005
TOTAL SOLIDS	MG/L		8134.000	8300.000	12134.000	6870.000	8324.000
TOX	MG/L		0.600	0.110	0.400	0.160	0.600
U-234	PCI/L		36.000	40.000	54.000	52.000	8324.000
U-238	PCI/L		24.000	26.000	41.000	40.000	24.000
VANADIUM	MG/L		< 0.010	0.020	< 0.010	0.020	< 0.010
ZINC	MG/L		0.090	< 0.005	0.200	< 0.005	0.060

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	739 06/07/85	740 03/22/85	740 06/07/85	741 03/26/85	741 06/07/85
ALKALINITY	MG/L CACO3		498.000	508.000	503.000	177.000	325.
ALUMINUM	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
AMMONIUM	MG/L		0.440	49.000	42.700	3.200	1.900
ANTIMONY	MG/L		< 0.003	< 0.003	0.003	< 0.003	< 0.003
ARSENIC	MG/L		< 0.010	< 0.010	< 0.010	0.010	< 0.010
BARIUM	MG/L		< 0.100	< 0.100	< 0.100	0.200	0.260
BORON	MG/L		0.790	0.670	0.670	0.720	0.630
CADMIUM	MG/L		< 0.001	< 0.002	< 0.001	< 0.002	< 0.001
CALCIUM	MG/L		630.000	510.000	600.000	42.300	41.400
CHLORIDE	MG/L		1130.000	650.000	707.000	1900.000	2020.000
CHROMIUM	MG/L		< 0.010	0.020	< 0.010	< 0.010	< 0.010
COBALT	MG/L		< 0.050	< 0.010	< 0.050	< 0.010	< 0.050
CONDUCTANCE	UMHO/CM		8024.000	7000.000	6344.000	6200.000	5000.000
COPPER	MG/L		< 0.020	0.020	< 0.020	< 0.010	< 0.020
CYANIDE	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
FLUORIDE	MG/L		1.000	0.600	0.600	0.900	0.900
GROSS ALPHA	PCI/L		-----	245.000	-----	< 50.000	-----
GROSS BETA	PCI/L		-----	100.000	-----	< 50.000	-----
HYD. SULFIDE	MG/L		-----	< 0.200	-----	< 0.200	-----
IRON	MG/L		1.470	0.400	0.080	< 0.050	< 0.030
LEAD	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
MAGNESIUM	MG/L		600.000	410.000	470.000	7.500	1.940
MANGANESE	MG/L		1.760	3.700	2.960	< 0.050	< 0.010
MERCURY	MG/L		< 0.000	< 0.000	< 0.000	< 0.000	< 0.000
MOLYBDENUM	MG/L		0.140	0.110	0.050	< 0.010	0.020
NICKEL	MG/L		< 0.040	< 0.040	< 0.040	< 0.040	< 0.040
NITRATE	MG/L		< 1.000	2.000	< 1.000	< 1.000	< 1.000
ORG. CARBON	MG/L		23.300	11.400	11.400	1.300	4.600
PB-210	PCI/L		< 1.500	< 1.500	< 1.500	< 1.500	< 1.500
PH	SU		7.300	6.800	6.900	9.200	8.700
PHOSPHATE	MG/L		< 0.100	< 0.100	< 0.100	0.100	< 0.100
PO-210	PCI/L		< 1.000	< 1.000	< 1.000	< 1.000	< 1.000
POTASSIUM	MG/L		12.800	27.000	29.400	9.000	15.700
RA-226	PCI/L		< 1.000	< 1.000	< 1.000	< 1.000	< 1.000
RA-228	PCI/L		-----	< 1.000	-----	< 1.000	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	739 06/07/85	740 03/22/85	740 06/07/85	741 03/26/85	741 06/07/85
SELENIUM	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	0.005
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		8.800	9.400	8.200	9.900	5.800
SILVER	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
SODIUM	MG/L		1150.000	980.000	853.000	1300.000	1280.000
STRONTIUM	MG/L		6.930	5.400	5.380	1.600	1.840
SULFATE	MG/L		3680.000	3600.000	3260.000	46.000	25.900
SULFIDE	MG/L		< 0.100	-----	< 0.100	-----	< 0.100
TEMPERATURE	C - DEGREE		17.000	10.000	15.000	14.500	15.000
TH-230	PCI/L		< 1.000	< 1.000	< 1.000	< 1.000	< 1.000
TH-230	PCI/G		-----	-----	-----	-----	-----
TIN	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
TOTAL SOLIDS	MG/L		8444.000	6876.000	6872.000	3308.000	3798.000
TOX	MG/L		0.130	< 0.100	< 0.100	0.100	0.650
U-234	PCI/L		36.000	75.000	65.000	< 1.000	1.000
U-238	PCI/L		24.000	70.000	65.000	< 1.000	< 1.000
VANADIUM	MG/L		0.030	< 0.010	< 0.010	0.050	< 0.010
ZINC	MG/L		< 0.005	0.070	< 0.005	< 0.050	< 0.005

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	742 03/22/85	742 06/07/85	743 03/21/85	743 06/07/85	744 03/21/85
ALKALINITY	MG/L CACO3		535.000	502.000	447.000	325.	462.000
ALUMINUM	MG/L		< 0.100	< 0.100	< 0.100	< 0.1	< 0.100
AMMONIUM	MG/L		0.510	0.540	6.050	5.42	1.600
ANTIMONY	MG/L		< 0.003	0.003	< 0.003	< 0.003	< 0.003
ARSENIC	MG/L		< 0.010	< 0.010	< 0.010	< 0.01	< 0.010
BARIUM	MG/L		< 0.100	< 0.100	< 0.100	< 0.1	< 0.100
BORON	MG/L		0.700	0.790	0.330	0.26	0.250
CADMIUM	MG/L		< 0.002	< 0.001	< 0.002	< 0.001	< 0.002
CALCIUM	MG/L		570.000	655.000	66.000	92.	260.000
CHLORIDE	MG/L		590.000	673.000	650.000	838.	450.000
CHROMIUM	MG/L		0.030	< 0.010	0.040	< 0.010	0.070
COBALT	MG/L		< 0.010	< 0.050	< 0.010	< 0.05	< 0.010
CONDUCTANCE	UMHO/CM		6900.000	6100.000	5900.000	4500.	3200.000
COPPER	MG/L		0.010	< 0.020	0.030	< 0.02	0.010
CYANIDE	MG/L		< 0.010	< 0.010	< 0.010	< 0.01	< 0.010
FLUORIDE	MG/L		0.700	0.800	0.300	0.4	0.400
GROSS ALPHA	PCI/L		< 60.000	-----	< 40.000	-----	80.000
GROSS BETA	PCI/L		80.000	-----	< 50.000	-----	50.000
HYD. SULFIDE	MG/L		< 0.200	-----	< 0.200	-----	< 0.200
IRON	MG/L		5.700	0.560	< 0.050	0.11	1.000
LEAD	MG/L		< 0.010	< 0.010	< 0.010	< 0.01	< 0.010
MAGNESIUM	MG/L		460.000	550.000	24.000	4.07	140.000
MANGANESE	MG/L		4.600	2.770	< 0.050	< 0.01	2.000
MERCURY	MG/L		< 0.000	< 0.000	< 0.000	0.000	< 0.000
MOLYBDENUM	MG/L		0.040	0.010	0.020	< 0.01	0.020
NICKEL	MG/L		< 0.040	< 0.040	< 0.040	< 0.04	< 0.040
NITRATE	MG/L		< 1.000	2.000	< 1.000	< 1.	< 1.000
ORG. CARBON	MG/L		562.000	13.400	7.700	5.6	10.200
PB-210	PCI/L		< 1.500	< 1.500	< 1.500	< 1.5	< 1.500
PH	SU		6.700	7.000	10.200	11.4	7.050
PHOSPHATE	MG/L		< 0.100	< 0.100	< 0.100	< 0.1	< 0.100
PO-210	PCI/L		< 1.000	< 1.000	< 1.000	< 1.	< 1.000
POTASSIUM	MG/L		9.600	11.400	12.000	13.3	8.900
RA-226	PCI/L		< 1.000	< 1.000	< 1.000	< 1.	< 1.000
RA-228	PCI/L		< 1.000	-----	< 1.000	-----	< 1.000

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	742 03/22/85	742 06/07/85	743 03/21/85	743 06/07/85	744 03/21/85
SELENIUM	MG/L		< 0.005	< 0.005	< 0.005	0.009	< 0.005
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		11.100	9.700	5.500	4.2	8.200
SILVER	MG/L		< 0.010	< 0.010	< 0.010	< 0.01	< 0.010
SODIUM	MG/L		870.000	800.000	1340.000	1340.	420.000
STRONTIUM	MG/L		6.500	5.820	3.900	3.74	2.800
SULFATE	MG/L		3600.000	3460.000	2000.000	1900.	1200.000
SULFIDE	MG/L		-----	< 0.100	-----	0.6	-----
TEMPERATURE	C - DEGREE		12.000	15.000	13.500	13.5	10.500
TH-230	PCI/L		< 1.000	< 1.000	< 1.000	< 1.	< 1.000
TH-230	PCI/G		-----	-----	-----	-----	-----
TIN	MG/L		0.005	< 0.005	< 0.005	< 0.005	< 0.005
TOTAL SOLIDS	MG/L		6828.000	7126.000	4034.000	4316.	4462.000
TOX	MG/L		0.500	0.490	0.600	0.15	8.200
U-234	PCI/L		41.000	31.000	< 1.000	< 1.	19.000
U-238	PCI/L		31.000	31.000	< 1.000	< 1.	14.000
VANADIUM	MG/L		< 0.010	< 0.010	< 0.010	0.01	< 0.010
ZINC	MG/L		0.080	< 0.005	< 0.050	< 0.005	0.090

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	744 06/07/85	744 06/07/85	744 06/07/85	744 06/07/85	744 06/07/85
ALKALINITY	MG/L CAC03		332.000	332.000	332.000	332.000	332.000
ALUMINUM	MG/L		< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
AMMONIUM	MG/L		1.200	1.200	2.200	1.300	1.600
ANTIMONY	MG/L		< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
ARSENIC	MG/L		< 0.010	< 0.01	< 0.01	< 0.01	< 0.01
BARIUM	MG/L		< 0.100	< 0.1	< 0.1	< 0.1	< 0.1
BORON	MG/L		0.230	0.23	0.24	0.23	0.24
CADMIUM	MG/L		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
CALCIUM	MG/L		242.000	234.000	237.000	240.000	236.000
CHLORIDE	MG/L		202.000	204.000	199.000	204.000	202.000
CHROMIUM	MG/L		< 0.010	< 0.01	< 0.01	< 0.01	< 0.01
COBALT	MG/L		< 0.050	< 0.05	< 0.05	< 0.05	< 0.05
CONDUCTANCE	UMHO/CM		2150.000	2150.000	2150.000	2150.000	2150.000
COPPER	MG/L		< 0.020	< 0.02	< 0.02	< 0.02	< 0.02
CYANIDE	MG/L		< 0.010	< 0.01	< 0.01	< 0.01	< 0.01
FLUORIDE	MG/L		0.600	0.6	0.6	0.6	0.6
GROSS ALPHA	PCI/L		-----	-----	-----	-----	-----
GROSS BETA	PCI/L		-----	-----	-----	-----	-----
HYD. SULFIDE	MG/L		-----	-----	-----	-----	-----
IRON	MG/L		0.100	0.11	0.12	0.11	0.12
LEAD	MG/L		< 0.010	< 0.01	< 0.01	< 0.01	< 0.01
MAGNESIUM	MG/L		144.000	144.	142.	142.	143.
MANGANESE	MG/L		1.190	1.16	1.15	1.19	1.2
MERCURY	MG/L		< 0.000	< 0.000	< 0.000	< 0.000	< 0.000
MOLYBDENUM	MG/L		0.020	< 0.01	< 0.01	0.01	0.02
NICKEL	MG/L		< 0.040	< 0.04	< 0.04	0.04	< 0.04
NITRATE	MG/L		< 1.	< 1.	< 1.	< 1.	< 1.
ORG. CARBON	MG/L		9.4	9.8	10.4	9.4	9.2
PB-210	PCI/L		< 1.5	-----	-----	-----	-----
PH	SU		7.4	7.4	7.4	7.4	7.4
PHOSPHATE	MG/L		< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
PO-210	PCI/L		< 1.	-----	-----	-----	-----
POTASSIUM	MG/L		9.02	9.1	8.97	9.05	8.89
RA-226	PCI/L		< 1.	-----	-----	-----	-----
RA-228	PCI/L		-----	-----	-----	-----	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: 744 DATE: 06/07/85	744 06/07/85	744 06/07/85	744 06/07/85	744 06/07/85	744 06/07/85
SELENIUM	MG/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
SILCON	MG/L	-----	-----	-----	-----	-----	-----
SILICA	MG/L	6.7	6.7	6.6	6.7	6.6	6.6
SILVER	MG/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
SODIUM	MG/L	309.	312.	310.	312.	304.	304.
STRONTIUM	MG/L	2.41	2.36	2.33	2.37	2.28	2.28
SULFATE	MG/L	1150.	1120.	1110.	1150.	1140.	1140.
SULFIDE	MG/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
TEMPERATURE	C - DEGREE	14.	14.	14.	14.	14.	14.
TH-230	PCI/L	< 1.	-----	-----	-----	-----	-----
TH-230	PCI/G	-----	-----	-----	-----	-----	-----
TIN	MG/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
TOTAL SOLIDS	MG/L	2386.	2410.	2456.	2438.	2430.	2430.
TOX	MG/L	0.31	0.29	0.29	< 0.1	< 0.1	< 0.1
U-234	PCI/L	19.3	-----	-----	-----	-----	-----
U-238	PCI/L	13.4	-----	-----	-----	-----	-----
VANADIUM	MG/L	0.02	0.02	< 0.01	< 0.01	< 0.01	< 0.01
ZINC	MG/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	745 03/30/85	745 06/07/85	746 03/22/85	746 06/07/85	747 03/22/85
ALKALINITY	MG/L CAC03		460.000	343.	417.000	464.	520.000
ALUMINUM	MG/L		0.300	< 0.1	< 0.100	< 0.1	< 0.100
AMMONIUM	MG/L		0.640	0.51	0.290	0.34	95.900
ANTIMONY	MG/L		< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
ARSENIC	MG/L		< 0.010	< 0.01	< 0.010	< 0.01	< 0.010
BARIUM	MG/L		< 0.100	< 0.1	< 0.100	< 0.1	0.100
BORON	MG/L		0.600	0.58	0.580	0.83	0.420
CADMIUM	MG/L		< 0.002	< 0.001	< 0.002	< 0.001	< 0.002
CALCIUM	MG/L		490.000	431.	490.000	595.	580.000
CHLORIDE	MG/L		344.000	390.	460.000	637.	740.000
CHROMIUM	MG/L		0.020	< 0.01	< 0.010	< 0.01	0.020
COBALT	MG/L		< 0.010	< 0.05	< 0.010	< 0.05	0.010
CONDUCTANCE	UMHO/CM		5300.000	3900.	5500.000	5000.	7000.000
COPPER	MG/L		0.020	< 0.02	< 0.010	< 0.02	0.030
CYANIDE	MG/L		< 0.010	< 0.01	< 0.010	< 0.01	< 0.010
FLUORIDE	MG/L		0.700	0.8	1.100	1.5	0.400
GROSS ALPHA	PCI/L		80.000	-----	230.000	-----	< 65.000
GROSS BETA	PCI/L		< 50.000	-----	< 50.000	-----	90.000
HYD. SULFIDE	MG/L		< 0.200	-----	< 0.200	-----	< 0.200
IRON	MG/L		2.200	1.24	0.800	1.15	3.400
LEAD	MG/L		< 0.010	< 0.01	< 0.010	< 0.01	< 0.010
MAGNESIUM	MG/L		340.000	401.	380.000	570.	300.000
MANGANESE	MG/L		1.800	1.47	2.300	1.77	4.000
MERCURY	MG/L		< 0.000	< 0.000	< 0.000	< 0.000	< 0.000
MOLYBDENUM	MG/L		0.040	0.01	0.120	0.11	< 0.010
NICKEL	MG/L		< 0.040	< 0.04	< 0.040	< 0.04	0.080
NITRATE	MG/L		< 1.000	< 1.	< 1.000	< 1.	2.000
ORG. CARBON	MG/L		9.100	11.2	525.000	17.4	-----
PB-210	PCI/L		< 1.500	< 1.5	< 1.500	< 1.5	< 1.500
PH	SU		6.700	6.8	6.700	7.25	6.800
PHOSPHATE	MG/L		< 0.100	< 0.1	< 0.100	< 0.1	< 0.100
PO-210	PCI/L		< 1.000	< 1.	< 1.000	< 1.	< 1.000
POTASSIUM	MG/L		6.800	7.94	12.000	11.5	36.000
RA-226	PCI/L		< 1.000	< 1.	< 1.000	< 1.	< 1.000
RA-228	PCI/L		< 1.000	-----	< 1.000	-----	< 1.000

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	745 03/30/85	745 06/07/85	746 03/22/85	746 06/07/85	747 03/22/85
SELENIUM	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		10.400	7.9	10.500	9.9	10.300
SILVER	MG/L		< 0.010	< 0.01	< 0.010	< 0.01	< 0.010
SODIUM	MG/L		620.000	585.	650.000	747.	880.000
STRONTIUM	MG/L		4.800	4.89	5.600	5.87	6.000
SULFATE	MG/L		2700.000	2620.	2900.000	3410.	3100.000
SULFIDE	MG/L		-----	< 0.1	-----	< 0.1	-----
TEMPERATURE	C - DEGREE		10.000	16.5	13.000	16.	10.000
TH-230	PCI/L		< 1.000	< 1.	< 1.000	< 1.	< 1.000
TH-230	PCI/G		-----	-----	-----	-----	-----
TIN	MG/L		< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
TOTAL SOLIDS	MG/L		5458.000	5376.	6038.000	6878.	6780.000
TOX	MG/L		0.300	0.13	0.100	< 0.1	0.700
U-234	PCI/L		17.000	19.	22.000	30.	29.000
U-238	PCI/L		11.000	12.	16.000	20.	19.000
VANADIUM	MG/L		< 0.010	0.01	< 0.010	0.01	< 0.010
ZINC	MG/L		1.000	< 0.005	< 0.050	< 0.005	0.100

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: 747 DATE: 06/07/85
ALKALINITY	MG/L CAC03	571.
ALUMINUM	MG/L	< 0.1
AMMONIUM	MG/L	128.
ANTIMONY	MG/L	< 0.003
ARSENIC	MG/L	< 0.01
BARIUM	MG/L	< 0.1
BORON	MG/L	0.58
CADMIUM	MG/L	< 0.001
CALCIUM	MG/L	645.
CHLORIDE	MG/L	1030.
CHROMIUM	MG/L	< 0.01
COBALT	MG/L	< 0.05
CONDUCTANCE	UMHO/CM	5500.
COPPER	MG/L	< 0.02
CYANIDE	MG/L	< 0.01
FLUORIDE	MG/L	0.6
GROSS ALPHA	PCI/L	-----
GROSS BETA	PCI/L	-----
HYD. SULFIDE	MG/L	-----
IRON	MG/L	2.01
LEAD	MG/L	< 0.01
MAGNESIUM	MG/L	434.
MANGANESE	MG/L	3.13
MERCURY	MG/L	< 0.000
MOLYBDENUM	MG/L	< 0.01
NICKEL	MG/L	0.04
NITRATE	MG/L	< 1.
ORG. CARBON	MG/L	12.8
PB-210	PCI/L	< 1.5
PH	SU	7.
PHOSPHATE	MG/L	< 0.1
PO-210	PCI/L	< 1.
POTASSIUM	MG/L	39.7
RA-226	PCI/L	< 1.
RA-228	PCI/L	-----

TABLE F.3.7 GROUND-WATER QUALITY NEAR THE PROCESSING SITE (Concluded)

CONSTITUENT	UNIT OF MEASURE	LOC: 747 DATE: 06/07/85
SELENIUM	MG/L	0.005
SILCON	MG/L	-----
SILICA	MG/L	5.8
SILVER	MG/L	< 0.01
SODIUM	MG/L	1000.000
STRONTIUM	MG/L	5.81
SULFATE	MG/L	3360.
SULFIDE	MG/L	< 0.1
TEMPERATURE	C - DEGREE	13.000
TH-230	PCI/L	< 1.000
TH-230	PCI/G	-----
TIN	MG/L	< 0.005
TOTAL SOLIDS	MG/L	7174.000
TOX	MG/L	0.65
U-234	PCI/L	36.000
U-238	PCI/L	24.
VANADIUM	MG/L	< 0.01
ZINC	MG/L	< 0.005

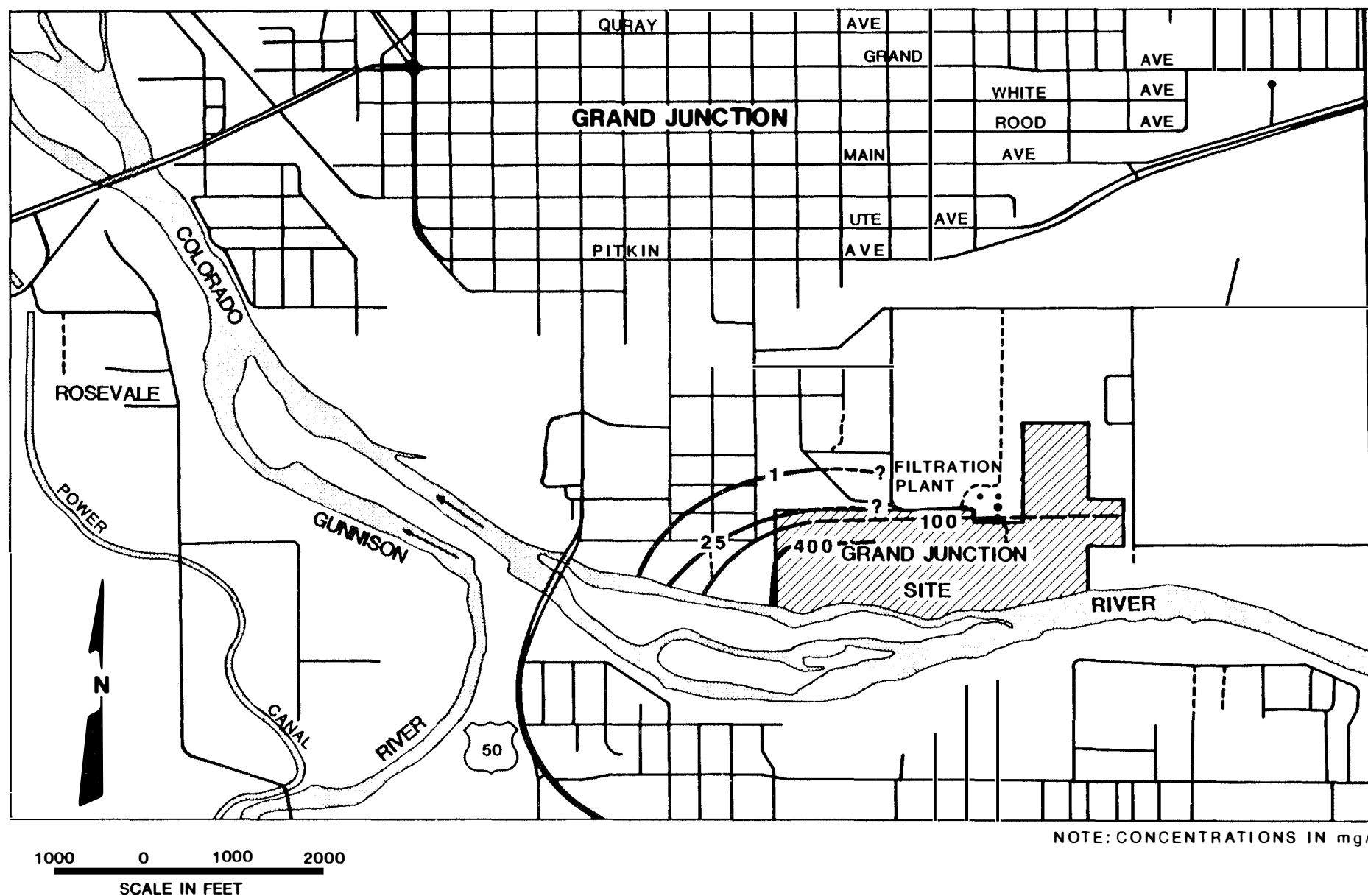


FIGURE F.3.15
ISO-CONCENTRATIONS OF AMMONIUM IN ALLUVIAL GROUND WATER FOR MARCH, 1985

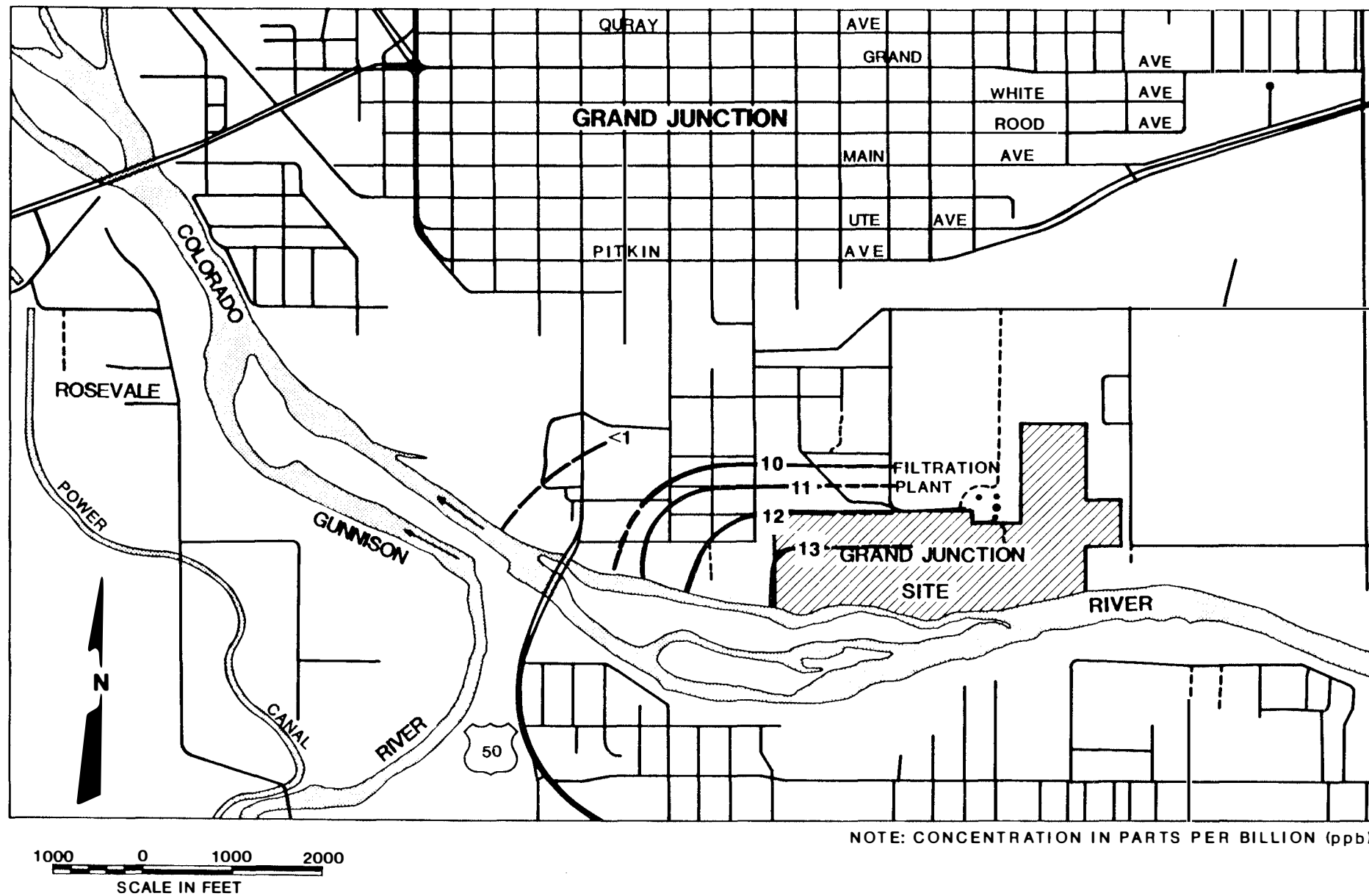


FIGURE F.3.16
ISO-CONCENTRATIONS OF ARSENIC IN MANCOS SHALE FOR MARCH, 1985

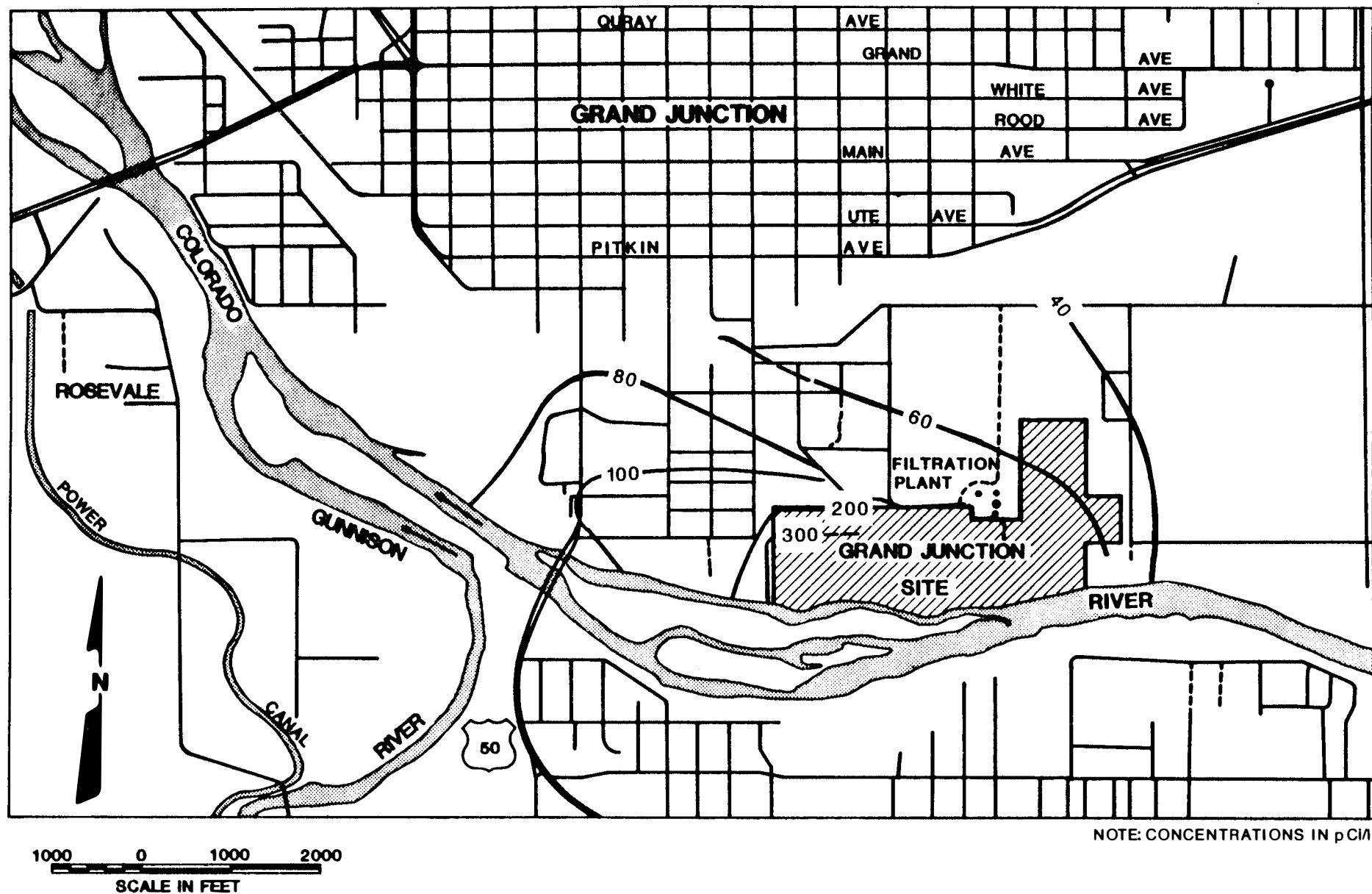


FIGURE F.3.17
ISO-CONCENTRATIONS OF URANIUM IN ALLUVIAL GROUND WATER FOR MARCH, 1985

- o Although well 588 shows some indications of contamination; e.g. the presence of vanadium in a sample taken in February, 1983, key constituents (e.g. uranium, TDS) had lower concentrations at 588 than at any other well sampled during recent investigations.
- o Water quality for the given wells is similar to that for alluvial wells several miles from the tailings (see data for Bureau of Reclamation wells 711 and 712, Table F.3.7).
- o The wells and the tailings are separated by a surface water body (duck pond) which would minimize groundwater flow from the tailings toward the wells. Therefore the samples collected from these wells have not been influenced by contamination from the tailings pile.

Water quality for samples taken from well 743 is defined as background for the Mancos Shale, based on two reasons:

- o The well is hydraulically upgradient from the tailings.
- o Water quality for a sample taken from the well is similar to or better in quality than reported water quality for other monitoring wells completed in Mancos Shale in the area (e.g., U.S. Bureau of Reclamation, 1978).

Background water quality for the Dakota Sandstone was more difficult to define than background in the alluvium or Mancos Shale. An extensive study of the artesian water supply of the Grand Junction area did not include samples from wells completed in the Dakota Sandstone (Lohman, 1965). It did, however, produce qualitative reports on the water quality in the Dakota Sandstone (Lohman, 1965): "The water generally is too poor for use..."

It is also reported that locally, water from either the Burro Canyon Formation or Dakota Sandstone or both, is satisfactory for domestic use (Lohman, 1965). Because of this apparent spatial variability in the quality of water in the Dakota Sandstone, problems in defining background quality for the Dakota Sandstone near the site were identified:

- o Samples from domestic wells completed in the Dakota Sandstone might not be representative of quality near the site.
- o The Mancos Shale thins from the east end of the site toward the west. A well drilled through the up-

gradient alluvium might not be representative of background quality for the Dakota Sandstone below the downgradient alluvium, where there is probably more interaction between water in the alluvium and the Dakota Sandstone.

These problems indicated the need to drill a background well in the Dakota Sandstone which was not only below the downgradient alluvium, but reasonably certain of being uncontaminated. A nest of wells were drilled on one of the islands west of the site, including wells in the Mancos Shale and Dakota Sandstone. Water quality from the well in the Dakota Sandstone (725) is defined as background based on the following reasons:

- o Flow in the Dakota Sandstone is probably from south to north; based on the dip of the beds, and identification of the probable recharge area as the outcrop area, which is to the south of the site (Lohman, 1965).
- o The alluvium overlying the Mancos Shale and Dakota Sandstone near the background well is separated from the contaminated portion of the alluvium in the immediate vicinity of the tailings by an arm of the Colorado River.
- o Water quality for samples at an adjacent well completed in the Mancos Shale (727) did not show indications of contamination.

The distribution of key chemical constituents in ground water is discussed below, indicating the distinction between contaminants which have a readily definable plume (e.g. patterned distribution) and those which although elevated, have a sporadic distribution. Emphasis is on samples collected in March, 1985, for a monitoring well network expanded from that used for collection of previous sample sets.

Aluminum. Background concentrations of aluminum appear to be near the lower detection limit (LDL) of 0.001 to 0.1 mg/l. Samples collected in September, 1983, detected aluminum at levels of 0.17 to 0.51 milligrams per liter (mg/l) near the tailings and 0.018 to 0.19 mg/l downgradient of the tailings. Samples collected in March, 1985, were analyzed using a LDL of 0.1 mg/l. Aluminum was detected in one upgradient alluvial well (745) at a concentration of 0.3 mg/l and in three downgradient wells completed in bedrock (729, 735, 731) at concentrations of 0.2 to 0.7 mg/l.

Ammonium. Ammonium is a key indicator of contamination. At background alluvial wells, concentrations do not exceed 2.1 mg/l. Below or near the tailings, concentrations in the alluvium range between 18 and 393 mg/l for samples col-

lected in March, 1985. Downgradient concentrations in the alluvium ranged from background levels up to 124 mg/l. A plume extends at least 1100 feet but less than 2600 feet downgradient in the alluvium (Figure F.3.15). Wells completed in the shallow bedrock also show elevated levels of ammonium, ranging from background (6.05 mg/l) to 18.1 mg/l. An industrial drainage (flood-control) well (710) had a reported concentration of 45 mg/l in March, 1985. It is not certain if this concentration represents contamination from the mill tailings or from another source. No other indications of contamination were found at this well with the possible exception of elevated uranium (see below).

Arsenic. Background arsenic concentrations appear to be the LDL of 0.01 mg/l. Samples collected from alluvial wells in March, 1985, found arsenic above the LDL only in wells near or below the tailings, at levels between 0.015 and 0.019 mg/l. Downgradient wells completed in the shallow bedrock showed arsenic at concentrations between 0.010 and 0.013 mg/l. Within the shallow bedrock a detectable plume of arsenic probably extends at least 2000 feet but less than 3000 feet downgradient from the tailings (Figure F.3.16).

Arsenic in the bedrock may represent residual contamination. During active milling arsenic concentrations in the alluvium could have been high enough to act as a source of contamination for the underlying Mancos Shale. Flow through the relatively high permeability alluvium could have flushed arsenic out of the alluvium (no arsenic was measured in downgradient samples from alluvial wells), whereas flow in the relatively low permeability shale did not flush out the arsenic.

Boron. Concentrations of boron in samples collected in March, 1985, were very similar to background concentrations.

Cadmium. Background concentrations of cadmium appear to be the LDL of 0.001 mg/l. Samples collected in March, 1985, showed cadmium in only two wells (583, 584) completed below the tailings, at concentrations of 0.010 and 0.097 mg/l.

Chromium. Background concentrations of chromium appear to be between the LDL of 0.01 mg/l and 0.03 mg/l. Only three wells sampled in March, 1985, fall outside this range (743, 744, 582). Elevated concentrations of chromium do not seem to be associated with the tailings.

Cobalt. Background concentrations of cobalt appear to be at the LDL. Samples collected in March, 1985, showed elevated concentrations of cobalt only in wells completed beneath the tailings (583, 584) or evaporation pond (747).

Iron. Iron concentrations are quite variable in background alluvial wells, ranging between the LDL to 3.4 mg/l. Iron concentrations in March, 1985, are quite variable

near the tailings, ranging up to 16 mg/l. There is no apparent downgradient plume of iron in the alluvium or the shallow bedrock.

Manganese. Manganese is absent in shallow bedrock wells except for one well completed beneath the tailings. Background concentrations of manganese in alluvial wells appear to range from 1.1 to 2.6 mg/l. Samples collected in March, 1985, showed elevated concentrations below or near the tailings, ranging up to 4.8 mg/l. There is no apparent downgradient plume.

Molybdenum. Molybdenum in ground water is commonly associated with uranium mill tailings. Molybdenum is also common in the waters of Colorado. It has been measured at a concentration of 0.033 mg/l in the Colorado River below Glenwood Springs, and at a concentration of 0.087 mg/l in the Colorado River between Kremmling and Dotsero (Voegeli and King, 1969). Background concentrations in the alluvial ground water are probably subject to a relatively high degree of uncertainty, but appear to range up to 0.12 mg/l.

Molybdenum appears to be present in elevated concentrations below the tailings, where concentrations up to 0.53 mg/l were measured in February, 1983. Based on an upper background concentration of 0.12 mg/l, and also looking at the spatial variations in concentration, there does not appear to be a downgradient plume.

Nickel. Background concentrations of nickel appear to be at or below the LDL of 0.04 mg/l. Elevated concentrations were found below the tailings and evaporation ponds, ranging up to 0.29 mg/l in March, 1985. One downgradient alluvial well (736) had a concentration of 0.10 mg/l, and one deep bedrock well west of the tailings had a possible anomalous concentration of 0.05 mg/l.

Radium-226. Background concentrations of radium-226 in the alluvium are less than LDL of one pCi/l. Background concentrations in the Dakota Sandstone are more difficult to determine. A national survey of uranium and radium concentrations in ground water found that in the Colorado Plateau, which includes Grand Junction, interpretation of ground water is complicated by the abundance of uranium deposits (Scott and Barker, 1962):

"The region is the chief uranium province of the United States, both areally and quantitatively. It was not possible before preparation of this report to collect sufficient samples of ground water for statistical treatment from sources known to be unassociated with uranium deposits."

As an alternate means of characterizing background, the recommendation of the same authors was followed (Scott and Barker, 1962): "The statistical results from the western

stable region might tentatively be used to evaluate this region, for these two regions were coextensive before the Laramide orogeny." The "anomaly threshold" for the western stable region is 7.3 pCi/l (Scott and Barker, 1962).

A single water sample from a well completed below the tailings had a radium-226 concentration of 29 pCi/l, and several water samples from below the tailings have had concentrations of 15 to 18 pCi/l. Radium-226 has not been detected at any wells away from the tailings, except for concentrations of 1.6 to 5.5 pCi/l at two bedrock wells to the west of the site (724,725), which is below the "anomaly threshold" used to define background.

Selenium. The background concentration of selenium appears to be at or below the LDL of 0.002 mg/l or 0.005 mg/l. Elevated concentrations of selenium are associated with the tailings, particularly at one well (584) where concentrations have reached 0.240 mg/l. Two downgradient wells (729, 735) completed in the shallow bedrock also show concentrations of selenium at concentrations of 0.011 and 0.024 mg/l in March, 1985. There is no apparent downgradient plume in the alluvium.

Sulfate. Background concentrations of sulfate are subject to uncertainty due to the hydrogeologic setting of the site. Shallow ground water in the Grand Junction area can have sulfate concentrations exceeding 9000 mg/l (U.S. Bureau of Reclamation, no date). Alluvial ground water very near the Colorado River might be expected to have concentrations less than 500 mg/l during some seasons. Concentrations of sulfate below the tailings are less than 4500 mg/l and exceed the concentrations which might be expected very near the river. Although concentrations of sulfate downgradient of the tailings are high, the contribution of the tailings is not clear. The spatial distribution of sulfate in March, 1985, was such that no clearly definable plume of sulfate was readily apparent.

Total dissolved solids. Concentrations of total dissolved solids (TDS) in the alluvium range from seasonal lows of less than 900 mg/l upgradient of the tailings (588) up to a local high of 12,000 mg/l (738). The highest concentrations off the site (738) exceed the highest concentrations measured below the tailings by a factor of three, and are probably a result of other sources of contamination (Section F.3.2.5), rather than contamination from the tailings. There is no readily apparent downgradient plume in the alluvium. On the basis of TDS (Hem, 1970) water quality in the alluvium ranges from seasonally fresh to brackish to salty. It is predominantly brackish.

Water quality in the Mancos Shale and Dakota Sandstone near the site can be classified as brackish. There is no readily apparent TDS plume in the shallow bedrock.

Uranium. Background concentrations of uranium in shallow ground water vary, reaching at least 40 pCi/l (Bureau of Reclamation well 712) and have been measured as low as 6.8 pCi/l (well 588). Uranium concentrations fluctuate seasonally by a factor of two to six. Below the tailings, concentrations have been measured as high as 610 pCi/l (584).

A plume of uranium elevated above background concentrations extends downgradient of the tailings (Figure F.3.17). Concentrations are 100 pCi/l at a distance of approximately 2000 feet from the site, and 80 pCi/l at a distance of approximately 3000 feet from the site. Wells 2000 feet north to northwest of the tailings (737, 739) are cross-gradient from the tailings. Concentrations at these wells were measured at 58 and 60 pCi/l for samples taken in March, 1985. Because of the variability and known high concentrations of uranium in the background, it is not certain if these concentrations reflect contamination. There are no correlative indicators of contamination at these wells (e.g. elevated concentrations of ammonium, vanadium, or other constituents associated with mill tailings).

Background concentrations of uranium in deep bedrock wells may be discerned from previous studies of geochemistry in the area. A sample population of 30 (Markos and Bush, 1983a) included several artesian wells and found a mean uranium concentration of 0.012 ppm (8.2 pCi/l), with a range calculated maximum of 0.034 ppm (23.1 pCi/l). A compilation of data on uranium concentrations in ground water found too little data to produce statistics for the geotectonic region which includes Grand Junction, but recommended the use of data for another region wherein the "anomaly threshold" for uranium was 0.048 mg/l (32.64 pCi/l) (Scott and Barker, 1962). Concentrations in samples collected in March, 1985, in bedrock wells near the tailings were all within the range calculated maximum and below the anomaly threshold. Uranium has not shown a tendency to migrate into the bedrock. Shallow bedrock wells (729, 735, 741) which exhibit other indications of contamination (see below) all had uranium concentrations below the lower detection limit.

One upgradient industrial drainage well (710) had a reported uranium concentration of 52 pCi/l. This is more than 25 percent above the highest measured background concentration of 40 pCi/l and may represent contamination.

Vanadium. Background concentrations of vanadium appear to be the LDL of 0.01 mg/l. For water samples collected in March, 1985, vanadium was seen at a few wells. Below the tailings (584) concentrations reached 7.48 mg/l. Downgradient of the tailings vanadium is seen in wells completed in the shallow bedrock (729, 741, 735, 731). No vanadium was reported for alluvial wells sampled in March, 1985.

Zinc. Background concentrations of zinc probably range up to 0.1 mg/l. For water samples collected in March, 1985, elevated concentrations are apparent below the tailings to 4.1 mg/l (584), at one well upgradient of the tailings (745) at 1.0 mg/l, and in shallow bedrock wells downgradient of the tailings (729, 735) at concentrations up to 5.3 mg/l. No elevation is readily apparent at downgradient alluvial wells.

Other radioisotopes. Samples collected in March, 1985, found no detectable concentrations of polonium-210 or thorium-230, for a LDL of one pCi/l. Lead-210 was reported in one background well (711) at 2.3 pCi/l and at one well below the tailings (584) at 2.8 pCi/l.

Organic compounds. Organic compounds were used in the milling process at Grand Junction, including di(2-ethylhexyl) phosphoric acid (EHPA), and tributyl phosphate (TBP) dissolved in No. 2 fuel oil (Merritt, 1971). Total organic carbon (TOC) and total organic halogen (TOX) were used as a screening guide in an attempt to determine if organic compounds were present in ground water near the site. Concentrations of TOC and TOX are reported in Table F.3.6.

Because TOC and TOX were found in the ground water, the following selected wells were sampled for analysis of organic compounds:

581,583 (below tailings)
732,736 (downgradient)
737 (cross-gradient, north of tailings)
744,746 (upgradient)
747 (below evaporation pond).

An analysis of water samples was done for EPA priority pollutants and up to 10 other compounds. No organic compounds were reported with the following exception:

- o Methylene chloride, found in four analyses at five to eight parts per billion (ppb), and thought to be from laboratory contamination.
- o Tetrahydrofuran, reported at well 583 at 46 ppb. The suggested permissible concentration in water is 8100 ppb (Sittig, 1981).
- o Bis(2-ethylhexyl) phthalate, reported at upgradient well 746 at 150 ppb.
- o Nine alkanes, reported at upgradient well 746 at concentrations between 26 to 72 ppb.

The Grand Junction tailings are in an area where there is substantial industrial, commercial, and agricultural activity which would involve the use of organic chemicals. The detection of organic chemicals in ground water at upgradient

well 746 can probably be attributed to one of these sources, as can the detection of one compound below the tailings (well 583) at a concentration well below the suggested permissible concentration in water. There is no apparent organic contamination of ground water associated with the tailings.

F.3.1.7 Proximity of site to surface water

The tailings are immediately adjacent to and hydraulically connected to the Colorado River. At times of high river stage the Colorado River flows directly against the covered tailings. The other prominent nearby bodies of surface water are a drainage ditch immediately adjacent to the east end of the tailings, a drainage ditch which flows north-south approximately 1500 feet east of the tailings, and a duck pond near the east end of the tailings. (Figure F.3.10). Numerous other major and minor canals, laterals, drainage ditches, and ephemeral drainages are within three miles of the tailings. The discharge of contaminants to surface water is discussed in Section F.3.2.4.

F.3.2 PHYSICAL AND CHEMICAL CHARACTERIZATION OF WASTE AND CONTAMINANT TRANSPORT

The physical and chemical characterization of waste and contaminant transport has several purposes:

- o Identification of the potential contaminants.
- o Determination of which contaminants have migrated from the tailings.
- o Identification of the extent and relative concentration of contamination, e.g., the contaminant plume.
- o Determination of the rate of contaminant migration.
- o Determination of the extent to which contaminated ground water is discharging to hydraulically connected surface water.
- o Separation of the contamination due to mill tailings from other contaminant sources.

F.3.2.1 Geochemistry of waste

The geochemical setting of the potentially affected hydro-geologic environment has been studied in detail on a site-specific basis. Pertinent findings of these studies are discussed below.

Milling. The Grand Junction mill was operated as an acid-leach process. Relative to other acid leach tailings, the pH is about two pH units higher (less acidic): ranging

from 4.0 to 6.5 with a median of 5.5. Both hydrochloric and sulfuric acid were used during the milling process. Iron, ammonia, and salt (NaCl) were other prominent constituents associated with the milling process (Merritt, 1971).

Tailings. The water-soluble concentration of chemical constituents in the tailings is an indicator of which constituents represent potential contamination. Among the constituents which have been found to be present in the tailings in water-soluble form at concentrations above background levels are uranium, vanadium, arsenic, cadmium, and molybdenum. The soils in the evaporation ponds also contain water-soluble concentrations of arsenic, uranium, and vanadium which are above background concentrations (Markos and Bush, 1983a).

Comparison of uranium and radium data for tailings versus adjacent, contaminated soils shows differences (Markos and Bush, 1983a). The migration of radium is much less than that of uranium. Uranium can be expected to be more mobile than radium because it forms sulfate and carbonaceous complexes, whereas radium forms precipitates with sulfate and carbonate.

The tailings also contain high concentrations of the anions sulfate and chloride. The high concentrations of these anions and the acidic conditions of the tailings enhance the mobility of most elements, including such elements as the water soluble constituents listed above as well as selenium, iron, and aluminum.

The mobility of these constituents decreases in the ground water relative to their mobility in the tailings. The migration rates of these constituents is less than the groundwater seepage velocity due to geochemical retardation processes such as precipitation and adsorption.

Some data on the leaching behavior of the tailings in fresh water are available (Veyera, 1980), and are presented in Table F.3.8 and Figure F.3.18. These data indicate that key constituents have leached from the tailings. The mobility of many of these constituents decreases in the ground water. Section F.3.1.6 discusses which constituents are detected above background concentrations in ground water.

F.3.2.2 Water-quality impacts

Water-quality impacts are evaluated for three cases: existing conditions, relocation of the tailings, and impacts for stabilization on the site.

Existing impacts. Water quality for the affected hydrogeologic regime is described in Section F.3.1.6. The concentration of several constituents exceeds EPA standards for drinking water as a result of tailings leachate. The tailings have not caused the quality of the Colorado River to

Table F.3.8 Chemical analysis of first effluent sample for
distilled water leaching test

Solid weight (g)		1,000	1,170
First sample weight (g)		273.8	275.0

Soil type		Beach sand	Slimes

Ca	ppm	687.00	607.00
Mg	ppm	169.00	2,230.00
Na	ppm	314.00	6,880.00
K	ppm	12.00	84.00
P	ppm	0.60	1.00
Al	ppm	0.30	76.00
Fe	ppm	0.03	1.53
Mn	ppm	0.36	7.84
Ti	ppm	0.01	0.08
Cu	ppm	0.07	13.00
Zn	ppm	0.04	225.00
Ni	ppm	0.05	7.51
Mo	ppm	2.68	0.31
Cd	ppm	0.01	6.44
Cr	ppm	0.02	0.08
Sr	ppm	2.80	6.39
B	ppm	0.19	1.60
Ba	ppm	0.08	0.13
Pb ^a	ppm	0.10	5.80
Hg ^a	ppm	0.01	- --
As ^a	ppm	1.60	- --
Se ^a	ppm	10.70	- --
HCO ₃	ppm	124.00	0.00
SO ₄	ppm	2,330.00	10,800.00
Cl ⁴	ppm	504.00	10,640.00
NO ₃	ppm	96.00	ND
pH	ppm	6.40	4.30
Cond	ppm	4,700.00	35,800.00
Tds	mg/l	4,560.00	35,560.00

ND - Not determined

^aHg, As, Se determined by NaBH₄ reducing technique (vapor generation) to avoid spectral interference.

Ref. Veyera, 1980.

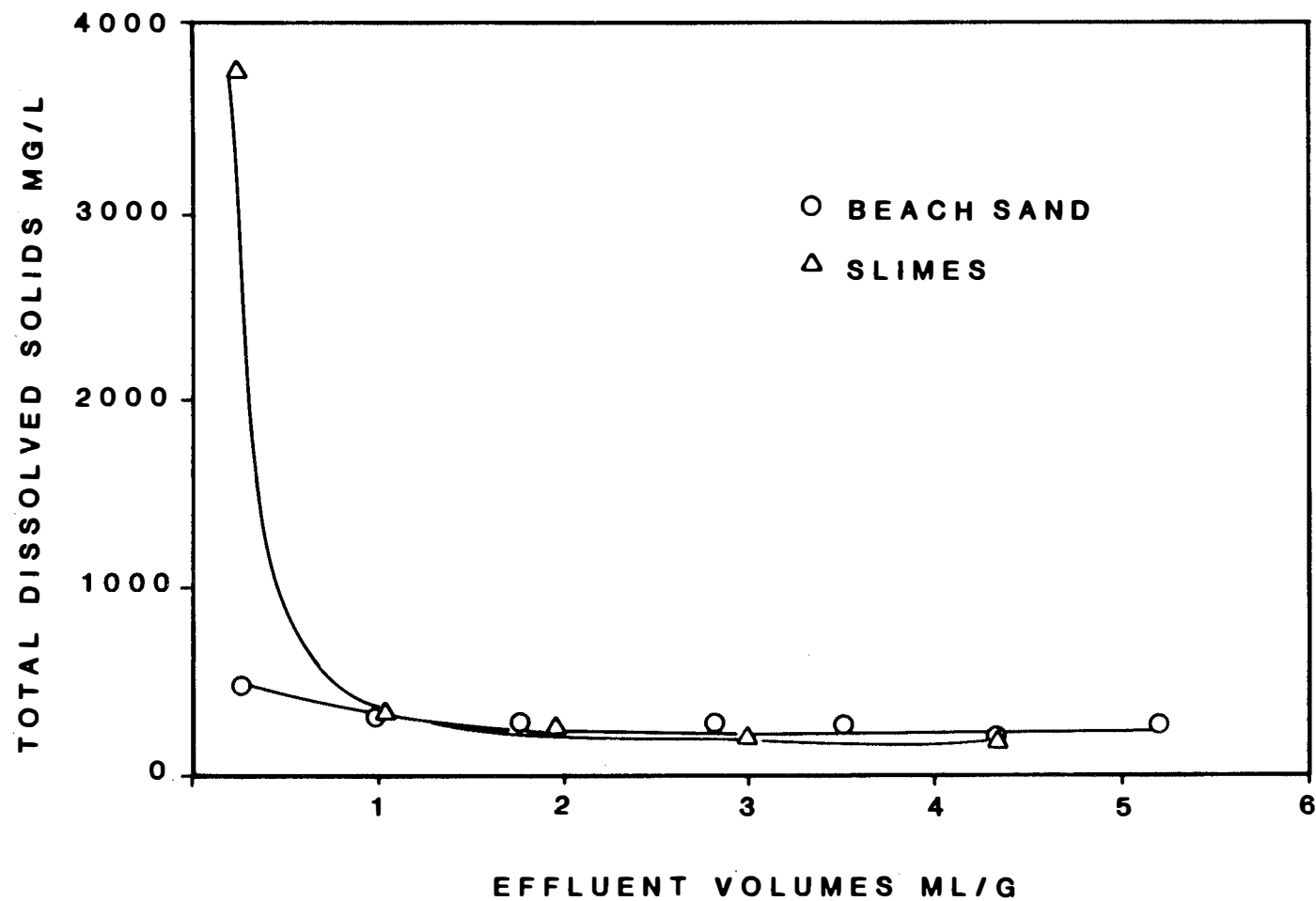


FIGURE F.3.18

RESULTS OF DISTILLED DRIP LEACH TESTS ON BEACH SAND AND SLIMES
Source: Veyera(1980)

fall outside Colorado water quality standards. The background quality of the ground water is predominantly brackish, and the affected system is not currently used for any purpose.

Relocation of the tailings - residual effects at the processing site. If the tailings are relocated to an alternate disposal site, impacts to water quality near the processing site would be due to residual contamination in the ground water, and possibly sorbed or precipitated contaminants in the alluvium. The impacts to ground water at the Cheney Reservoir and Two Road sites are discussed in Sections F.4 and F.5, respectively.

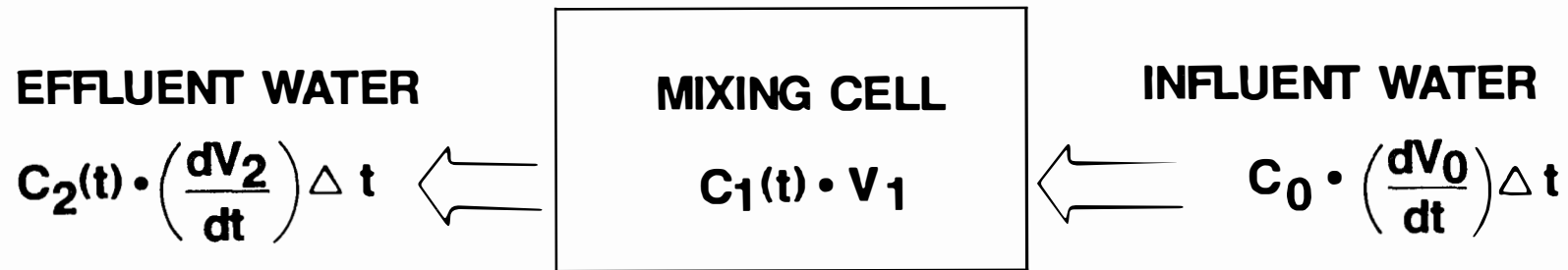
EPA standards require an evaluation of the persistence and permanence of adverse effects of the ground water. A mixing cell model was used to evaluate the persistence of residual contamination at Grand Junction. A single cell model for water quality is created by assigning a water quality to each component of the water balance for the cell. A mixing cell model was chosen because:

- o The varied flow direction within the shallow ground water would tend to make the system analogous to a mixing cell.
- o A single cell mixing cell model is simple and is easy to use.

The mixing cell model for the alluvial system has the following features:

- o The water balance consists of ground-water inflow, transient storage, and ground-water outflow. Net infiltration and seepage to, or from, deeper aquifers is considered negligible.
- o The mixing cell is treated as a completely mixed system. Dispersivity is not treated explicitly, but is considered only in that it enhances mixing and essentially, creates a dilution problem.
- o Geochemical retardation (i.e. sorption, precipitation), desorption, and radioactive decay are not considered. This assumption overestimates contaminant migration rates and may underestimate flushing times.
- o Time is discretized on an annual basis.

A schematic illustration of the conceptual model and the equations representing the model are shown in Figure F.3.19. The results of the model for the gradual dilution of uranium are presented in Table F.3.9. A range of results is found, depending on the initial concentrations in the ground-water background concentrations, volume of alluvial ground water below the tailings (calculated using drainable porosity), and the



LEGEND	RULES
C_n DENOTES CONCENTRATION V_n DENOTES VOLUME	C_0 AND V_1 ARE CONSTANTS $\frac{dV_0}{dt} = \frac{dV_2}{dt}$ AND ARE CONSTANT $C_2(t_{n+1}) = \frac{C_0 \cdot \left(\frac{dV_0}{dt}\right) \Delta t + C_1(t) \cdot V_1 - C_1(t) \left(\frac{dV_0}{dt}\right) \Delta t}{\left(\frac{dV_0}{dt}\right) \Delta t + V_1}$ $C_1(t_{n+1}) = C_2(t_{n+1})$

FIGURE F. 3. 19
MIXING CELL MODEL OF GROUND-WATER QUALITY

Table F.3.9 Results of mixing cell model for residual uranium concentration in ground water

Ground-water flux rate ^a	Background concentration ^b	Cell volume ^c	Average initial concentration under tailings ^d	Effluent concentrations ^e			
				10 yrs	25 yrs	50 yrs	100 yrs
5.7×10^6	20	7.0×10^7	600	285	102	32	20
1.6×10^7	20	1.4×10^8	600	217	59	23	20
1.0×10^8	20	2.5×10^8	600	40	20	20	20
1.6×10^7	20	1.4×10^8	125	56	27	20	20
1.6×10^7	20	1.4×10^8	300	115	39	21	20
1.6×10^7	6.8	1.4×10^8	300	106	26	8	6.8
1.6×10^7	40	1.4×10^8	300	128	57	41	40

^aIn liters per year, from Table F.3.4.

^bIn pCi/l, from Table F.3.6.

^cIn liters, from Table F.3.5.

^dIn pCi/l, highest seasonal concentrations below tailings, from Table F.3.6.

^eIn pCi/l, for given number of years after remedial action.

rate of ground-water flux. This range in results gives some indication of the sensitivity of the model, and of the physical system, to the uncertainty or variability in various factors.

The results of the model show that residual uranium would be flushed from the aquifer within 100 years, but that concentrations of uranium greater than the EPA's health advisory level of 10 pCi/l may persist for more than 25 years. However, background concentrations of uranium may be more than the advisory level (Section F.3.1.6).

Residual concentrations of contaminants other than uranium were not evaluated with the mixing cell model. Other than uranium, only ammonium had a readily definable plume in the alluvial ground water. The sporadic distribution of other contaminants indicates that one or more of several processes is occurring:

- o The constituents are subject to substantial geochemical retardation.
- o The effects of leaching of constituents into ground water are obscured by the concentrations present in the background water.
- o The constituents are rapidly flushed from the ground water.

Because of the absence of definable plumes, and considering the existing and expected use of the alluvial ground water (none), it is concluded that these contaminants other than uranium would be rapidly flushed from the alluvial ground water, relative to the predicted time required to flush uranium.

Stabilization on the site. For stabilization on the site, water-quality impacts would be due to two causes:

- o Existing contamination in the ground water.
- o Continuing contamination of the ground water by tailings leachate.

These impacts can be evaluated by expansion of the mixing cell model used to evaluate the water-quality impacts of tailings relocation. A new term is added to the water balance to account for infiltration through the tailings, and a water-quality description is attached to that term.

There are no available data on the concentration of uranium within the tailings pore water, and for the mixing cell model a concentration of 600 pCi/l will be assumed (610 pCi/l was the highest measured concentration of uranium in a well completed below the tailings). Because ground water moves

through the tailings, this appears to be a representative concentration of the contaminant source strength.

Results of mixing cell calculations are presented in Table F.3.10 for two different rates of infiltration corresponding to two different values of hydraulic conductivity for the cover (Section F.3.3.2) and for various values of hydraulic and water-quality parameters. It can be concluded that the concentration of contaminants in the ground water is relatively sensitive to the rate of infiltration through the cover. For the case of uranium, a higher infiltration rate indicates long-term concentrations in the range of 39 to 235 pCi/l, several times EPA's health advisory level. For the lower infiltration rate, the mixing cell model indicates long-term concentrations of uranium of 8.8 to 52 pCi/l. This is slightly below to several times above the EPA's health advisory level. The range in concentrations reflects variability in background concentrations and hydraulic parameters.

For the toxic non-radioactive contaminants in the ground water, a quantitative assessment was not performed. Uranium and ammonium are the only constituents for which a definite plume could be defined, while other constituents are sporadically distributed in alluvial ground water or are not present at concentrations above background levels (Section F.3.1.6). Stabilization on the site would include removal of the tailings from the ground water, and thus would remove the main source of the sporadically distributed constituents. Because these constituents are not mobile enough to develop a definable plume, removal of their main source means that they would probably be rapidly flushed from the alluvial ground water, relative to the rate of flushing of uranium.

F.3.2.3 Extent of contaminant plume

Iso-concentration maps for those constituents for which a plume could be defined are presented in Section F.3.1.6.

F.3.2.4 Discharge of plume to surface water

Review of existing data. A site-specific geochemical investigation of the Grand Junction tailings (Markos and Bush, 1983a) included experiments to investigate the possible movement of contaminants into the Colorado River (Bush et al., 1980). These studies concluded that "The Colorado River, however, contains no measurable contamination from the tailings." (Markos and Bush, 1983a).

Continuously-monitored water-quality data from the Colorado River system near Grand Junction are available from two sources: the U.S. Geological Survey (USGS, various dates) and the Radium Monitoring Network (EPA, 1973). As of 1983,

Table F.3.10 Results of mixing cell model of uranium concentration in ground water for stabilization on site

Ground-water flux rate ^a	Back ground concentration ^b	Infiltration rate ^c	Leachate concentration ^d	Cell volume ^e	Average initial concentration under tailings ^f	Effluent concentrations ^g			
						10 yrs	25 yrs	50 yrs	100 yrs
5.7x10 ⁶	20	8.9 x 10 ⁻¹	600	7.0 x 10 ⁷	600	343	253	236	235
5.7 x 10 ⁶	20	8.9 x 10 ⁻²	600	7.0 x 10 ⁷	600	292	122	61	52
1 x 10 ⁸	20	8.9 x 10 ⁻¹	600	2.5 x 10 ⁸	600	57	39	39	39
1 x 10 ⁸	20	8.9 x 10 ⁻²	600	2.5 x 10 ⁸	600	42	22	22	22
1 x 10 ⁸	20	8.9 x 10 ⁻²	600	2.5 x 10 ⁸	125	25	22	22	22
1 x 10 ⁸	6.8	8.9 x 10 ⁻²	600	2.5 x 10 ⁸	125	13	8.8	8.8	8.8
1 x 10 ⁸	40	8.9 x 10 ⁻²	600	2.5 x 10 ⁸	125	45	42	42	42

^aIn liters per year, from Table F.3.4.

^bIn pCi/l, from Table F.3.6.

^cIn cm/year, from Table F.3.11.

^dIn pCi/l, highest measured concentration below the tailings, from Table F.3.6.

^eIn liters, from Table F.3.5.

^fIn pCi/l, highest seasonal concentrations below tailings, from Table F.3.6.

^gIn pCi/l, for given number of years after remedial action.

the USGS reported water-quality information for stations at Cameo (upstream of Grand Junction), the Gunnison River near Grand Junction, and the Colorado River near the Colorado-Utah state line. As of 1972 the Radium Monitoring Network (RMN) reported water-quality for stations at DeBeque (upstream of Grand Junction), the Gunnison River at Grand Junction, and the Colorado River near Fruita, Colorado (downstream of Grand Junction). The RMN was reduced after 1972, and its usefulness was impaired (EPA, 1973).

The USGS data include measurements of specific conductance, common ions such as calcium, magnesium, sodium, potassium, alkalinity, sulfate, and chloride; and other dissolved constituents such as arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, selenium, silver, and zinc. The RMN data include measurements of radium-226, uranium, and occasional measurements of total alpha, gross beta, thorium-alpha, lead-210, strontium-90, and polonium-210.

Evaluation of USGS data for the 1982 water year failed to show any measurable changes in Colorado River water quality attributable to the tailings. This is to be expected due to several factors:

- o The relatively large flow of the Colorado River would dilute and disperse contaminants originating from the tailings.
- o The effect of the tailings would be overshadowed by effects of influx of the Gunnison River into the Colorado River one mile downstream of the tailings.
- o The influx to the Colorado River of irrigation return flow, urban runoff, and ephemeral drainages should overshadow the effects of the tailings.

Evaluation of the RMN data for the years 1962 to 1972 showed no evidence of contamination in the Colorado River which could be attributable to the Grand Junction tailings, even though milling operations were active during the time. The mill site lies between upstream stations on the Colorado River at DeBeque and the Gunnison River upstream of Grand Junction, and the downstream station on the Colorado River near Fruita. The EPA stated that radium concentrations did not appreciably increase through the reach but uranium did increase by about 20 percent. Part or all of that increase is due to the high concentrations of uranium in the Gunnison River upstream of Grand Junction, which exceed concentrations in the Colorado River at DeBeque. It is evident that there would be no clear indication of (e.g., measurable contamination) radiometric contamination of the Colorado River water by the Grand Junction tailings because:

- o The relatively large flow of the Colorado River dilutes known ground-water inflow from beneath the tailings.

- o The effects of the tailings are overshadowed by the effects of influx of the Gunnison River into the Colorado River one mile downstream of the tailings.
- o The ambient concentrations of radionuclides in Colorado River water overshadow the effects of the Grand Junction tailings.
- o The cumulative effects of uranium milling on the Colorado River system above Grand Junction would tend to obscure the effects of the Grand Junction tailings.

Impact assessment. Although the effects of the Grand Junction tailings on Colorado River water quality have not been measured to date, there is an unmeasurable but estimatable minimal impact on the water resource. The degree of this impact may be estimated for a given water-quality constituent by calculating the dilution of that constituent in the Colorado River. For example, calculations could be based on an average flow in the Colorado River above Imperial Dam of 10,900 cubic feet per second (USGS, 1979), an average ground-water flux under the tailings of 7.1×10^7 liter per year (7.95×10^{-2} cubic feet per second), and an average concentration of total dissolved solids (TDS) of 6000 mg/l in the ground water. The flux of 7.1×10^7 liters per year is in the range of fluxes calculated using Darcy's law (Section F.3.1.5), and is the same as calculated in a previous study (NUS, 1983). Based on these numbers a dilution factor of 137,000 is calculated, and influx of contaminated ground water into the Colorado River would contribute 4.4×10^{-2} mg/l TDS to the Colorado River. A U.S. Bureau of Reclamation study (URS, 1983) estimated an annual loss of \$540,000 for each increase of one mg/l TDS in the Colorado River at Imperial Dam (along the Arizona-California border). Based on these assumptions and approximate calculations, the TDS load due to the tailings may represent an annual loss of \$23,760 in the value of the resource to downstream water users.

Using similar assumptions health effects can be addressed. Using ground-water flow volumes of 1.6×10^8 to 1×10^9 liters per year (Table F.3.5), an average concentration of uranium in the ground water of 600 pCi/l, and a flow in the Colorado River of 3780 cfs (the 49-year average at Cameo; USGS, 1979), the influx of contaminated ground water into the Colorado River would contribute 2.9×10^{-3} to 1.8×10^{-2} pCi/l opposite the tailings. This is an over-estimate because 600 pCi/l represents the highest measured concentration of uranium in the ground water, not an average. Health effects of ingesting water are discussed in detail in Appendix I, Radiation Health Effects.

F.3.2.5 Contaminant sources other than mill tailings

There are several potential contaminant sources other than mill tailings within the potentially affected hydrologic setting. These include:

- o Irrigation return flow.
- o Urban runoff.
- o Landfills or buried trash.
- o Industrial activities.

The most easily identifiable source of ground-water contamination in the area is irrigation return flow, including seepage from canals, deep percolation of irrigation water, and urban seepage from water mains, sewers, and gardening. This water percolates through the alluvium and into the Mancos Shale, where it leaches salts. Concentrations of salts exceed 3000 to 4000 mg/l in the Mancos Shale. This leachate moves toward the active alluvium along the Colorado River and then into the river. The entire Grand Valley contributes enough salt to the Colorado River to increase the salinity of the river at Imperial Dam by more than 43 mg/l (U.S. Bureau of Reclamation, 1978). The annual costs of this leachate can be estimated at more than \$23 million using a similar estimation approach as the one presented above (Section F.3.2.4).

The impacts of urban runoff on ground-water quality in the Grand Junction area have not been quantified. It is known that contaminants present on street surfaces contribute to water pollution (EPA, 1972). Among the contaminants known to be present on city streets are phosphates, nitrates, heavy metals, and pesticides.

At one boring location down-gradient of the tailings (733) trash was encountered. The extent of this "landfill" is unknown. This material could contribute to ground-water contamination.

There are numerous industries in the vicinity of the tailings. Several of these use chemicals in their operations. The effects of these industries on ground-water quality, if any, are unknown.

F.3.3 CLIMATIC EFFECTS ON CONTAMINANT MIGRATION

F.3.3.1 Climate

The climate in the vicinity of Grand Junction is relatively dry. Annual precipitation averages about 8.9 inches (22.6 cm). Simmons and Gee (1981) report values of potential evapotranspiration (PET) for Grand Junction in the range of 180 cm per year. Thus the ratio of PET to precipitation is in the range of seven to eight. Selected data for pan evaporation are shown in Table F.3.11.

F.3.3.2 Contaminant migration in the unsaturated zone

Existing conditions. During the period of active milling and up to the present time, the impact of contaminant transport in the unsaturated zone has been relatively minor.

Table F.3.11 Selected pan evaporation data for the Grand Junction area

Year	Months of record	Total evaporation (inches)
GRAND JUNCTION 6 ESE		
1977	May-September	55.87
1978	May-September	54.93
1979	May-September	57.29
1980	May-July, September	41.78
Average (period of record)	May-September	74.81
MONTROSE 1		
1977	April, June-October	38.23
1978	April-November	52.93
1979	April-October	50.13
1980	May-October	45.90
Average (period of record)	April-November	52.89

Ref. NOAA, 1977-1980.

The major impacts to ground water have been the drainage of the initially saturated tailings after deposition and the flow of ground water through those portions of the tailings which are below the water table.

Future conditions. Infiltration of incident precipitation through the tailings can generate leachate which can move out of the stabilized site embankment. It is difficult to predict the precipitation which would infiltrate; however, calculations have been made to provide an upper bound on infiltration.

A variety of methods are used to compensate for the difficulty in predicting infiltration rates. The various methods are briefly described below, while predicted infiltration rates are presented in Table F.3.12.

One conservative method of calculating an upper bounding value of infiltration through the tailings embankment is to assume a constant saturated flux through the cover (method 1, Table F.3.11). This calculation uses Darcy's Law to calculate flux:

$$q = K \frac{dh}{dl}$$

where

q = flux (l/t)

K = saturated hydraulic conductivity (l/t)

dh/dl = hydraulic gradient

Net infiltration would probably be significantly less than calculated with method 1, because the flux of moisture into the cover is not constant and because moisture also moves out of the cover by evapotranspiration. A lower, more representative value of net infiltration was calculated using the following assumptions (method 2):

- o The sloping embankment cover promotes lateral runoff of excess moisture.
- o Infiltration occurs only under a snowpack or during significant (i.e. more than 0.1 inch) precipitation events.
- o A downward, unit hydraulic gradient exists only under a snowpack or during significant precipitation events.
- o Contribution of snowpack to infiltration is minimal, because snows are light and they seldom remain on the ground for long periods of time (U.S. Bureau of Reclamation, 1978).

Table F.3.12 Predicted infiltration rate through the cover
at the Grand Junction site

Method ^a	Cover hydraulic conductivity ^b	Duration of flow ^c	Infiltration rate (cm/yr)
1	1×10^{-6}	constant	3.15×10^1
1	1×10^{-7}	constant	3.15×10^0
2	1×10^{-6}	246	8.90×10^{-1}
2	1×10^{-7}	246	8.90×10^{-2}
3			Data not available
4			Not applicable

^aMethod 1 is constant Darcy flow under unit hydraulic gradient;
Method 2 is constant Darcy flow during rainfall events > 0.1 inch;
Method 3 is wetting front advance during rainfall events > 0.1 inch;
Method 4 is water balance.

^bIn cm/sec. Hydraulic conductivity of cover would be specified in engineering design.

^cIn hours per year.

- o Significant net infiltration occurs only during days with precipitation greater than 0.1 inch of precipitation. For precipitation events less than 0.1 inch, it is assumed that the overlying rock cover would cause large interception losses. For the period 1965-1981, the area averaged 41 days with precipitation greater than 0.1 inch (Colorado Climatological Office, 1982).
- o For days with precipitation greater than or equal to 0.1 inch, the precipitation occurs over a six-hour period. For the period January, 1981, through March, 1985, climatic data for Grand Junction shows that days with precipitation greater than or equal to 0.1 inch averaged 5.5 hours of measurable precipitation (NOAA, 1981-1985).

Based on these assumptions, a unit hydraulic gradient occurs for a limited period:

$$41 \text{ days} \times 6 \frac{\text{hours}}{\text{days}} = 246 \text{ hours}$$

This calculated duration of a downward, unit hydraulic gradient is used to calculate annual net infiltration (Table F.3.11).

An alternate means (method 3) of calculating annual infiltration is made using a formula for advancement of a wetting front during constant infiltration (Stallman, 1967):

$$dw/hc + \log 1/(1 + dw/hc) = kt/hcSc$$

where

dw = depth of wetting front at time t

hc = pressure head across wetting front

k = saturated hydraulic conductivity

t = time after the ground surface is wetted

Sc = change in volumetric water content across the wetting front

The use of this equation for calculating infiltration is as follows:

- o Infiltration occurs only when there is a surface source of water, although the wetting front would continue to advance after the source is removed.
- o Sc equals the difference between the -15 bar and saturation moisture percentage.

- o Net infiltration occurs only during precipitation events of 0.1 inch or greater (see method 2 for reasoning), which are assumed to last six hours.
- o Net infiltration equals $dw \times Sc$.

This method was not used for the Grand Junction site, but was used for the Cheney Reservoir site (Section F.4). An alternative means of estimating the net infiltration is to assume that it would be less than or equal to the existing net infiltration through the undisturbed soils at the site, and estimate the existing infiltration rate using a water balance calculation (method 4). The reasoning behind this estimate would be that the engineered cover will have a lower permeability than the undisturbed soils, which would tend to restrict infiltration to less than existing rates. It must be noted that factors other than the permeability of the soil control infiltration, e.g. evapotranspiration by the existing vegetation. The existing rate of net infiltration still provides a qualitative measure of what infiltration through the covered tailings could be.

Previous studies. The Grand Junction site was used to investigate the use of vegetation and rock covers to stabilize uranium mill tailings (Mayer et al., 1981). The investigation consisted of simulating moisture movement through the tailings and cover layers. The simulation used a version of the computer code, UNSAT (Gupta et al., 1978). The version is called UNSATV and accounts for the important factors influencing the unsaturated zone:

- o Water infiltration from precipitation or irrigation.
- o Evaporation.
- o Transpiration.
- o Runoff.
- o Drainage.
- o Water vapor diffusion (a feature of UNSATV).

The simulations were run for a one-year period to initialize the model, and then for a two-year period using either the repeated climatic data for 1979 (wettest year in 1976 to 1979 period) or the repeated climatic data for 1976 (driest year 1976 to 1979).

The results of the simulation study have several limitations which restrict their applicability to the current designs for stabilizing the tailings. It should be noted that although the simulations are limited in their applicability, these limitations tend to overestimate moisture movement and thus, discussion of these limitations follows:

- o The cover system design used in the simulations was quite different from the current design. Most significant is that the simulated profile had a low-permeability layer at depth (1.3 meters) within the multi-layer cover, whereas the current conceptual de-

sign has a low-permeability layer near the top of the cover system. The simulated cover had a 1.3-meter thick layer of overburden which could retain moisture, tending to drive water down through the low-permeability cover.

- o The low-permeability layer used in the simulation was only 15 cm thick, approximately one-tenth (1/10) the thickness of the current design. Using Darcy's Law modified for unsaturated flow (Hillel, 1971):

$$q = -K(\theta) \frac{dh}{dl}$$

where

q = flux

K = unsaturated hydraulic conductivity

θ = water content

dh/dl = hydraulic gradient

dh = change in total head

dl = length of flow path

It can be seen that for a given value of K and a given change in head across a tailings system; the greater the length of the flow path across the low-permeability layer the smaller the flux. The ratio K/dl is sometimes called the "Effectiveness Factor" (Buel and Barnes, 1981). The current design has an effectiveness factor approximately four times that of the simulation study.

- o The simulation was performed using a one-dimensional model, therefore lateral drainage was not considered. And more importantly, the model does not calculate runoff directly, and does not take into account the effects of a sloped surface on runoff. The current conceptual design includes a cover top slope of two to four percent to promote runoff, with sideslopes of 20 percent.

It can be concluded that the previous simulation study (Mayer et al., 1981) included several aspects which would tend to overestimate net infiltration and which limit the applicability of the simulation study to the current design. The current conceptual design would be more effective in minimizing infiltration and leachate production than the design used in the previous simulation study.

The Grand Junction tailings were also the location of a field study of the use of vegetation and rock covers (Beedlow, 1984). Field measurements of matrix potential and volumetric

moisture for two sets of two dates in 1982 corroborate the simulation studies. The vegetated cover showed very little change in moisture content relative to rock cover (the changes in moisture content under the vegetative cover are near the resolution of the neutron probe that was used to make the measurements).

The applicability of the field study to the current design is also limited by differences between the two cover designs. The test plots were relatively flat (see Figure 1 in Kirkham et al., 1982), which would minimize runoff. The current conceptual design includes a cover sloped three to four percent, with side slopes of 20 percent, to promote runoff. The test plots had a low-permeability layer at depth with overburden which could retain moisture, which would tend to drive water through the low-permeability layer. Also, the thickness of the low-permeability layer is less than in the current site design although the hydraulic conductivity is lower. The net result was that the current design has a greater effectiveness factor than the test plot. These differences all indicate that net infiltration would tend to be less with the current design than for the test plots.

F.3.4. EXISTING USAGE AND VALUE OF WATER RESOURCES

F.3.4.1 Ground water

Usage. Utilization of ground water in the Grand Junction area is predominantly from deeper confined aquifers rather than from the shallow aquifers. The lack of usage of shallow ground water can be attributed to three factors: the poor quality and low yield of shallow aquifers, and the ready availability of alternate water supplies. Reports on the hydrogeology of the Grand Junction area corroborate this (Lohman, 1965):

"In the Grand Junction area, unconfined aquifers yield but little water or water of poor quality, or both ... Where thick, the alluvium along the principal streams probably would yield considerable water to properly constructed wells, but the water probably would be too hard for domestic or public supplies. It would be suitable chemically for irrigation, but irrigation water from the rivers is abundantly available at lower cost."

In the immediate vicinity of the tailings only one unregistered well, an industrial drainage well upgradient of the tailings, is known to be completed in the alluvium. This upgradient well is used only in summer months when high groundwater levels in the alluvium flood land adjacent to the Colorado River. Location of the well (710) is shown in Figure F.3.1.

There are four artesian aquifers in the Grand Junction area, which are, in order of importance and productivity, (Lohman, 1965):

- o The Entrada Sandstone.
- o The Wingate Sandstone.
- o The lenticular sandstone beds in the Salt Wash Member of the Morrison Formation and in some places in the Brushy Basin Member.
- o The Dakota Sandstone and sandstone in the Burro Canyon Formation.

The Dakota Sandstone is the uppermost artesian aquifer in the vicinity of tailings. No registered wells are known to be completed in the Dakota Sandstone within the potentially affected hydrogeologic environment of the tailings.

Value. The value of shallow ground water in the vicinity of the tailings can be judged by the value of alternative water supplies in the area. The actual value is probably less than alternative water supplies because of the poorer quality of the ground water versus the quality of alternative water supplies. A rate schedule for delivery of city water is shown in Table F.3.13.

Table F.3.13 Rate schedule for water users
within Grand Junction city limits

Quantity per month (gallons)	Charge
First 3,000	\$5.35
Next 7,000	\$0.90/1000 gal.
Next 10,000	\$1.05/1000 gal.
More than 20,000	\$1.25/1000 gal.

Ref. City of Grand Junction, 1985.

Because ground water in the Dakota Sandstone varies significantly in yield and quality depending on location, its value must be judged according to yield and quality. The Dakota Sandstone is not utilized in the near vicinity of the tailings, and therefore has only a future value (Section F.3.6).

F.3.4.2 Surface water

Usage. The Colorado River mainstream below the tailings is used by several states and by Mexico for various purposes including domestic use, industrial use, irrigation, livestock watering, and for fish and wildlife.

There are no major domestic users of Colorado River water for 200 miles downstream from Grand Junction (FBDU, 1977). The normal water supplies for Grand Junction are obtained from Grand Mesa surface water, the Juniata and Perdy Mesa reservoirs being the major sources. During dry spells, Grand Junction can use Gunnison River water, the intake being approximately one mile upstream from the confluence with the Colorado River. The Ute Water District uses Colorado River water during dry spells, but its intake is just upstream from Palisade and therefore upstream from the pile.

Value. In the highest category of use, municipal rate schedules are indicative of the highest potential value of Colorado River water (Table F.3.13). Another way to look at value is to look at the incremental losses due to pollution of the river. A 1983 study by the Bureau of Reclamation has estimated an annual loss of \$540,000 for each increase of one mg/l in the total dissolved solids (TDS) content of the Colorado River at Imperial Dam (URS, 1983).

F.3.5 ALTERNATE WATER SUPPLIES

The tailings have not affected any ground water that is currently used. Should the affected ground water be considered for use, there would be potential alternate water supplies. Alternate water supplies in the potentially affected hydrogeologic setting would include several sources:

- o Grand Junction municipal water system.
- o Commercial water supply (delivery by tanker).
- o Drilling of wells into multiple artesian aquifers.
- o Appropriation of Colorado River water (subject to availability).

F.3.6 FUTURE USAGE AND VALUE OF WATER RESOURCES

F.3.6.1 Ground water.

Usage. Future usage of shallow ground water in the affected hydrogeologic environment will be minimal because of the availability of the city water, the seasonally low quality of the alluvial aquifer, and the impact of other contaminant sources on the water (Section F.3.2.5). The only known existing use of the alluvial aquifer, at a well upgradient of the tailings, occurs only seasonally when the river is at high stage, and is only for drainage of flooded land.

Future use of the uppermost artesian aquifer is also expected to be minimal:

"The sandstones in the Dakota Sandstone and Burro Canyon Formation are tapped by very few wells but, because of the generally poor quality of the water. . . very little additional development of water from these formations is likely or anticipated." (Lohman, 1965).

Value. Estimates of the future value of water resources are difficult to establish, and are severely limited as to the duration over which they can be deemed reliable. One reason for the uncertainty of estimates of water value is that water value is strongly related to population and water demand, and estimates of population changes tend to be very short term. In the Grand Junction area future water demand would also be tied to such uncertain factors as the economics of oil-shale development (oil-shale processing may consume large amounts of water).

Estimates of the value of shallow ground water near the Grand Junction tailings must be based on the fact that it is not a discrete water resource. The shallow ground water is hydraulically connected to the Colorado River and any capture of ground water would draw water from the river. It cannot be "mined" as can some ground-water systems, e.g. there is no non-renewable portion of the alluvial system.

Several factors can be used to qualitatively judge the future value of shallow ground water near the tailings. These factors are:

- o Expected future usage (low).
- o Extent (limited to area adjacent to Colorado River).
- o Amount of system which is non-renewable (none).
- o Quality versus alternative sources (poor-exceeds EPA drinking water standards).
- o Availability of alternative supplies (readily available).

Based on these qualitative factors, it can be concluded that the expected future value of the shallow ground water is relatively low.

F.3.6.2 Surface water

Usage. In the immediate vicinity of the tailings, future usage will be minimal. This is because of the same reasons as the expected low use of ground water in the area (the ready availability of good quality municipal water).

Value. The value of Colorado River water in the area can be expected to increase. Increasing population, agricultural development, and mineral or energy development in the Grand Junction area and the Colorado River Basin would be expected to increase demand for Colorado River water. The increasing demand would increase the value placed on the water.

F.3.7 IMPACTS IN AFFECTED HYDROGEOLOGIC ENVIRONMENT

Impacts on the affected hydrogeologic environment are discussed both for existing conditions and for future conditions. Future conditions can be affected by any of the alternative actions:

- o No action.
- o Stabilization on the site.
- o Relocation to an alternate disposal site.

F.3.7.1 Human health risks

Health effects of ingesting ground water and surface water are discussed in detail in Appendix I, Radiation Health Effects.

Existing conditions. To date, there are no known users of ground water in the affected hydrogeologic environment and therefore there are no known human health risks from the ingestion of this ground water.

Future conditions. For the no action alternative, impacts on ground-water and surface-water quality would probably be about the same as existing conditions (Section F.3.1.6). The probability of human ingestion of ground water would be low (Section F.3.6.1).

For stabilization on the site, contaminated ground water would be flushed from the affected environment until it approached background conditions. Until the flushing is complete, concentrations of some constituents (e.g. arsenic, cadmium, iron, manganese, selenium, and zinc) would exceed Federal drinking water standards in the ground water below the tailings. During the time of flushing (less than 100 years), the probability of human ingestion would be low due to the low probability of future use of this water (Section F.3.6.1). Potential human health effects due to ingestion of surface water would decline over this same short period. Uranium concentrations would persist at concentrations above background (Section F.3.2.2). Human health risks due to ingestion of ground water containing elevated concentrations of uranium would be minimal, because the expected use of the ground water is low (Section F.3.6.1). Health effects are discussed in more detail in Appendix I, Radiation Health Effects.

F.3.7.2 Damage to crops and vegetation

There is no known agricultural activity overlying the affected hydrogeologic system. There has been no known impact to crops or vegetation. The future likelihood of damage to crops and vegetation is minimal because of the urban setting of the affected hydrogeologic system.

F.3.7.3 Damage to wildlife

There have been no known impacts to wildlife due to ingestion of contaminated ground water. Considering the magnitude of contamination relative to that caused by other sources (e.g. irrigation return flow), the likelihood of damage attributable to the tailings is relatively small.

F.3.7.4 Persistence and permanence of adverse effects

Quantitative and qualitative conclusions on the persistence of ground-water contamination are discussed in Section F.3.2.2. Based on the lack of known adverse impacts at present and the projection of decreasing amounts of contamination, persistent or permanent adverse effects are expected to be minimal.

F.3.8 AQUIFER RESTORATION

For affected ground water at UMTRA Project sites the decision on whether to institute remedial action, what specific action to take, and to what levels an aquifer should be protected or restored should be made on a case-by-case basis (40 CFR Part 192.20). The decision must take into account several factors:

- o Technical feasibility of improving the aquifer in its hydrogeologic setting.
- o Cost of applicable restorative or protective programs.
- o Present and future value of the aquifer as a water resource.
- o Availability of alternative water supplies.
- o The degree to which human exposure is likely to occur.

As indicated by the regulations, remedial actions for affected aquifers can be divided into two basic approaches: ground-water protection and aquifer restoration. A remedial action strategy can also be a combination of these two approaches. At the Grand Junction site, ground-water contamination has probably already reached a maximum physical extent because the contamination has been ongoing for a relatively long time in an alluvial aquifer with relatively large annual flux (inflow and outflow). Therefore, protective measures would have only future benefit to the affected aquifer. Protective measures are incorporated into the remedial action: removal of the tailings to an alternate site or, for stabilization in place, removal of the tailings from the ground water and use of a low-permeability cover to minimize infiltration. The discussion that follows covers only aquifer restoration.

F.3.8.1 Technical feasibility

Two basic approaches to aquifer restoration are plume capture and plume management. An aquifer restoration program could also be a combination of the two approaches. Cost differences between the various technical alternatives will be discussed separately from feasibility.

Plume capture consists of some method or methods of obtaining contaminated ground water, which is then pumped or fed by gravity flow to a treatment facility. Among the methods for obtaining contaminated ground water are drains, wells, sumps, and trenches.

Plume management consists of injecting uncontaminated water into the aquifer. The uncontaminated water displaces the plume, forcing it in a direction determined by the injection set-up. Injection can be performed using wells or spreading basins. The injection can be performed to obtain several effects:

- o To keep the plume away from existing or potential ground-water users.
- o To force the plume toward a collection system.
- o To force the plume toward a discharge area.

In the case of the contaminated ground water at Grand Junction, there are no known existing ground-water users (Section F.3.4) downgradient of the tailings, and only one upgradient industrial well which may have been affected by the tailings (Section F.3.1.6). The upgradient well is on the edge of the contaminated shallow ground water, and is used to control high water levels which flood a truck scale at an industrial facility adjacent to the Colorado River. The water is pumped back into the Colorado River, and is rarely used (Seevers, 1985). Plume management could be performed to force contaminated ground water toward a collection system or toward a discharge area. The discharge area in this case would be the Colorado River. Discharge to the Colorado River would only transfer contamination from one water resource (ground water) to another (surface water). Plume management would be of most benefit if it is used to force the plume toward a collection system.

Plume capture near the Grand Junction tailings is complicated by both physical and cultural features. The presence of the Colorado River adjacent to the plume means that there is a ready source of recharge to the alluvial aquifer. Pumping in the shallow aquifer would induce flow from the river to the drain, well, sump, or trench (Figure F.3.20). The flow from the nearby river dilutes the contaminated ground water. Therefore, an increased volume of water would be captured and treated, and thus costs for each activity would be increased.

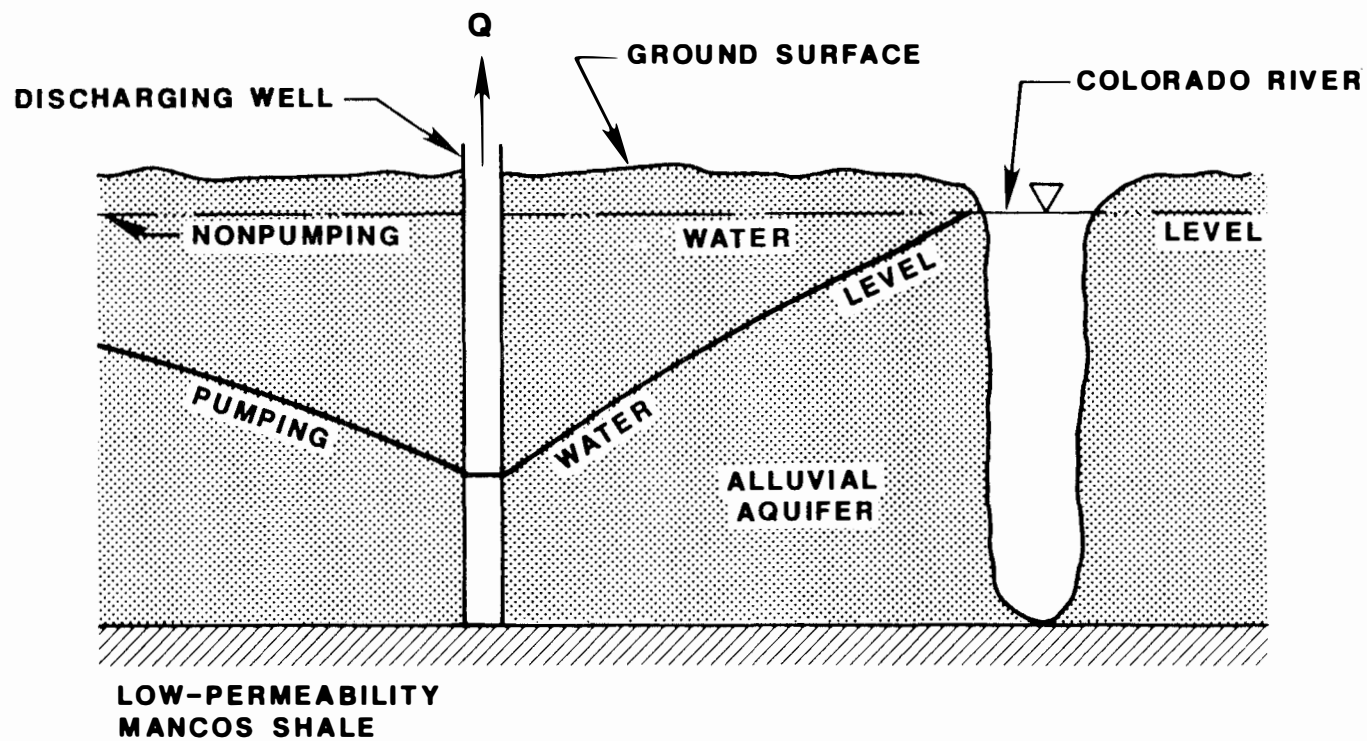


FIGURE F.3.20

PUMPING GROUND WATER NEAR A RIVER INDUCES FLOW

The amount of induced flow can be reduced by various pumping schemes (e.g. more wells pumping less water) or by installing a low-permeability slurry wall as a barrier (Figure F.3.21). Each of these measures would also increase costs for plume capture.

Cultural complications to aquifer restoration at Grand Junction are due to the contaminated ground water underlying a populated area with a concentration of cultural features (buildings, roads, pipes, and the like). A capture scheme may be difficult to implement. There may not be enough available land to effectively implement trenches. Drains or wells (with the accompanying pipelines to the treatment plant) would involve trenching and corresponding disruption to the community.

Plume treatment can be accomplished in a couple of ways. There are various methods of removing contaminants from water; these do not merit further discussion except to conclude that it is technically feasible to clean up the captured water, if given sufficient monetary resources. The treatment system can either be an existing one or one specifically constructed for aquifer restoration.

An existing treatment system could be utilized by routing contaminated water into the existing waste water (sewage) treatment system of the city of Grand Junction. This has the advantage of the using existing waste transmission systems (sewers). It has the disadvantage of mixing the plume waste water with the normal municipal waste water. Municipal wastewater treatment plants usually do not use treatment technologies designed to remove constituents such as those in the tailings plume. Different capabilities could be added to the existing treatment plant; however, these must treat not only the captured plume but also the municipal waste water which is diluting it. It may be ineffective to dilute a waste before treating it.

A scheme for treating the captured plume can also be a treatment system near the mill tailings site. This scheme can be any physical, biological, or chemical means of removing contaminants from the water. It can also be as simple as evaporating the contaminated water, and disposing of the residual salts. The main disadvantage of treatment at the site in Grand Junction is the necessity for a waste-water transmission system which would have to transect the many cultural structures in the area.

F.3.8.2 Cost

Based on the EPA standards for inactive uranium mills (40 CFR Part 192) it has been determined that aquifer restoration is not needed at the Grand Junction site. This determination took into account, as required by the EPA standards, the cost of a restoration program. The following discussion is included to demonstrate how cost was considered in determining the

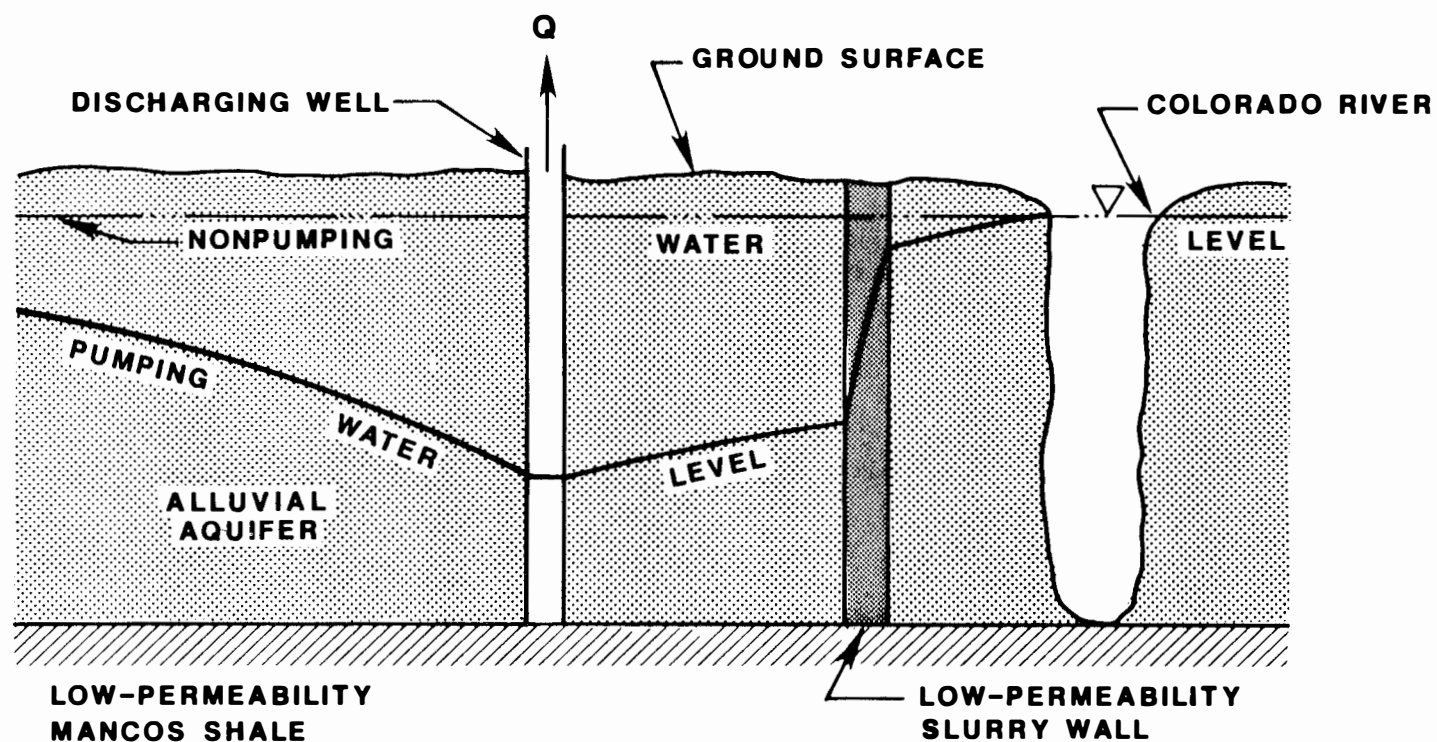


FIGURE F.3.21
LOW-PERMEABILITY BARRIER REDUCES INDUCED
FLOW FROM RIVER

need for aquifer restoration. The estimation of costs which follows is not meant to be a rigorous analysis, but only an initial investigation of approximate costs. For the Grand Junction site this initial investigation of costs appeared to be adequate for evaluating the need for aquifer restoration.

Remedial action for the Grand Junction tailings would include dewatering and waste-water treatment. This would in effect clean up alluvial ground water below and adjacent to the site. Aquifer restoration could be done for off-site areas within the extent of contaminant plumes.

It is possible to determine some approximate costs of an aquifer restoration program without doing a precise cost estimate. Necessary expenditures for an aquifer restoration program can be identified and approximate costs assigned to them. At a minimum, necessary aspects of an aquifer restoration program for the off-site alluvial ground water at Grand Junction would include:

- o Well installation to capture contaminated ground water.
- o Pumps to lift the water out of the wells.
- o Pipe to carry the captured water to a treatment plant.
- o Trenching to place the pipe below grade.
- o Road repair (asphalt paving) where the pipe crosses city streets.
- o A water treatment plant or added capacity for the waste-water treatment plant on the site.
- o Well abandonment for the capture wells.
- o Operation and maintenance of the restoration system.
- o Decommissioning of the wells and pipeline.

Some approximate costs are presented in Table F.3.14. The system described in this table is for 20-foot-deep wells 250 feet apart. These costs could be scaled down depending on how much of the plume is to be captured.

Costs could also be changed by changing well spacing. Note that the table does not include costs for operation and maintenance, nor for water treatment capacity; these costs would normally constitute a major portion of the total costs of an aquifer restoration program. Thus the total cost listed in the table could possibly be increased by a factor of two or more to account for water treatment capacity, operation, and maintenance. Considering the option of scaling down the program described in Table F.3.14 and the unaccounted costs, an aquifer restoration program at Grand Junction could cost between a few hundred thousand dollars to more than a million dollars.

Table F.3.14 Approximate costs for some expenditures required for aquifer restoration

Item	Unit price(\$)	Unit description	Units	Costs (\$)
Well installation				
easement purchase			- not included-	
legal survey			- not included-	
well drilling	30	feet	1760	52,800
4-inch casing, installed	12	feet	1760	21,120
100-gpm pump	1975	unit	88	173,800
well development	100	hour	176	17,600
setting pump	105	unit	88	9,240
field engineer	25	hour	200	5,000
Pipeline installation				
easement purchase			- not included-	
legal survey			- not included-	
engineering (design)			- not included-	
2-inch PVC pipe	2	feet	24,000	48,000
trenching (backhoe)	5	feet	24,000	120,000
asphalt paving	2	square feet	2,000	4,000
field engineer			-not included-	
Miscellaneous				
fencing, installed	250	unit	88	22,000
electrical hook-up	600	unit	88	52,800
water treatment plant			-not included-	
Operation and maintenance				
water treatment			-not included-	
electricity (pumping)	2500	month	24	65,320
water sampling and analysis	260	sample	264	68,640
Decommissioning				
pulling pump	105	unit	88	9,240
pump resale	64%	unit	88	-111,232
dismantling fence	30	unit	88	2,640
trenching (backhoe)	5	feet	24,000	120,000
asphalt paving	2	square feet	2,000	4,000
well abandonment	263	unit	88	23,144
TOTAL COST				708,112

Some other costs of an aquifer restoration program are not addressed in the discussion above. Because the program would be done in a metropolitan area, there would be other direct and indirect costs such as traffic barriers, relocation of utilities or tunneling where pipelines cross utility easements, temporary disruption to businesses, among others. It would be difficult to quantify indirect costs such as disruption to businesses.

F.3.8.3 Future value of the resource

The future value of the affected ground water is discussed fully in Section F.3.6.

F.3.8.4 Availability of alternative water supplies

Water use in the Grand Junction area is discussed in Section F.3.4. In the area overlying the plume of contaminated ground water, good quality potable water is readily available from water mains. There is little reason at present for people in the area immediately adjacent to the tailings to drill wells into the alluvial aquifer.

F.3.8.5 Degree of human exposure likely to occur

Several circumstances indicate that the likelihood of human exposure to contaminated shallow ground water is low. These are:

- o A water distribution system is already in place and fully used in the area overlying contaminated ground water.
- o The existing water distribution system can be easily hooked into by future development in the area.
- o The shallow ground water and Colorado River in the general area are known to be of poorer quality than available water supplies.
- o The taste and short-term effects of ingesting contaminated ground water (e.g., laxative effects due to sulfate) would discourage long-term usage, and long-term usage is necessary to cause a high probability of harm.
- o Only one existing user is possibly within the extent of contaminated ground water, and the well is used for flood control.

F.3.8.6 Summary

The need for aquifer restoration in the affected shallow ground water has been considered using the recommended factors of 40 CFR Part 192.20. The following conclusions have been reached:

- o It is technically difficult to improve the aquifer in its hydrogeologic setting. The effort would be complicated by recharge from the nearby river.
- o Conducting an aquifer restoration program could cause a disruption to the community.
- o In monetary terms only, cost of the restorative program would be relatively high compared to the benefit.
- o There are no known users of the affected ground water.
- o The present and future value of the aquifer as a water resource is much lower than the cost of restoration.
- o Alternative water supplies are readily available and are currently being used.
- o The degree of human exposure which is likely to occur is low.
- o One industrial user upgradient of the tailings may be within the affected (e.g. contaminated) hydrogeologic setting. The well is used primarily to control high water levels which occur during high stage in the Colorado River. Measures other than aquifer restoration would seem appropriate to ensure that there are no health effects from ingestion of this water.

Based on these criteria, aquifer restoration of the shallow ground water is neither a cost effective nor a necessary means of mitigating ground-water contamination caused by the uranium mill tailings at Grand Junction.

F.3.9 NO ACTION ALTERNATIVE

One of the alternatives addressed in this EIS is the "no action" alternative. It is difficult to quantify the impacts due to no action. On a qualitative basis it can be concluded that the impacts would be very similar to conditions in the existing environment. The following general conclusions can be reached regarding the no action alternative:

- o In the short-term the tailings would remain in contact with the ground water and would continue to act as a source of contamination. Water-quality impacts in the short term would be very similar to those seen in the existing environment.

- o In the long-term there is a high probability that erosion could remove the existing temporary cover. The tailings could be dispersed over a wider area and the potential for leaching of contaminants could be increased.

The water-quality impacts due to the no action alternative will not be further assessed within this appendix. More detailed discussion of the impacts of no action may be derived by reviewing the description of the existing hydrogeologic environment (Section F.3.1).

F.4 POTENTIALLY AFFECTED HYDROGEOLOGIC ENVIRONMENT-CHENEY RESERVOIR SITE

F.4.1 CHARACTERIZATION OF HYDROGEOLOGIC ENVIRONMENT

F.4.1.1 Previous investigations

The Cheney Reservoir area has been included within regional hydrogeologic studies; however it has been the subject of only one site-specific study. The Colorado Geological Survey (CGS, 1982) performed a reconnaissance level study of the location's potential use as a mill tailings disposal site.

F.4.1.2 Recent investigations

The field programs have involved exploratory drilling, hydraulic testing, monitoring well installation, and water sampling in two phases. The first phase was begun with drilling in November to December, 1982. The second phase was begun with drilling in March, 1985.

In the first phase, six exploratory borings were drilled and sampled for stratigraphic logging and to obtain soil samples for laboratory testing. These borings were also used for field permeability tests. An additional three borings were drilled and used for monitor well installation.

In the second phase, two borings were drilled for monitoring well installation. These borings were sampled during drilling for stratigraphic logging. Well construction details for both the first and second phases are presented in Table F.4.1, and well locations are presented in Figure F.4.1.

The first phase was conducted in accordance with a work plan for geotechnical and ground-water hydrology work (Golder Associates, 1982). All field and laboratory work in the second phase was completed in accordance with standard operating procedures. These standard operating procedures are on file with the U.S. DOE UMTRA Project Office in Albuquerque, New Mexico.

F.4.1.3 Stratigraphy

The stratigraphy of the disposal site has been defined through a series of borings (Figures F.4.2 through F.4.4).

On a hydrogeologic basis the stratigraphy can be divided into four zones:

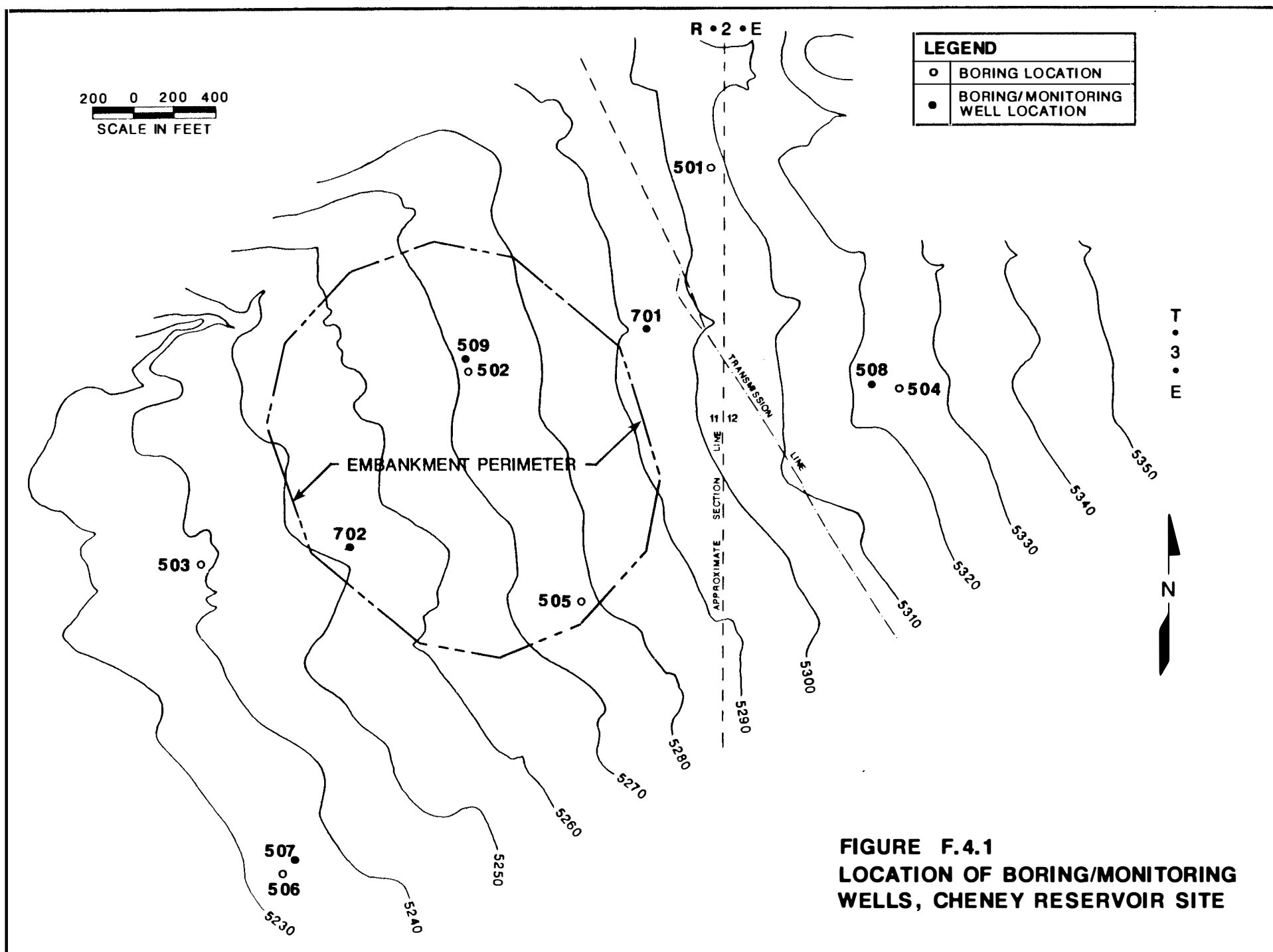
- o A surficial layer of unconsolidated deposits.
- o The upper weathered zone of the Mancos Shale.

TABLE F.4.1 CHENEY RESERVOIR SITE BOREHOLE AND WELL INFORMATION

LOCATION ^a ID	NORTH ^b COORDINATE	EAST ^b COORDINATE	WELL DIAMETER [IN.]	TOTAL DEPTH [FT.]	SURFACE ELEVATION [FTMSL]	TOP OF CASING [FTMSL]	SCREENED INTERVAL		BOREHOLE DEPTH [FTFD]
							BEG DP [FTFD]	LENGTH [FT.]	
501	15241.1	95359.8			5301.80				49.83
502	14281.7	94162.6			5271.70				51.00
503	13348.9	92836.0			5238.40				50.00
504	14140.3	96238.6			5325.80				55.70
505	13132.9	94694.8			5279.30				50.50
506	11834.9	93198.0			5233.10				50.50
507	11902.9	93261.4	2.000	53.40	5235.14	5236.54	32.40	21.0	52.00
508	14169.1	96180.2	2.000	52.60	5324.06	5325.96	32.60	20.0	50.70
509	14336.4	94130.7	4.000	102.50	5271.57	5273.07	82.50	20.0	105.00
701	14463.1	95021.4	2.000	40.00	5293.10	5295.02	28.00	10.0	38.00
702	13412.9	93568.3	2.000	39.50	5252.96	5254.73	27.50	5.0	37.50

^a 501-506 correspond to GCH-1 through GCH-6 in DOE, 1983; 507-509 correspond to GWCH-1 through GWCH-3 in DOE, 1983.

^b Site coordinate system is based on a truncation of modified Colorado coordinate system.



200 0 200 400
SCALE IN FEET

LEGEND	
○	BORING LOCATION
●	BORING/MONITORING WELL LOCATION

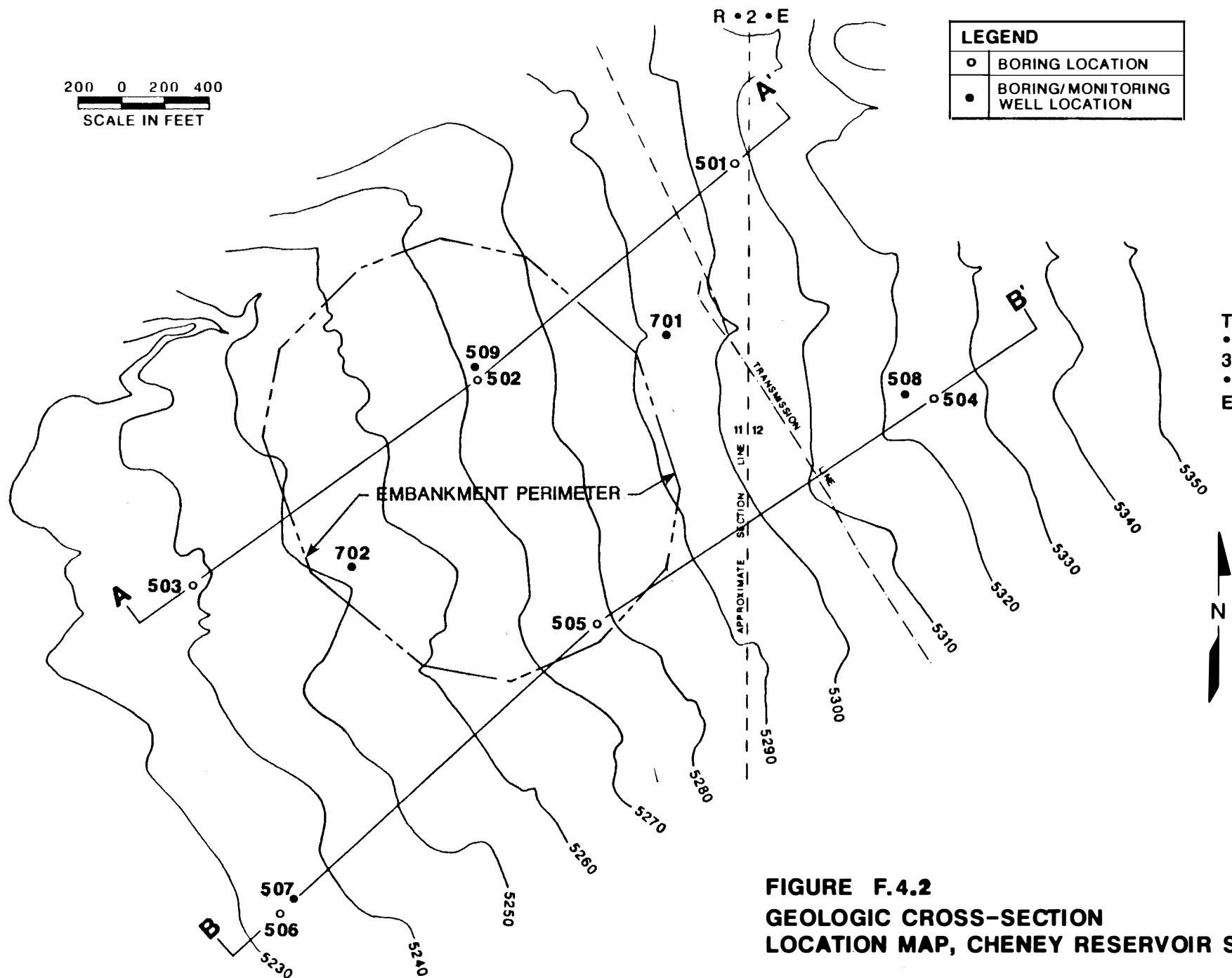
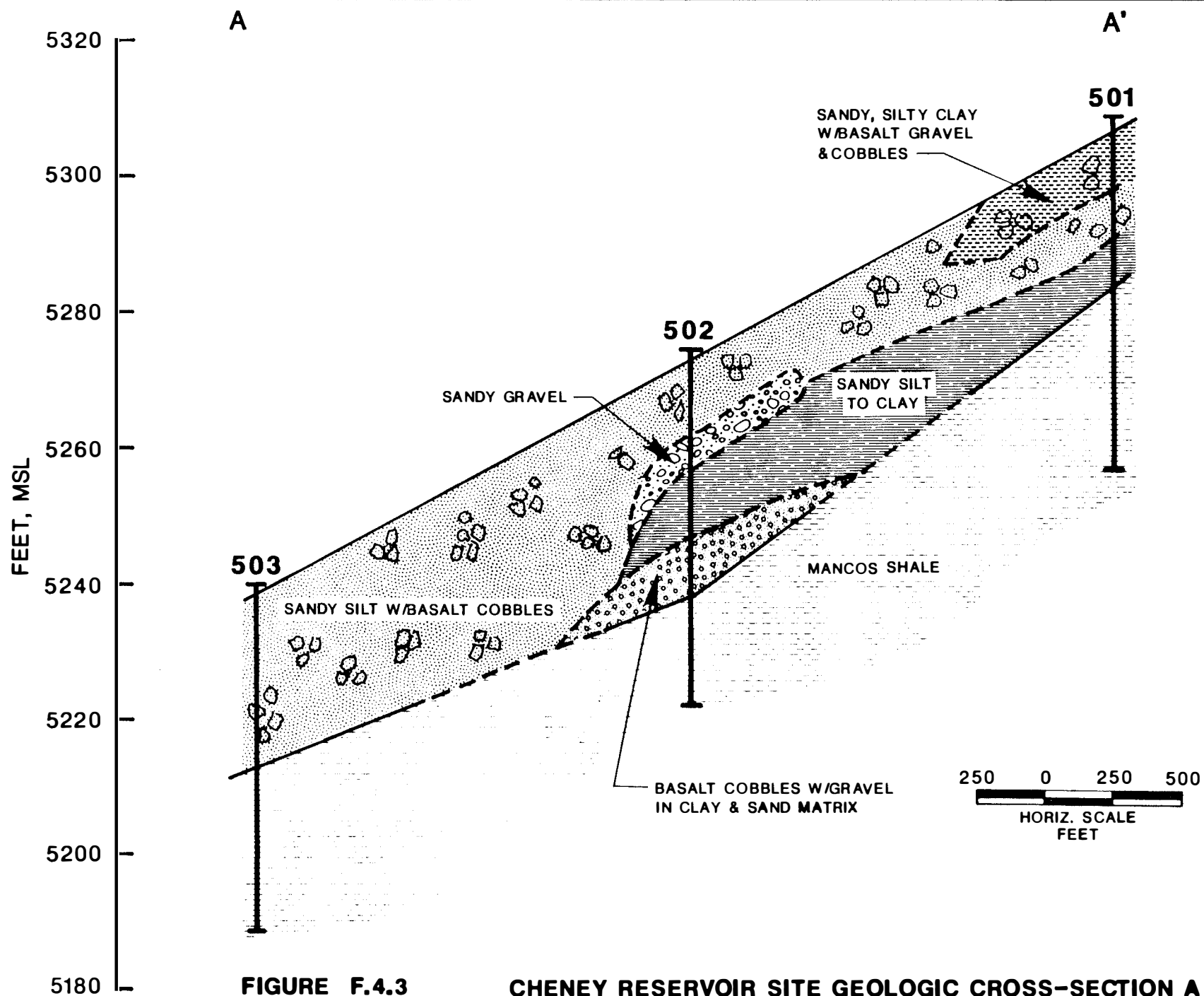


FIGURE F.4.2
GEOLOGIC CROSS-SECTION
LOCATION MAP, CHENEY RESERVOIR SITE



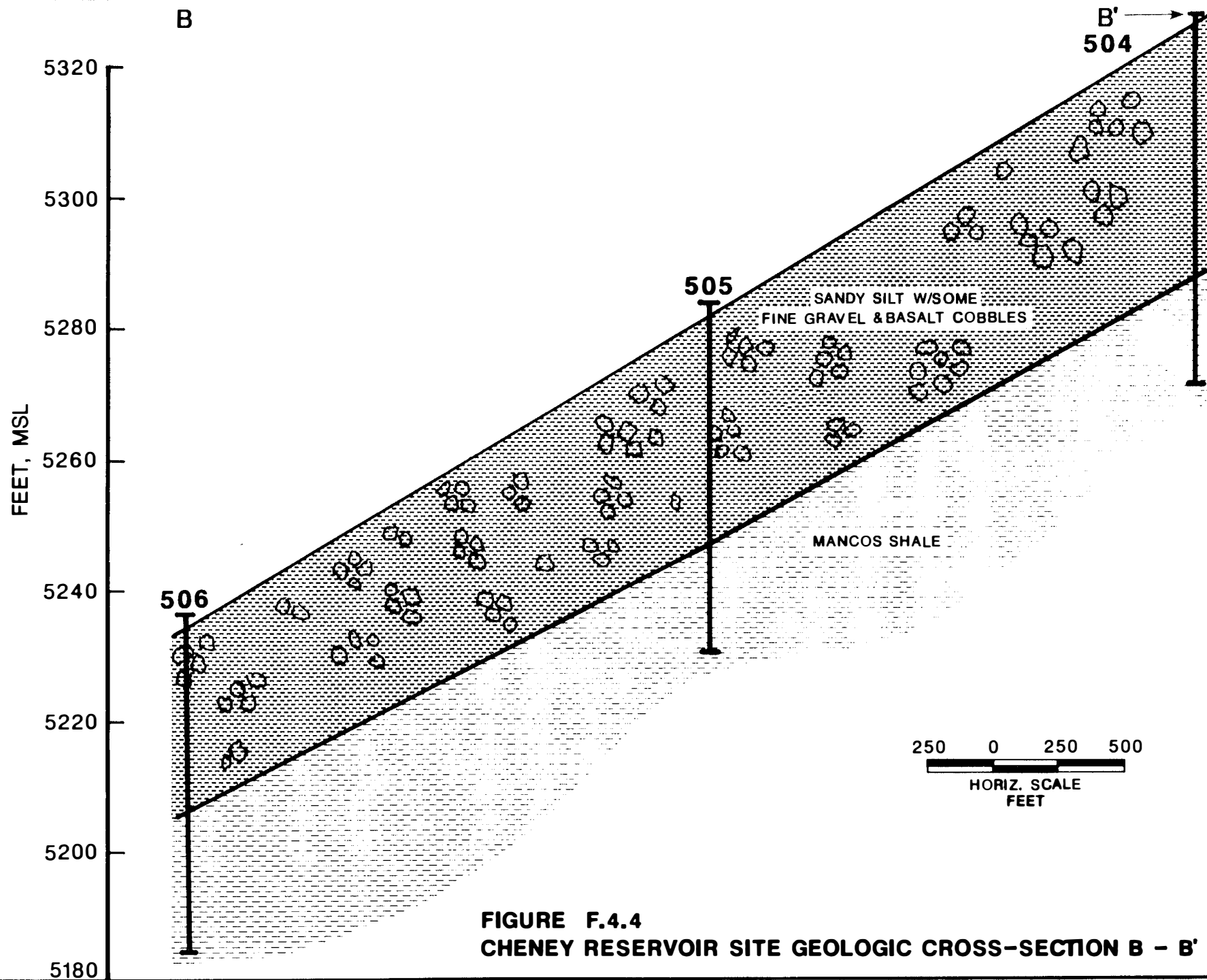


FIGURE F.4.4
CHENEY RESERVOIR SITE GEOLOGIC CROSS-SECTION B - B'

- o The lower, less-weathered portion of the Mancos Shale.
- o The Dakota Sandstone and other formations underlying the Mancos Shale.

Surficial layer. The Cheney Reservoir site is on a pediment surface as can be seen by the uniformly-sloping surface of the Mancos Shale in Figures F.4.3, F.4.4, and F.4.5. The unconsolidated deposits, based on the logs of nine borings, range in thickness from 23.5 to 42.0 feet. A brown to reddish brown eolian silt with some clay and sand and occasional gravel to boulder sized fragments of basalt, varies from zero to two to three feet at the surface. This material is underlain by interlayered clay, silt, sand, and gravel, with occasional layers of cobbles and boulders of basalt. This layer apparently represents mixed alluvial and colluvial deposits, and has been mapped as a pediment gravel (Cole and Sexton, 1981).

Limited data regarding the geochemical characteristics of the surficial layer are available, and are presented in Tables F.4.2 and F.4.3. The occurrence of water in the surficial zone is discussed in Section F.4.1.5.

Weathered Mancos Shale. At other locations, including Shiprock, New Mexico (DOE, 1984), it has been determined that the upper portions of the Mancos Shale will transmit measurable quantities of water. The hydraulic properties of the Mancos Shale would be expected to vary depending on location and stratigraphic position within the shale. At the Cheney Reservoir site data are available regarding the capacity of the local shale to transmit water:

- o None of the 11 borings at the site encountered noticeable amounts of water in the shale at the time of drilling.
- o The two wells completed below the top of the shale (507, 509) have remained dry for over two years.
- o The three wells which have encountered ground water are completed partly in the upper shale and partly in the overburden.
- o In-situ permeability tests (Table F.4.4) indicate that near one of the dry wells (501) there is little difference between the permeability of the shale and the permeability of the overlying unconsolidated deposits. This is also true for one of the wells (508) with measurable ground water.

200 0 200 400
SCALE IN FEET

LEGEND	
5220	ISO-CONTOUR OF MANCOS SHALE SURFACE
5287 + 504	BORING LOCATION WITH SPOT ELEVATION OF MANCOS SHALE SURFACE

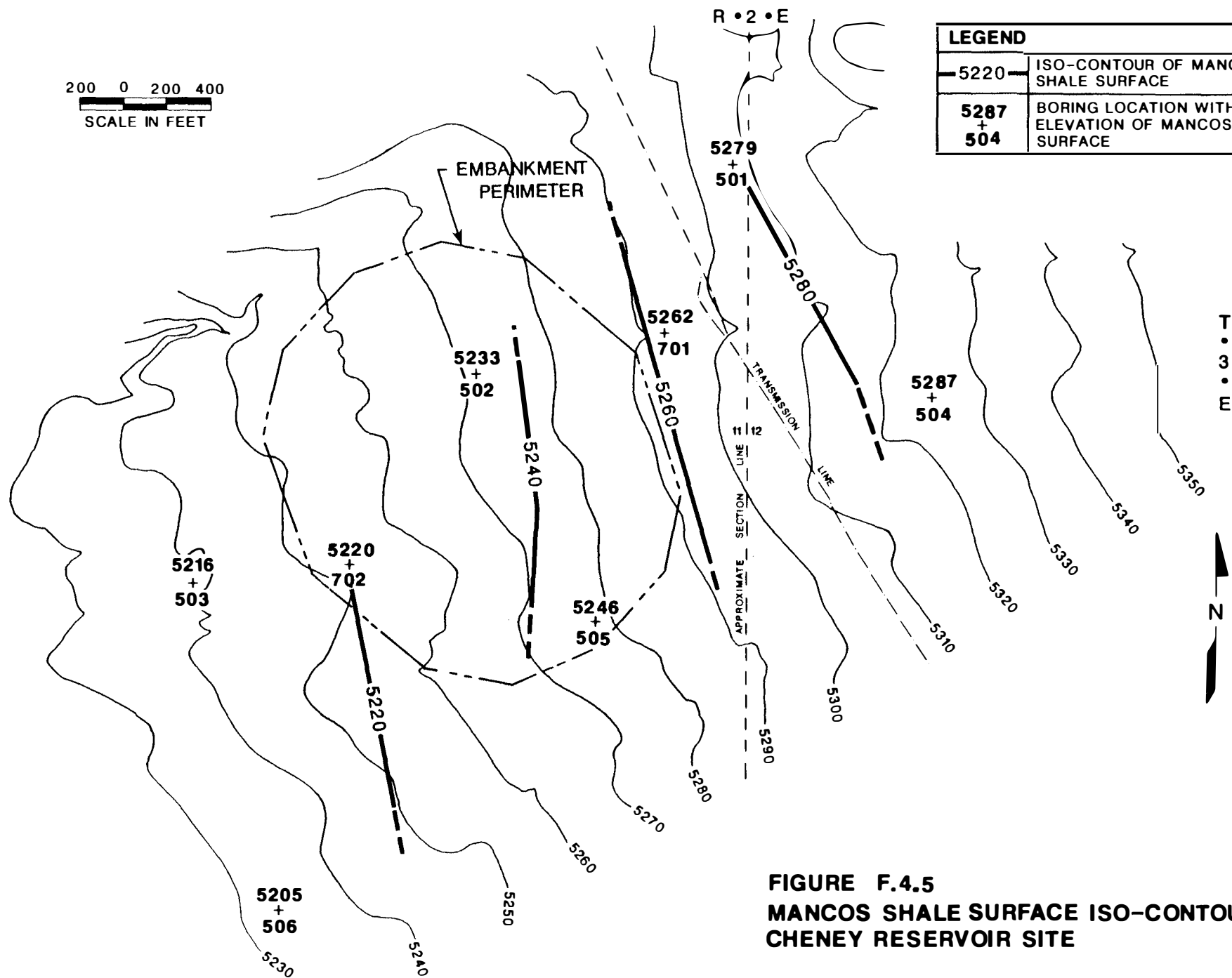


FIGURE F.4.5
MANCOS SHALE SURFACE ISO-CONTOURS,
CHENEY RESERVOIR SITE

Table F.4.2 Cation-exchange capacity results

Parameter	Units ^a
Exchangeable sodium	22.1
Soluble sodium	19.2
Exchangeable potassium	0.28
Soluble potassium	0.04
Exchangeable calcium	91.3
Soluble calcium	5.69
Exchangeable magnesium	4.38
Soluble magnesium	1.22
CEC	20.0
Sulfate	2.21
Carbonate	9.50

^aAll except sulfate and carbonate data expressed in milliequivalents per 100 grams. Values for sulfate and carbonate expressed in weight-percent.

Ref. NUS, 1983.

Table F.4.3 Mineralogy analysis of bulk and clay-size fractions of soils at the Cheney Reservoir site

Phase	Bulk sample
Analcime	1
Ankerite (Fe-dolomite)	1
Apatite	--
Calcite	7
Clays(s) + chlorite	4
Cristobalite	--
Gypsum	11
Hematite	2
K-feldspar	10
Mica-illite	8
Plagioclase-feldspar	8
Pyroxene	4
Quartz	28
Siderite	1
Amorphous	15

Phase	Clay-size-fraction sample ^a
Calcite	1
Chlorite (+kaolinite?)	8
Gypsum	--
K-feldspar	<1
Mica-illite	13
Mixed-layer clays	--
Montmorillonite	75
Plagioclase feldspar	<1
Quartz	2

^a17.8 weight percent less than 2 microns.

Ref. NUS, 1983.

Table F.4.4 In-situ permeability tests at Cheney Reservoir

Location ^a	Depth interval (ft)	Permeability (cm/sec)
501	12-22	4×10^{-6}
	21-31	1×10^{-6}
	31-40	$<1 \times 10^{-7}$
	40-50	$<1 \times 10^{-7}$
502	10-14	2×10^{-4}
	20-31	3×10^{-6}
	36-46	$<1 \times 10^{-7}$
	41-51	$<1 \times 10^{-7}$
503	8-14	5×10^{-5}
	14-28	1×10^{-7}
	30-40	$<1 \times 10^{-7}$
	40-50	1×10^{-6}
504	10-18	3×10^{-5}
	22-34	5×10^{-6}
	35-44	6×10^{-5}
	44-56	$<5 \times 10^{-8}$
505	8-18	1×10^{-5}
	18-28	9×10^{-6}
	23-35	1×10^{-5}
	38-51	1×10^{-7}
506	10-19	6×10^{-5}
	21-29	1×10^{-4}
	29-40	6×10^{-5}
	40-51	to 1×10^{-4} 1×10^{-5} to 5×10^{-5}

^aBoring locations are shown in Figure F.4.1

Ref. NUS, 1983.

These data show that the upper weathered Mancos Shale is not transmitting significant amounts of water; however, there may be zones in the upper weathered Mancos Shale which are transmitting small amounts of water, but these zones are locally perched and laterally discontinuous.

Communication with deep aquifers. The Colorado Geological Survey reports that the site appears to be underlain by about 300 to 700 feet of Mancos Shale (CGS, 1982). The Mancos Shale is more than 400 feet thick beneath the site, as determined from the structural contours of Williams (1964). The Dakota Sandstone would be the uppermost potential aquifer underlying the Mancos Shale.

The Mancos Shale is generally regarded as a low-permeability formation which retards the movement of water (Lohman, 1965; Cooley et al., 1969). Because of the low permeability and thickness of the Mancos Shale, hydraulic communication between geologic units above and below the shale is expected to be minimal.

F.4.1.4 Unsaturated zone hydraulics

The description of unsaturated zone hydraulics at an alternate disposal site can include both vertical and horizontal movement of moisture. The characterization of hydraulic properties of the Grand Junction tailings has been documented elsewhere (see Section F.3.1.4), and includes properties for the in-situ tailings as well as properties for different mixtures and different degrees of compaction (Veyera, 1980).

The flux of moisture away from the site boundaries would be controlled by the properties of the surrounding soil or rock matrix, and by the properties of the engineered cover. Field permeability tests of the matrix determined saturated permeability values ranging from 2×10^{-4} cm/sec to less than 5×10^{-8} cm/sec. These tests are summarized in Table F.4.4. The unsaturated hydraulic conductivity will be less than the saturated permeability.

F.4.1.5 Saturated zone hydraulics

Five monitoring wells were installed at the Cheney Reservoir site. Three of the wells encountered saturated conditions, and all three were completed across the interface between the Mancos Shale and the overlying unconsolidated formation. This indicates the existence of water table conditions in the lower part of the unconsolidated zone or in the upper weathered zone of the Mancos Shale. Figure F.4.6 is a water-level map for May, 1985. Water levels for March, 1985, were all within 0.5 foot of the May water levels. Slug test results for two wells are summarized in Table F.4.5.

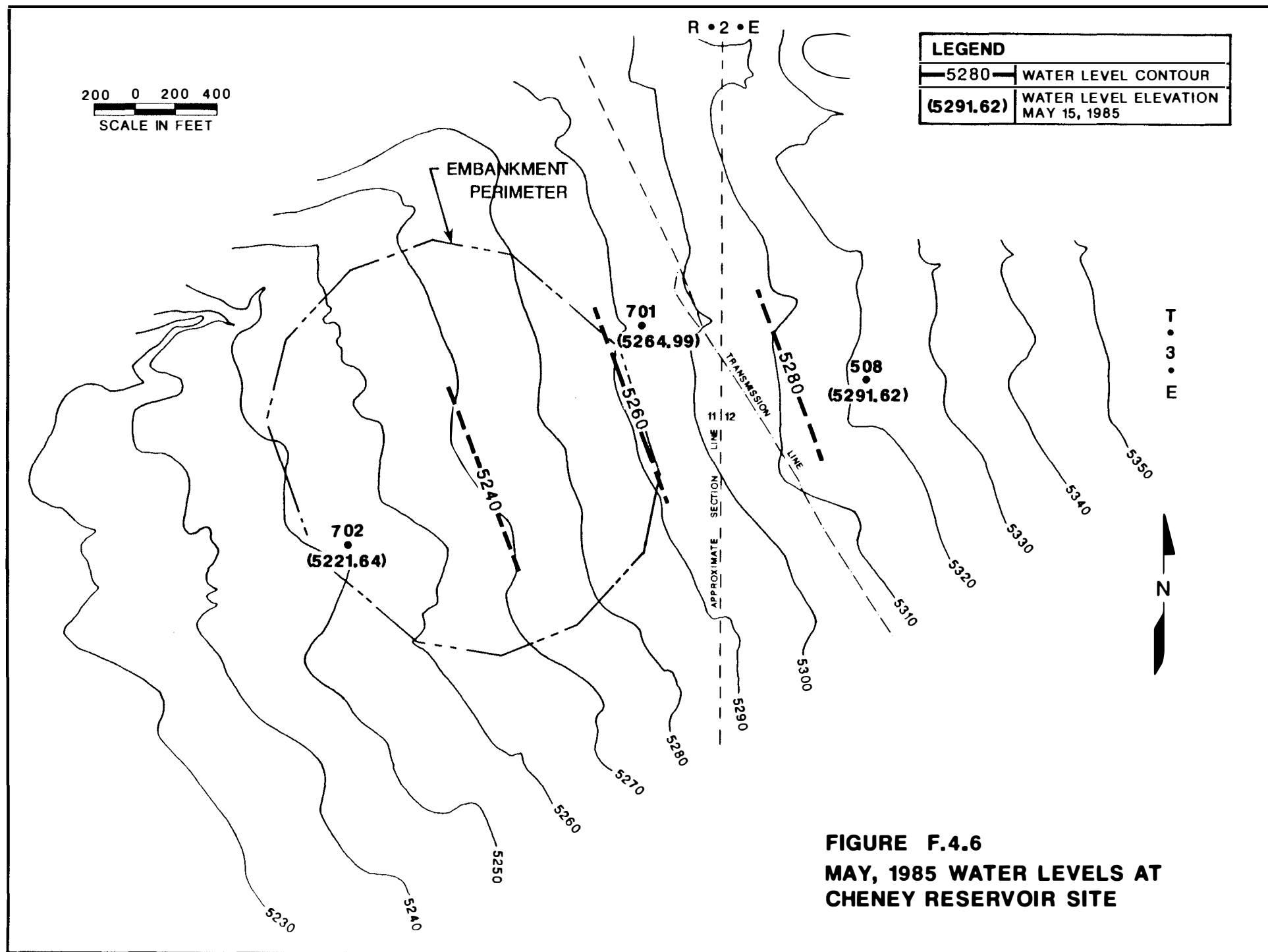


FIGURE F.4.6
MAY, 1985 WATER LEVELS AT
CHENEY RESERVOIR SITE

Table F.4.5 Slug test results for the Cheney Reservoir site

Location	Hydraulic conductivity (cm/sec)
508	4.8×10^{-6}
701	2.1×10^{-5}

Test analyzed with Bouwer-Rice Method (Bouwer, 1978).

Based on Figure F.4.6, the average hydraulic gradient in this shallow system is approximately 0.025. The hydraulic conductivity in the saturated zone is known from in-situ permeability tests (Table F.4.4) and slug tests (Table F.4.5). These data were used to calculate an average linear or Darcian ground-water flux in the shallow system using Darcy's Law:

$$q = K \frac{dh}{dl}$$

where

q = flux (l/t)

K = hydraulic conductivity

dh/dl = hydraulic gradient (dimensionless).

The lowest measured hydraulic conductivity in one of the two slug tests was 5×10^{-6} cm/sec.

For this permeability the flux is:

$$\begin{aligned} q &= (5 \times 10^{-6})(0.025)(3.1536 \times 10^7 \text{ sec/yr}) \\ &= 3.9 \text{ cm/yr} \\ &= 0.13 \text{ ft/yr} \end{aligned}$$

For the higher permeability of 1×10^{-5} cm/sec, which seems to be representative of the saturated zone (Table F.4.4) and is approximately the measured value of the other slug test:

$$\begin{aligned} q &= (1 \times 10^{-5})(0.025)(3.1536 \times 10^7 \text{ sec/yr}) \\ &= 8 \text{ cm/yr} \\ &= 0.26 \text{ ft/yr.} \end{aligned}$$

Using these flux rates, the ground-water discharge can be calculated for a cross-section of the ground-water system, using Darcy's Law. This calculation is based on the assumption of a continuous ground-water system. If the system

is laterally discontinuous the flux would be less than the rate calculated below. Based on the presence or absence of saturated conditions in monitoring wells completed at different depths, the thickness of the system appears to be less than 10 feet. The discharge for a 0.5-mile-wide section of the system is:

$$Q = q \times A$$

where

$$Q = \text{discharge (l}^3/\text{t)}$$

$$A = \text{cross-sectional area (l}^2\text{)}$$

$$\begin{aligned} Q &= (0.13 \text{ to } 0.26 \text{ ft/yr})(10 \text{ feet} \times 2640 \text{ feet}) \\ &= 3432 \text{ to } 6864 \text{ ft}^3/\text{yr.} \end{aligned}$$

The average velocity of the ground water can be calculated if the effective porosity with respect to the medium is known (Bear, 1979). The specific yield is sometimes called effective porosity (Bear, 1979). Specific yield was not measured at the Cheney Reservoir site, but can be assumed based on published values for similar soil types found at the site. Using these assumed values of effective porosity (Todd, 1980), average velocity can be calculated as follows (Bear, 1979):

$$V = Q/n_{ef} A$$

where

$$V = \text{average velocity (l/t)}$$

$$Q = \text{flow rate (l}^3/\text{t)}$$

$$n_{ef} = \text{effective porosity}$$

$$A = \text{cross-sectional area (l}^2\text{)}$$

$$\begin{aligned} V &= (3432 \text{ to } 6864 \text{ ft}^3/\text{yr}) / (0.03 \text{ to } 0.23) \times \\ &\quad (26400 \text{ ft}^2) \\ &= 0.57 \text{ to } 8.67 \text{ ft/yr} \end{aligned}$$

The uncertainty in the assumed range of effective porosity is reflected in the calculated average velocity of the ground water.

Recharge. Recharge of shallow ground water in the vicinity of the Cheney Reservoir site probably comes from several sources including seepage losses from Whiting's Ditch (Figure F.4.7), infiltration of precipitation, and seepage from ephemeral and intermittent streams. Of these sources, seepage from Whiting's Ditch probably predominates for two

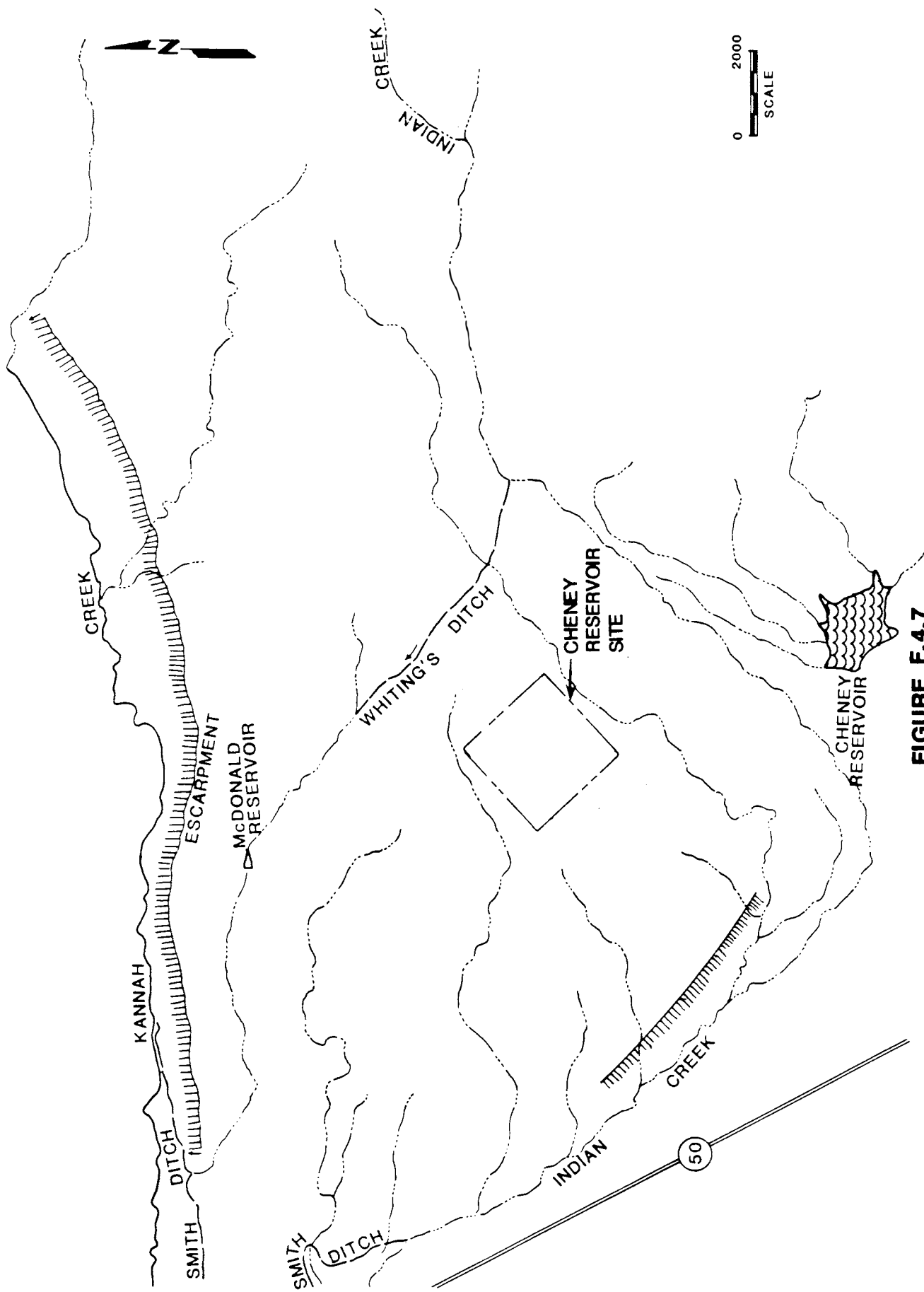


FIGURE F.4.7
HYDROLOGIC SETTING CHENEY RESERVOIR SITE

reasons: it is a constant head source for part of the year, and it is directly uphill from the site area.

Infiltration of precipitation is probably a minor source of recharge. Using the flux values calculated above, an estimate of the bounding maximum value of net infiltration can be made using the hydrologic equation (Chow, 1964):

$$I - O = dS$$

where

dS = change in storage

I = inflow

O = outflow

In a long-term, steady state condition, inflow must equal outflow to satisfy the continuity equation. A maximum value of infiltration results if it is assumed that all inflow is due to infiltration.

To estimate a maximum rate of infiltration, the area over which infiltration occurs must be known or assumed:

- o For discharge through the 0.5-mile-wide cross-section (see above), it is assumed that infiltration occurs over an area 0.5-mile-wide extending one mile uphill of the cross-section.

- o Infiltration over the area is uniform.

These assumptions are reasonable because reconnaissance of the area shows it to be relatively uniform with respect to factors which would influence infiltration including slope, vegetation type and coverage, and surficial geology. The maximum infiltration rate is then:

$$I_{\max} = Q/A_i$$

where

$I_{\max}$ = maximum infiltration rate (l/t)

Q = discharge through cross-section (l^3/t)

A_i = area of infiltration

$$I_{\max} = (3.4 \times 10^3 \text{ to } 6.8 \times 10^3 \text{ ft}^3/\text{yr}) / (2640 \text{ ft} \times 5280 \text{ ft})$$

$$= 2.4 \times 10^{-4} \text{ to } 4.9 \times 10^{-4} \text{ ft/yr}$$

$$= 2.9 \times 10^{-3} \text{ to } 5.9 \times 10^{-3} \text{ in/yr.}$$

Although this value of recharge is very low, it is consistent with the findings of studies elsewhere in the area. For example, at the Two Road site (Section F.5) ground water is not present in the shallow unconsolidated deposits or Mancos Shale, indicating a very low rate of recharge.

If a substantial fraction of the ground-water recharge is derived from seepage from Whiting's Ditch or Indian Creek, the net infiltration of precipitation would be much less than the calculated value.

Discharge. Natural discharge of ground water occurs through three main components (Ward, 1975):

- o Evapotranspiration.
- o Discharge by means of spring flow and seepage into surface water bodies.
- o Leakage into adjacent aquifers.

Leakage from the shallow system into adjacent aquifers is probably negligible (Section F.4.1.3). Discharge by evapotranspiration, spring flow, or seepage into surface water bodies can be expected to occur where the ground surface intersects the water table and where an underlying relatively impermeable layer crops out. West of the site there is a topographic break where the slope increases, and the Mancos Shale crops out in some places in ephemeral drainages. Because this area seems like a favorable place for ground-water discharge to occur a reconnaissance was conducted in May, 1985.

During the reconnaissance a walking tour was made of three areas which could be potential discharge areas: incised drainages above the topographic break, the hillslope along the topographic break, and drainages below the topographic break. No signs of seepage were observed. Some small areas of salt accumulation were seen along Mancos Shale outcrops in the incised drainages; however, there are many such areas of salt accumulation within the Grand Valley (Lohman, 1965). Because there were no observed signs of seepage, no definite conclusion about the area of ground-water discharge can be made. Instead, several potential means of ground-water discharge can be postulated:

- o The ground-water discharge is small and discharge is in the form of diffuse seepage over a relatively large area. This type of discharge occurs in homogeneous geologic materials (Davis and DeWiest, 1966). The discharge is consumed by direct evaporation and transpiration, and there is no evidence of seepage.
- o The ground-water flux moves down the topographic break through the unconsolidated deposits on the hillslope. The unconsolidated deposits are essentially continuous with the Mancos Shale cropping out only in the incised drainages that transect the topographic break. There is no seepage at the topographic break, and the ground water moves through unconsolidated deposits to discharge at the Gunnison River several miles to the west.

- o Near the topographic break the Mancos Shale is closer to the ground surface and the weathered, more permeable, zone of the shale thickens. Ground water moves across the topographic break deep in the shale and eventually discharges at some unknown point.
- o A combination of the three postulated means of discharge occurs.

Whichever of these postulated means of discharge occurs, it can be concluded that discharge either occurs at a point relatively far from the site or discharge is mostly consumed by evapotranspiration.

Yield. The shallow ground-water system appears to have a small potential yield, where potential "safe yield" is defined as the amount of water that can be withdrawn without running out of water (Lohman, 1972). On a quantitative basis, the Thiem equation with Dupuit assumptions can be used to estimate the safe yield of the system (Todd, 1980):

$$Q = (Pi)K \frac{h_o^2 - h_w^2}{\ln(r_o/r_w)}$$

where

Q = discharge (l³/t)

K = hydraulic conductivity(l/t)

h_o = original head (pre-pumping or no drawdown)

h_w = head at well

r_o = radius to point of negligible drawdown

r_w = radius of well

For a two-inch well at the uphill side of the site, assuming negligible drawdown at the recharge source (Whiting's Ditch), an initial saturated thickness of 10 feet, and drawdown of eight feet:

K = 1.4 to 2.8 x 10⁻² ft/day

h_o = 10 feet

h_w = 2 feet

r_o = 2600 feet

r_w = 0.0833 feet

Q = 3 to 6 gallons per day.

However, because the ground-water system is sloping and there is no recharge source on the downhill side of the well, sustained yield of ground water can come only from the uphill semicircle surrounding the well and the potential yield is halved:

$Q = 1.5$ to 3 gallons per day.

The estimated flow through a one-mile wide cross-section in the shallow system is 3432 to 6864 ft³/year (Section F.4.1.5). A well or wells capturing all of this water (an impossibility) would yield only 70 to 141 gallons per day.

F.4.1.6 Water quality

Water-quality analyses for three monitoring wells are presented in Table F.4.6. The water quality at the farthest upgradient well can be described as fresh, and as brackish at the other two wells. The ground water exhibits a definite increase in total dissolved solids in the downgradient direction. This increase can be attributed to contact with the marine origin Mancos Shale. Concentrations of several constituents exceeding National Interim Primary or Secondary Drinking Water Standards include iron, manganese, pH, sulfate, total dissolved solids, and uranium (health advisory level).

Total organic carbon (TOC) exceeded 700 mg/l at the two wells installed in 1985. This may be due to the slow breakdown of biodegradable organic drilling fluid additives, as has been noted by other investigators (Barcelona, 1984; Ericson et al., 1985). The wells were purged after installation and were bailed dry several times prior to sampling. The persistence of high concentrations of TOC may indicate that the system is relatively stagnant with low flow rates.

F.4.1.7 Proximity of site to surface water

The Cheney Reservoir site is approximately 0.8 mile north-northwest of Cheney Reservoir. To the north of the site Kannah Creek and Smith Ditch (an irrigation canal) are approximately one mile from the site.

Several ephemeral drainages of varying size run generally northwest to southeast within one mile of the site. These drainages flow into Indian Creek, an ephemeral drainage approximately 0.1 to 0.5 mile west-southwest of the site. The Colorado Geological Survey (CGS, 1982) noted that an irrigation ditch of unknown nature crosses the upper part of the site which was investigated. The ditch (Whiting's Ditch) is approximately 0.25 mile northeast of the site boundary as it is now designated. The ditch flows into McDonald Reservoir, a stock-watering and irrigation reservoir approximately one mile northwest of the designated site boundary.

TABLE F.4.6 GROUND-WATER QUALITY AT THE CHENEY RESERVOIR SITE

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	508 02/21/83	508 03/27/85	508 06/07/85	701 03/27/85	701 06/07/85
ALKALINITY	MG/L CAC03		280.000	413.000	365.000	581.000	403.000
ALUMINUM	MG/L		-----	< 0.100	< 0.100	< 0.100	< 0.100
AMMONIUM	MG/L		-----	0.680	< 0.100	0.620	0.100
ANTIMONY	MG/L		-----	< 0.003	< 0.003	0.005	< 0.003
ARSENIC	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
BARIUM	MG/L		< 0.020	< 0.100	< 0.100	< 0.100	< 0.100
BORON	MG/L		-----	0.110	0.110	0.290	0.090
CADMIUM	MG/L		0.000	< 0.002	< 0.001	< 0.002	< 0.001
CALCIUM	MG/L		164.000	86.000	116.000	530.000	154.000
CHLORIDE	MG/L		33.000	22.000	210.00	120.000	22.100
CHROMIUM	MG/L		< 0.001	< 0.010	< 0.010	< 0.010	< 0.010
COBALT	MG/L		< 0.001	< 0.010	< 0.050	00.040	< 0.050
CONDUCTANCE	UMHO/CM		1200.000	890.000	1006.000	3100.000	1098.000
COPPER	MG/L		0.001	0.030	< 0.020	< 0.010	< 0.020
CYANIDE	MG/L		-----	< 0.010	< 0.010	< 0.010	< 0.010
FLUORIDE	MG/L		-----	0.500	0.500	0.300	0.500
GROSS ALPHA	PCI/L		-----	25.000	-----	< 40.000	-----
GROSS BETA	PCI/L		-----	< 50.000	-----	60.000	-----
HYD. SULFIDE	MG/L		-----	< 0.200	-----	< 0.200	-----
IRON	MG/L		0.006	0.200	0.340	7.700	0.530
LEAD	MG/L		0.047	< 0.010	< 0.010	< 0.010	< 0.010
MAGNESIUM	MG/L		57.800	44.000	55.200	131.000	56.200
MANGANESE	MG/L		0.340	0.500	0.440	6.600	1.430
MERCURY	MG/L		< 0.000	< 0.000	< 0.000	< 0.000	< 0.000
MOLYBDENUM	MG/L		0.040	< 0.010	< 0.010	< 0.010	< 0.010
NICKEL	MG/L		-----	< 0.040	< 0.040	< 0.040	< 0.040
NITRATE	MG/L		< 0.100	< 1.000	< 1.000	< 1.000	< 1.000
ORG. CARBON	MG/L		80.900	170.200	23.000	775.000	15.000
PB-210	PCI/L		-----	< 10.500	< 10.500	< 10.500	< 10.500
PH	SU		7.000	70.200	7.400	60.200	7.150
PHOSPHATE	MG/L		-----	< 0.100	< 0.100	< 0.100	< 0.100
PO-210	PCI/L		-----	< 1.000	< 1.000	< 1.000	< 1.000
POTASSIUM	MG/L		5.070	3.700	3.830	13.100	4.480
RA-226	PCI/L		< 0.500	< 1.000	< 1.000	< 1.000	< 1.000
RA-228	PCI/L		-----	< 1.000	-----	< 1.000	-----

TABLE F.4.6 GROUND-WATER QUALITY AT THE CHENEY RESERVOIR SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	508 02/21/83	508 03/27/85	508 06/07/85	701 03/27/85	701 06/07/85
SELENIUM	MG/L		0.002	< 0.005	< 0.005	< 0.005	< 0.005
SILCON	MG/L		-----	-----	-----	-----	-----
SILICA	MG/L		-----	18.900	17.200	22.800	18.400
SILVER	MG/L		< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
SODIUM	MG/L		71.100	94.000	79.800	243.000	77.000
STRONTIUM	MG/L		-----	1.000	1.120	4.200	1.160
SULFATE	MG/L		420.000	145.000	256.000	910.000	343.000
SULFIDE	MG/L		-----	-----	0.200	-----	0.200
TEMPERATURE	C - DEGREE		16.000	14.000	16.000	14.000	16.000
TH-230	PCI/L		-----	< 1.000	< 1.000	< 1.000	< 1.000
TIN	MG/L		-----	< 0.005	< 0.005	< 0.005	< 0.005
TOTAL SOLIDS	MG/L		1000.000	656.000	782.000	3746.000	898.000
TOX	MG/L		-----	0.100	0.170	< 0.100	0.460
U-234	PCI/L		-----	-----	1.800	-----	50.300
U-238	PCI/L		-----	-----	1.000	-----	30.500
URANIUM	MG/L		0.024	0.008	-----	0.046	-----
VANADIUM	MG/L		0.015	< 0.010	< 0.010	< 0.010	< 0.010
ZINC	MG/L		0.020	0.100	< 0.005	0.070	< 0.005

TABLE F.4.6 GROUND-WATER QUALITY AT THE CHENEY RESERVOIR SITE (Continued)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	702 ^a 03/27/85	702 ^a 06/07/85	704 ^b 06/07/85
ALKALINITY	MG/L CAC03		270.000	670.000	87.000
ALUMINUM	MG/L		< 0.100	< 0.100	< 0.100
AMMONIUM	MG/L		0.500	0.100	0.200
ANTIMONY	MG/L		< 0.003	< 0.003	< 0.003
ARSENIC	MG/L		< 0.010	0.010	< 0.010
BARIUM	MG/L		< 0.100	< 0.100	< 0.100
BORON	MG/L		0.090	0.230	< 0.010
CADMIUM	MG/L		< 0.002	< 0.001	< 0.001
CALCIUM	MG/L		360.000	215.000	20.400
CHLORIDE	MG/L		250.000	95.900	1.700
CHROMIUM	MG/L		< 0.010	< 0.010	< 0.010
COBALT	MG/L		< 0.010	< 0.050	< 0.050
CONDUCTANCE	UMHO/CM		2800.000	1357.000	202.000
COPPER	MG/L		0.040	< 0.020	< 0.020
CYANIDE	MG/L		< 0.010	< 0.010	< 0.010
FLUORIDE	MG/L		0.400	0.600	0.100
GROSS ALPHA	PCI/L		-----	-----	-----
GROSS BETA	PCI/L		-----	-----	-----
HYD. SULFIDE	MG/L		< 0.200	-----	-----
IRON	MG/L		50.500	0.720	< 0.030
LEAD	MG/L		< 0.010	< 0.010	< 0.010
MAGNESIUM	MG/L		50.000	99.000	9.380
MANGANESE	MG/L		1.700	1.530	< 0.010
MERCURY	MG/L		< 0.000	< 0.000	< 0.000
MOLYBDENUM	MG/L		0.010	< 0.010	0.120
NICKEL	MG/L		< 0.040	< 0.040	< 0.040
NITRATE	MG/L		< 1.000	< 1.000	< 1.000
ORG. CARBON	MG/L		742.000	29.400	8.200
PB-210	PCI/L		-----	< 1.500	< 1.500
PH	SU		6.400	6.800	8.100
PHOSPHATE	MG/L		< 0.100	< 0.100	< 0.100
PO-210	PCI/L		-----	< 1.000	< 1.000
POTASSIUM	MG/L		11.000	7.560	2.330
RA-226	PCI/L		-----	< 1.000	< 1.000
RA-228	PCI/L		-----	-----	-----
SELENIUM	MG/L		< 0.005	< 0.005	0.012
SILICON	MG/L		-----	-----	-----

TABLE F.4.6 GROUND-WATER QUALITY AT THE CHENEY RESERVOIR SITE (Concluded)

CONSTITUENT	UNIT OF MEASURE	LOC: DATE:	702 ^a 03/27/85	702 ^a 06/07/85	704 ^b 06/07/85
SILICA	MG/L		13.000	27.200	7.900
SILVER	MG/L		< 0.010	< 0.010	< 0.010
SODIUM	MG/L		260.000	234.000	6.470
STRONTIUM	MG/L		2.700	2.510	0.080
SULFATE	MG/L		1200.000	304.000	15.300
SULFIDE	MG/L		-----	0.700	< 0.100
TEMPERATURE	C - DEGREE		12.000	17.000	25.000
TH-230	PCI/L		-----	< 1.000	< 1.000
TIN	MG/L		< 0.005	< 0.005	< 0.005
TOTAL SOLIDS	MG/L		-----	1584.000	202.000
TOX	MG/L		-----	0.270	< 0.100
U-234	PCI/L		-----	2.400	< 1.000
U-238	PCI/L		-----	1.500	< 1.000
URANIUM	MG/L		-----	-----	-----
VANADIUM	MG/L		< 0.010	< 0.010	< 0.010
ZINC	MG/L		0.300	< 0.005	< 0.005

^aAnion-cation balance not achieved, probably due to high concentration of TOC.

^bAnalysis is included for qualitative comparison.

^bLocation 704 is Whiting's Ditch (Figure F.4.7).

F.4.2 CLIMATE EFFECTS ON CONTAMINANT MIGRATION

F.4.2.1 Climate

The site is less than 15 miles from the processing site and about 600 feet higher in elevation. Except for local topographic effects, the long-term climate is probably very similar to that at the processing site (Section F.3.3.1).

F.4.2.2 Contaminant migration in the unsaturated zone

The predicted rate of net infiltration through the stabilized tailings is a key indicator of the rate of contaminant migration, because infiltration would generate leachate. Four methods of calculating infiltration rates are described in Section F.3.2.2. These same methods are used to predict infiltration rates through the stabilized tailings at the Cheney Reservoir site. The results are summarized in Tables F.4.7 through F.4.9.

F.4.3 EXISTING USAGE AND VALUE OF WATER RESOURCES

F.4.3.1 Ground water

Usage. There are no registered wells within about two miles of the site, and no shallow wells within about 3.5 miles of the site. Existing usage of ground water in the vicinity of the Cheney Reservoir site is minimal due to three factors. First, the current low population density in the area results in a low demand for water in the area. Second, the limited availability of shallow ground water is shown by the fact that monitoring wells drilled on the site failed to encounter significant quantities of shallow ground water and is supported by estimates of yield (Section F.4.1.5). The Mancos Shale is not considered to be water-bearing in the Grand Junction area (Lohman, 1965). Significant quantities of deeper ground water may be available, but at greater drilling costs. Third, shallow ground water is probably too poor in quality for domestic use, except in localized areas.

A homeowner on Highway 50 approximately 1.5 miles southwest of the site reported that she and her immediate neighbors hauled their water from Grand Junction. A 150-foot test well on her property yielded water that was too saline for use. Where shallow ground water is present in this vicinity, it can be expected to be saline due to contact with the marine-origin Mancos shale; as is the case for shallow ground water in the Grand Valley (Lohman, 1965).

Another homeowner at a location approximately 0.5 mile northwest of the site reported that she and her immediate neighbors also hauled water from a location in the Kannah Creek community.

Table F.4.7 Predicted infiltration rate through the cover at the Cheney Reservoir site

Method ^a	Cover hydraulic conductivity ^b	Duration of flow ^c	Infiltration rate (cm/yr)
1	1×10^{-6}	Constant	3.15×10^1
1	1×10^{-7}	Constant	3.15×10^0
2	1×10^{-6}	246	8.90×10^{-1}
2	1×10^{-7}	246	8.90×10^{-2}
3			Table F.4.8
4			7.4×10^{-3} to 1.5×10^{-2}

^aMethod 1 is constant Darcy flow under unit hydraulic gradient;
Method 2 is constant Darcy flow during rainfall events > 0.1 inch;
Method 3 is wetting front advance during rainfall events > 0.1 inch;
Method 4 is water balance (Section F.4.1.5).

^bIn cm/sec. Hydraulic conductivity of cover would be specified in engineering design.

^cIn hours per year.

Table F.4.8 Calculated infiltration rates using equation
for wetting front advance

t, sec	k (cm/sec)	hc (cm)	Sc (%) ^a	dw	Infiltration		
					Event (cm)	Annual events	I (cm)
21,600	1×10^{-6}	15700	7	0.55	3.8×10^{-2}	41	1.6×10^0
21,600	1×10^{-6}	5235	4.3	0.89	3.8×10^{-2}	41	1.6×10^0
21,600	1×10^{-6}	1047	2.1	1.80	3.8×10^{-2}	41	1.6×10^0
21,600	1×10^{-7}	15700	7	0.055	3.8×10^{-3}	41	1.6×10^{-1}
21,600	1×10^{-7}	5235	4.3	0.089	3.8×10^{-3}	41	1.6×10^{-1}
21,600	1×10^{-7}	1047	2.1	0.18	3.8×10^{-3}	41	1.6×10^{-1}

^aFrom Table F.4.9.

Table F.4.9 Capillary moisture retention for Cheney Reservoir
cover source

Capillary pressure (Bar)	Water retention, %
0.1	--
0.3	24.47
0.5	23.74
0.7	--
1.0	22.38
3.0	21.02
5.0	20.19
7.0	19.55
10.0	18.24
15.0	17.59

Note: Above tests performed using both ASTM D3152 and D2325 test methods.

Value. Because there is no existing usage of shallow or deep ground water within the potentially affected hydrogeologic environment, ground water has no existing present value and only a very low future value (Section F.4.5).

F.4.3.2 Surface water

Usage. Perennial streams with headwaters in Grand Mesa, east of the site, include Kannah Creek and Indian Creek. Kannah Creek is utilized for irrigation along some of its length; however, residents along Kannah Creek obtain potable water for domestic use from a city of Grand Junction water supply line which runs along the Creek.

Indian Creek is tapped by an unlined ditch which diverts flow to McDonald Reservoir (Figure F.4.7). According to the operator of the ditch, the diversion is used for stock-watering and for irrigating pasture near McDonald Reservoir.

Value. The value of surface water in the vicinity of the site can be evaluated by two means. One is to determine the cost of alternative water supplies in the area. A rate schedule for water supplied by the city of Grand Junction to bulk water users in the Whitewater area is shown in Table F.4.10. Another alternative source of water is delivery from commercial suppliers based in Grand Junction, who report charges of \$16 to \$25 per 1100 gallons for delivered water in the Whitewater and Kannah Creek area. These charges can vary significantly depending on the exact location of the delivery and the total quantity of water to be delivered. These charges reflect a much higher value than would be attached with the probably poor quality water underlying the site.

Table F.4.10 Rate schedule for bulk water users
near Whitewater

Quantity per month (gallons)	Charge
First 3,000	\$9.40 (minimum)
Next 7,000	\$1.40/1000 gal
Next 10,000	\$1.70/1000 gal
More than 20,000	\$2.10/1000 gal

Ref. City of Grand Junction, 1985.

F.4.4 ALTERNATE WATER SUPPLIES

Stabilization of the tailings at the Cheney Reservoir site would not affect any currently used water resources, and use of the potentially affected ground water would be unlikely (Section F.4.5). Should the potentially affected ground water be considered for use, several alternate sources of water are available.

Water supplies in the immediate vicinity of the Cheney Reservoir site could be obtained from several sources. Homeowners in the area already haul water or obtain it from a City of Grand Junction water line running along Kannah Creek. Surface water could be obtained from perennial streams such as Kannah Creek and Indian Creek if appropriate water rights were obtained. Deep ground water may be available but its potential is unknown.

F.4.5 FUTURE USAGE AND VALUE OF WATER RESOURCES

F.4.5.1 Ground water

Usage. In February, 1985, a homeowner at a location approximately 0.5 mile northwest of the site reported that she had plans to drill a well to a depth of less than 1000 feet. Attempts to utilize deep ground-water resources in the area within several miles of the site may be anticipated. The controlling factors would be the extent to which the population increases, the extent to which other water resources and their distribution systems are developed, and the success of attempts to find usable deep ground water.

Some zones of fresh or potable shallow ground water can be found near creeks and ditches in the area, where the surface water represents a source of recharge. The extent of these zones is probably limited to an area very near the recharge source. The areal extent of these potable zones is limited by the small amount of recharge and the tendency of the underlying Mancos Shale to degrade water quality. The potential sustained yield of the zones is also small (Section F.4.1.5). The potential for development of shallow ground water is minimal.

Value. The difficulty of establishing the future value of water resources is discussed in Section F.3.6.1. The value of shallow ground water in the vicinity of the site would be limited by the low potential yield (Section F.4.1.5) of the system. On a qualitative basis, it can be concluded that the resource value of shallow ground water is low.

F.4.5.2 Surface water

Usage. The nearest potentially developable sources of surface water are Indian Creek and a diversion ditch which carries water from Indian Creek. In years of higher flow in Indian Creek these both could be used to develop greater use of surface water in the vicinity of the site. The degree of development would probably be governed by land use restrictions on the Federal land, by economic factors on nearby private land, and by the availability of additional water rights.

Value. The difficulty of establishing the future value of water resources is discussed in Section F.3.6.1. In the vicinity of the Cheney Reservoir site water is used for various agricultural purposes. The value of water in the area would probably parallel the value of agricultural products. Alternatively, population growth in the area could increase demand for a domestic water supply. On a qualitative or relative basis, it can be concluded that the value of surface water resources in the area is moderate to high.

F.4.6 IMPACTS IN AFFECTED HYDROGEOLOGIC ENVIRONMENT

The impacts in the potentially affected hydrogeologic setting at the Cheney Reservoir site are discussed below.

F.4.6.1 Human health risks

There is no known existing use of shallow ground water in the potentially affected hydrogeologic environment, and future use of shallow ground water is expected to be minimal. Because the probability of human ingestion of potentially affected ground water would be minimal, the probability of human health risks would be minimal.

F.4.6.2 Damage to crops and vegetation

There is no known existing use of shallow ground water by crops and vegetation in the potentially affected hydrogeologic environment, and future use of shallow ground water is expected to be minimal. Because the probability of water use by crops and vegetation would be minimal, the probability of damage to crops and vegetation would be minimal.

F.4.6.3 Damage to wildlife

There is no known existing use of shallow ground water by wildlife, and no known location where wildlife could potentially ingest it. It can be concluded that damage to wildlife due to ingestion of ground water would be minimal.

F.4.6.4 Persistence and permanence of adverse effects

Adverse effects due to ingestion of ground water by humans, crops and vegetation, and wildlife are discussed above. It is concluded that the probability of ingestion of potentially affected ground water would be minimal. Therefore it can be concluded that adverse effects due to ingestion of ground water would be neither persistent nor permanent.

F.5 POTENTIALLY AFFECTED HYDROGEOLOGIC ENVIRONMENT-TWO ROAD SITE

F.5.1 CHARACTERIZATION OF HYDROGEOLOGIC ENVIRONMENT

F.5.1.1 Previous investigations

The Two Road area has previously been the subject of two investigations which included characterization of the hydrogeologic regime. The Colorado Geological Survey (CGS, 1982) did a reconnaissance level study of the location's potential use as a mill tailings disposal site. The Bureau of Reclamation has studied a larger area which includes the proposed tailings disposal area (URS, 1983). The latter investigation was part of the Colorado River Water Quality Improvement Program: the Two Road area is a proposed location for evaporation ponds. The latter investigation included 23 borings and the installation of 22 wells.

F.5.1.2 Recent investigations

The field program has involved exploratory drilling, soil testing, monitoring well installation, and water sampling. The program was begun with drilling in March, 1985. Previous investigations by the U.S. Bureau of Reclamation for a separate project (Section F.5.1.1) included two exploratory borings, field and laboratory testing, and the installation of two monitoring wells within the designated site boundary.

In the March, 1985, field program, 16 exploratory borings were drilled on a four-by-four grid pattern. Monitoring wells were installed in five of the borings. Soil samples were collected from the borings for stratigraphic logging and for laboratory testing. Well construction details are presented in Table F.5.1.

All field and laboratory work was performed in accordance with standard operating procedures. These standard operating procedures are on file with the U.S. DOE UMTRA Project Office in Albuquerque, New Mexico.

F.5.1.3 Stratigraphy

The stratigraphy at the site has been defined by 18 borings. Geologic cross-sections are presented in Figures F.5.1 through F.5.4. On a hydrogeologic basis the stratigraphy can be divided into three zones:

- o A surficial layer of unconsolidated deposits.
- o Mancos Shale.

TABLE F.5.1 TWO ROAD SITE BOREHOLE AND WELL INFORMATION.

LOCATION ID ^a	NORTH ^b COORDINATE	EAST ^b COORDINATE	WELL DIAMETER (IN.)	TOTAL DEPTH (FT.)	SURFACE ELEVATION (FTMSL)	TOP OF CASING (FTMSL)	SCREENED INTERVAL		BOREHOLE DEPTH (FTFD)
							BEG DP (FTFD)	LENGTH (FT.)	
501	48501.0	19098.6	2.000	56.00	4943.00		51.00	5.0	56.00
502	48476.0	21762.7	2.000	41.00	4918.00		36.00	5.0	41.00
701	49506.5	19243.6	2.000	36.90	4959.42	4961.66	29.90	5.0	35.00
702	49609.9	19826.2			4959.14				20.00
703	49614.0	20354.3			4959.29				30.50
704	49619.1	20832.1	2.000	25.20	4954.52	4956.84	18.20	5.0	23.00
705	48786.9	20834.3			4948.67				28.00
706	48777.1	20338.9	2.000	34.80	4951.42	4935.13	27.80	5.0	33.00
707	48772.4	19800.2			4949.97				25.60
708	48764.2	19247.5			4954.53				30.50
709	48053.9	19253.5			4944.75				27.00
710	48041.7	19782.0	2.000	37.80	4943.13	4945.45	30.80	5.0	36.00
711	48030.5	20326.8			4943.11				27.00
712	48016.8	20791.5			4943.42				26.00
713	47298.7	20763.0	2.000	33.00	4933.59	4936.02	26.00	5.0	31.00
714	47303.8	20318.3			4936.71				39.00
715	47308.8	19753.7	2.000	29.40	4933.35	4935.67	22.40	5.0	27.40
716	47314.7	19255.8			4937.30				18.00

^a 501 and 502 are U.S. Bureau of Reclamation borings and monitor wells C-1 and C-2 in URS(1983).

^b Site coordinate system is based on a truncation of modified Colorado coordinate system.

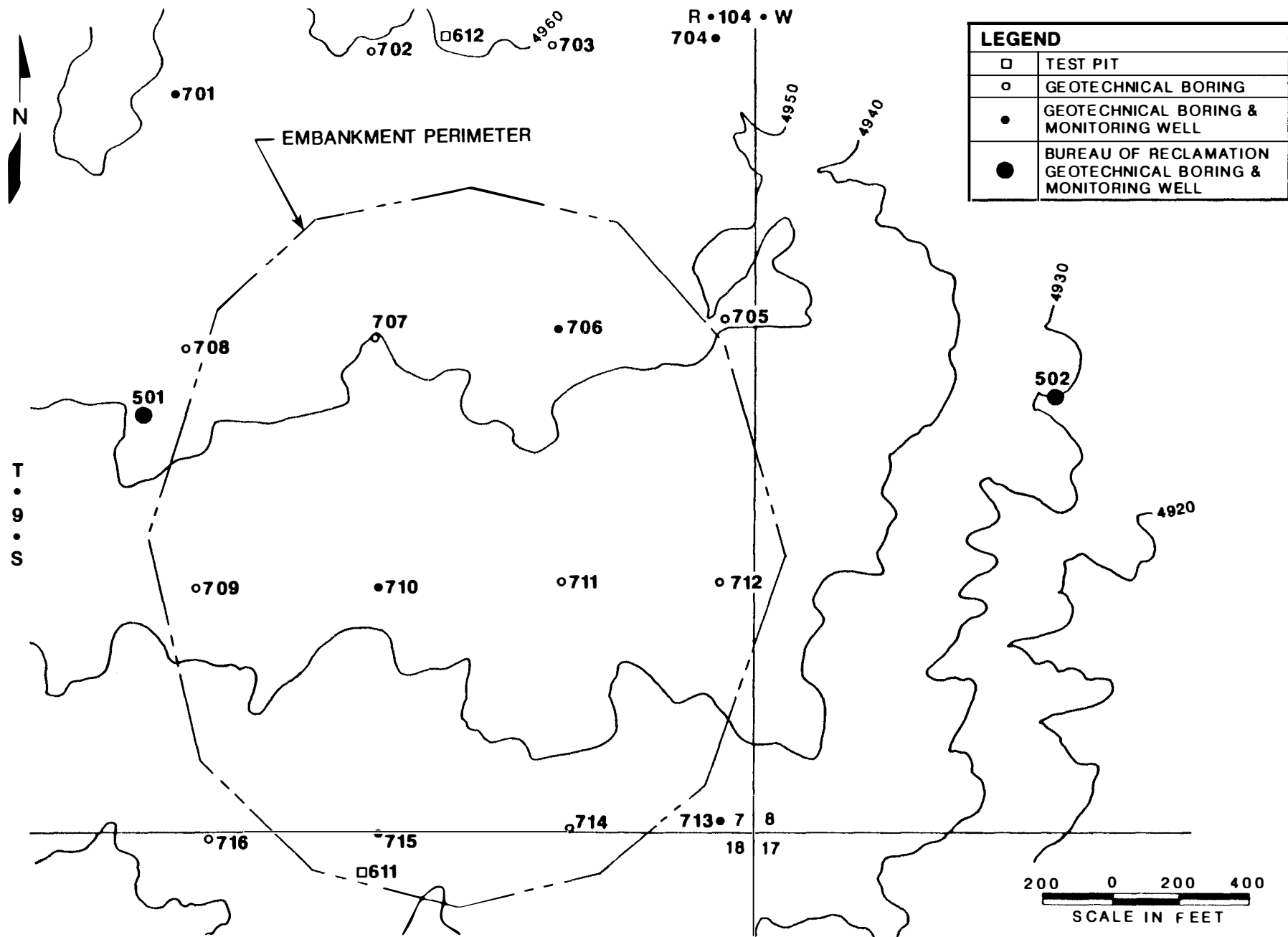


FIGURE F.5.1

LOCATION OF BORING/MONITORING WELLS, TWO ROAD SITE

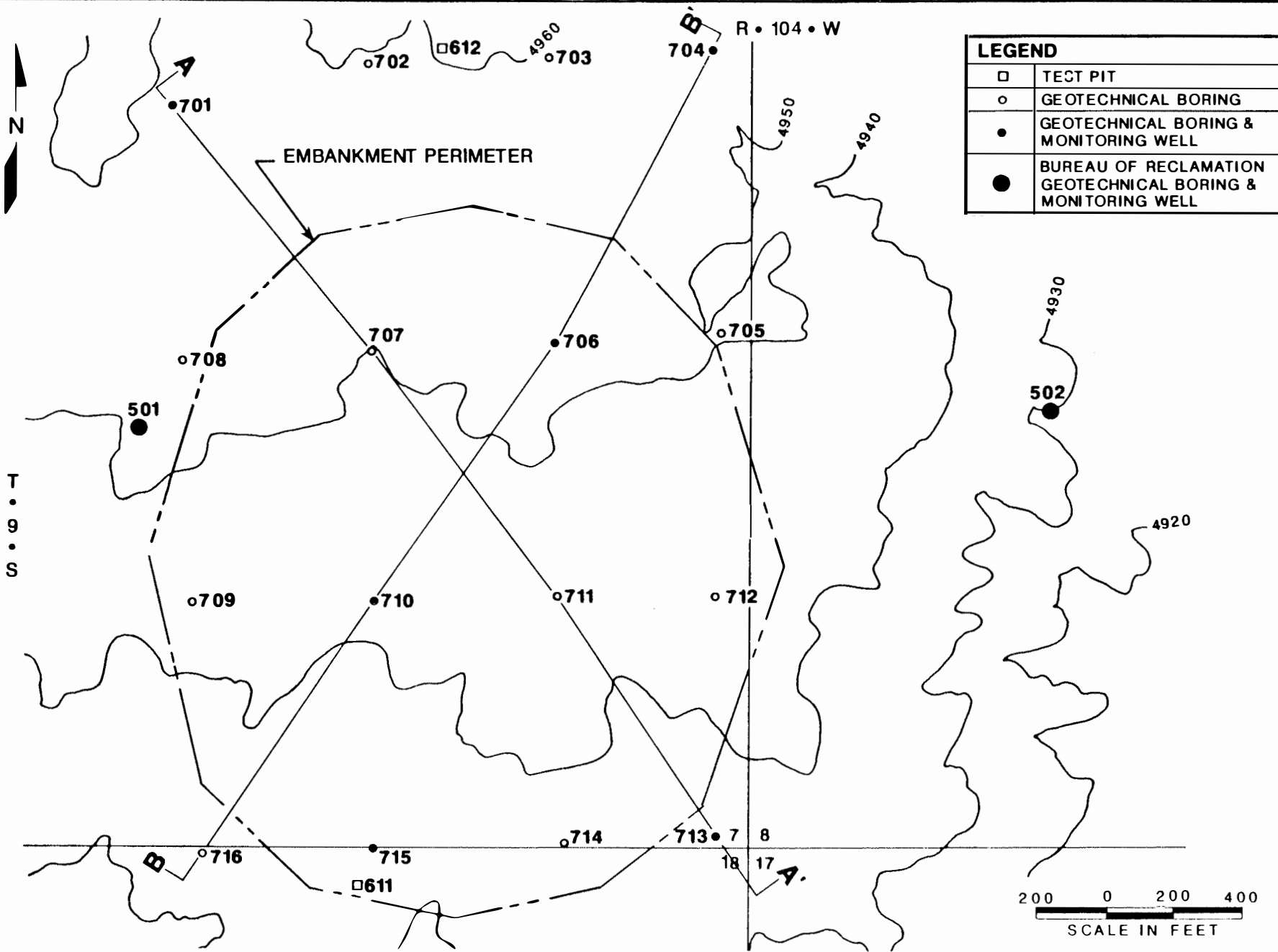


FIGURE F.5.2

GEOLOGIC CROSS-SECTION LOCATION MAP, TWO ROAD SITE

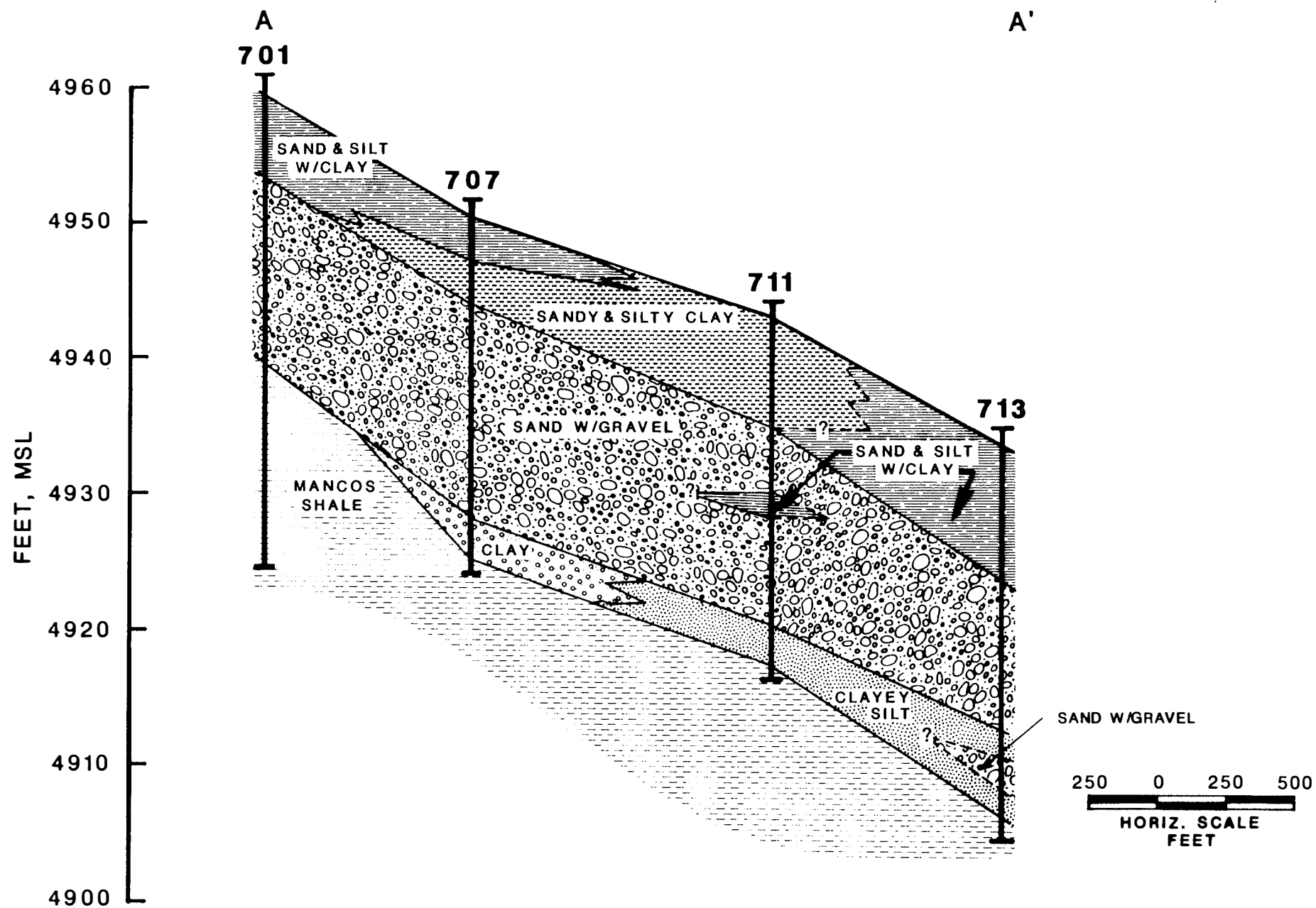


FIGURE F.5.3

TWO ROAD SITE GEOLOGIC CROSS-SECTION A - A'

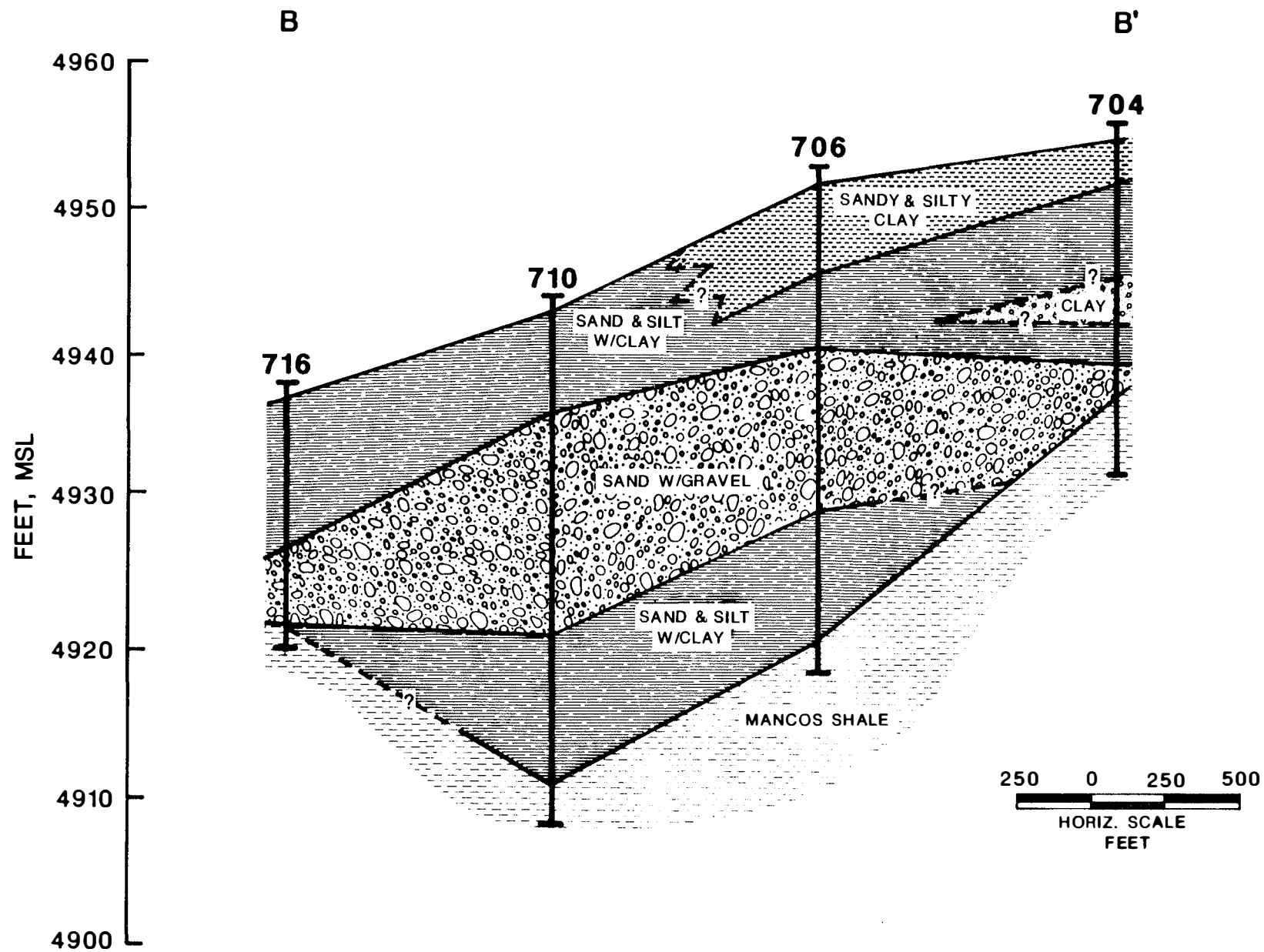


FIGURE F.5.4 TWO ROAD SITE GEOLOGIC CROSS-SECTION B - B'

- o The Dakota Sandstone and other formations underlying the Mancos Shale.

Surficial layer. The site is on a pediment surface formed by erosion of the Mancos Shale. The dominant surficial materials present in the site area are residual soils formed by weathering of the Mancos, pediment gravels, and eolian deposits. Ground water was not encountered in the surficial deposits. Intermittent ground water has been reported in one well adjacent to a stock pond (U.S. Bureau of Reclamation, 1978).

Communication with deep aquifers. The Colorado Geological Survey reports that the site is underlain by approximately 500 to 1100 feet of Mancos Shale (CGS, 1982). The log of an oil well drilled less than 0.5 mile from the designated site boundary reported the top of the Dakota Sandstone at 748 feet below land surface. The Dakota Sandstone would be the uppermost potential aquifer underlying the Mancos Shale. Mancos Shale is generally acknowledged to be a low-permeability formation on a regional basis, as reported by various authors (Lohman, 1965; Cooley et al., 1969). Because of the low permeability and thickness of the Mancos Shale, hydraulic communication between geologic units above and below the shale is expected to be minimal.

F.5.1.4 Unsaturated zone hydraulics

The description of unsaturated zone hydraulics at an alternate disposal site can include both vertical and horizontal movement of moisture. The vertical movement of moisture is controlled to a large extent by the properties of the mill tailings and the engineered cover. The characterization of hydraulic properties of the Grand Junction tailings has been documented elsewhere, and includes properties for the in-situ tailings as well as properties of different mixtures and different degrees of compaction (Veyera, 1980).

The horizontal flux of moisture away from the site boundaries is partially controlled by the properties of the surrounding soil or rock matrix. Field permeability tests of the matrix have been reported for two boreholes within the site boundaries (URS, 1983), ranging from 1.29×10^{-4} cm/sec to 1.4×10^{-3} cm/sec. These tests are summarized in Table F.5.2. The unsaturated hydraulic conductivity will be less than the saturated permeability.

F.5.1.5 Saturated zone hydraulics

All of the monitoring wells installed during March, 1985, were dry in April or May, 1985. Two Bureau of Reclamation wells which are within the proposed site were dry in May, 1985. These wells had been installed more than two years

Table F.5.2 In-situ permeability tests at Two Road

Location ^a	Depth interval (ft)	Type of test	Permeability (cm/sec)
501 ^b	0-1	bucket	1.4×10^{-3}
	4-7.5	shallow well	4.2×10^{-4}
	8.5-12.7	shallow well	1.4×10^{-3}
	16-20	shallow well	7.8×10^{-4}
	31.4-40.9	packer	1.6×10^{-4}
	40.5-50.1	packer	1.3×10^{-4}
	51-56	packer	2.1×10^{-4}
502 ^c	11-21	packer	2.1×10^{-4}
	21-31	packer	1.8×10^{-4}
	31-41	packer	1.5×10^{-4}

^aBoring locations are shown in Figure F.5.1.

^bURS boring C-1.

^cURS boring C-2.

Ref. URS, 1983.

before. It may be concluded that there is no existing shallow zone of saturation. In-situ permeability tests are described in Section F.5.1.4. If significant quantities of water were to move as saturated flow at the Two Road site, the results of the permeability tests are probably indicative of the hydraulic properties of potential zones of saturation.

F.5.1.6 Water quality

Because of the absence of a saturated shallow ground-water system in the vicinity of the site (Section F.5.1.5), there are no data regarding shallow ground-water quality. There may be ground water in the ephemeral washes on either side of the site. The quality of alluvial ground water is described by comments made about an old well located on a wash, about four miles southwest of the site (State of Utah, 1938).

"This water is used as a supplemental supply of water for stock... during the winter season only; it is not fit for domestic use at any season of the year, and in the summer the mineral content is too high."

F.5.1.7 Proximity of site to surface water

The Two Road site is located in an area of ephemeral drainages. Two ephemeral drainages bound either side of the pediment surface on which the site lies, and are within 0.1 mile of the proposed site boundary. Both of these unnamed washes are tributary to Bitter Creek, an ephemeral wash to the southwest of the site. The hydrologic setting of the site is presented in Figure F.5.5.

F.5.2 CLIMATIC EFFECTS ON CONTAMINANT MIGRATION

F.5.2.1 Climate

Some short-term site-specific climatic data are available from the U.S. Bureau of Reclamation's study of the Two Road site. The site is less than 20 miles from the processing site and is about 100 feet higher in elevation. Except for local topographic effects, the long-term climate is probably very similar to that at the processing site (Section F.3.3.1).

F.5.2.2 Contaminant migration in the unsaturated zone

Ground water was not encountered in wells at the Two Road site. This indicates that infiltration rates are too low to maintain a shallow zone of saturation, and are consistent with the results of water balance calculations of recharge for the Cheney Reservoir site (Section F.4.2.2). Other qualitative indications of low recharge rates in the area are available.

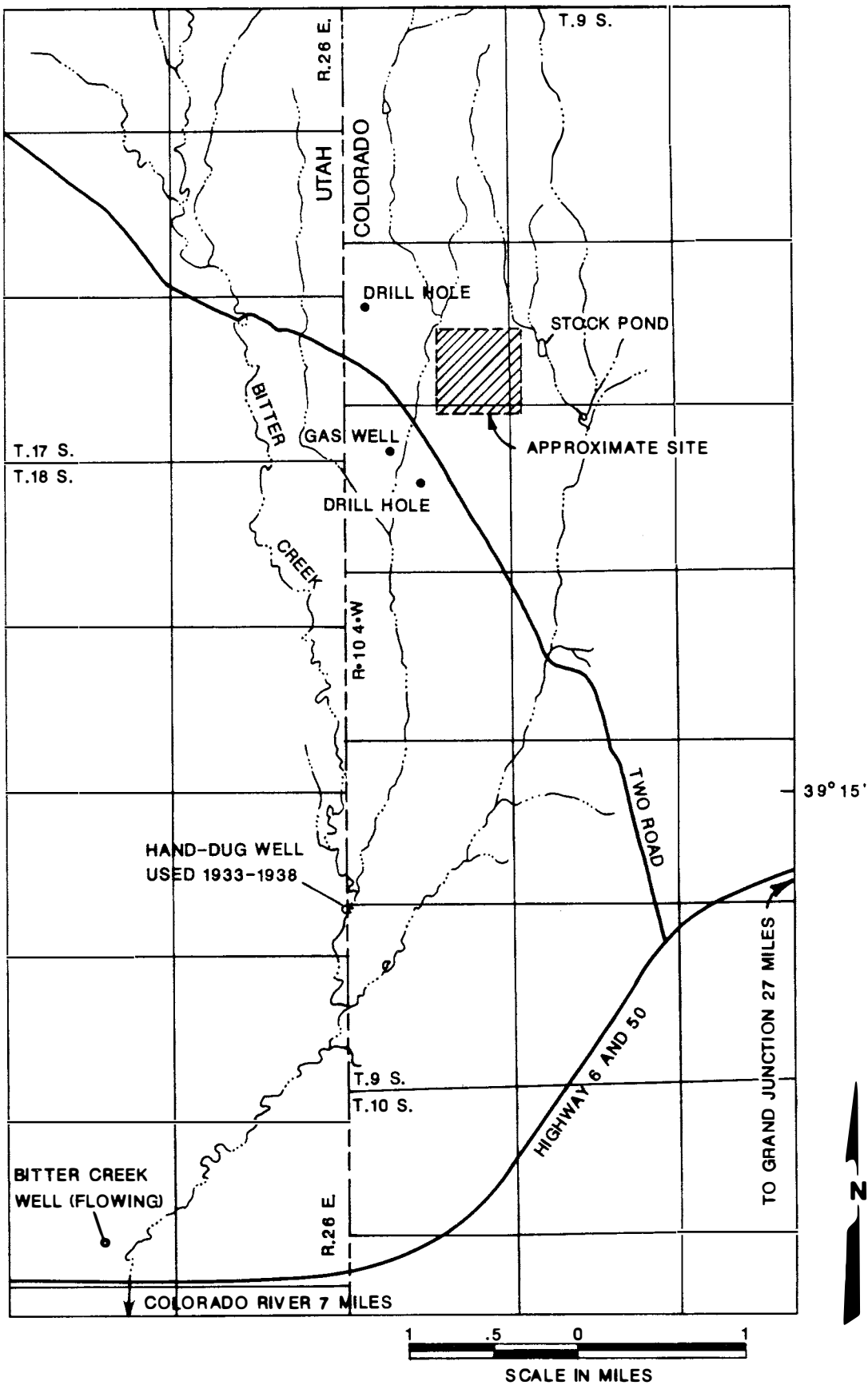


FIGURE F.5.5
HYDROLOGIC SETTING TWO ROAD SITE

An investigation of ambient soil moisture content in the Grand Junction area found relatively low values (Rogers et al., 1981). The study was done specifically to investigate expected long-term moisture contents in materials likely to be used for covers on stabilized mill tailings. Soil samples from the site were collected during a U.S. Bureau of Reclamation study (URS, 1983). These samples showed very low moisture contents, in the range of two to six percent.

The transition from saturation to partial saturation (i.e. decreasing soil moisture content) entails a steep drop in hydraulic conductivity (Hillel, 1971). Using Darcy's law modified for unsaturated flow (Hillel, 1971), it can be shown that under a unit hydraulic gradient the flux rate is exactly equal to the unsaturated hydraulic conductivity. Thus a low ambient soil moisture content is indicative of a low flux rate and a low rate of recharge.

The site conceptual design for stabilization of the tailings involves placement of the tailings at low moisture contents. Further drainage beyond that which has already occurred at the processing site would be relatively small.

The construction of a compacted low-permeability cover would minimize infiltration. If infiltration rates were approximately equal to those in the existing uncompacted soils, it would be expected that relatively little migration of contamination would occur.

Impact assessment. The distance from the proposed location of the stabilized tailings to surrounding drainages is relatively short, less than 0.1 mile. These drainages are topographic lows and represent potential outlets for contaminants. Although the development of the conceptual model for potential contaminant migration did not include site-specific analytical or numerical calculations, a qualitative assessment of potential impacts can be made:

- o Existing and expected usages and values of water resources in the area are low (Sections F.5.3 and F.5.5).
- o Because there is no existing ground-water system at the site, potential seepage could build up in the upper Mancos Shale and overburden before flowing away from the site. Contaminant migration away from the site would be delayed while moisture deficits are replenished.
- o Existing water quality in the adjacent drainages is brackish. If seepage were to reach the alluvium the affected water would already be of poor quality.

- o Vegetated slopes are found on each side of the site. If low rates of seepage reached these areas, the water would potentially be consumed by evaporation or transpiration.

F.5.3 EXISTING USAGE AND VALUE OF WATER RESOURCES

F.5.3.1 Ground water

Usage. Review of records of the Colorado Division of Water Resources shows that there is no existing usage of shallow or deeper ground water in the vicinity of the site. There are no registered wells in the township surrounding the site. There are monitoring wells adjacent to the site which were installed by the U.S. Bureau of Reclamation's Colorado River Water Quality Control Program.

Review of records of the State of Colorado has shown that there are no existing water rights in the township immediately to the west of the site (T17S, R26E). There are two wells in T18S, R26E which is to the southwest of the site (Figure F.5.5). One is a hand-dug well 11 feet deep in Section 16, approximately four miles from the site. The other is the U.S. Bureau of Reclamation's Bitter Creek Well in Section 30, approximately six miles from the site.

Value. Because there is no existing usage of ground water in the vicinity of the site, it has no existing present value and only potential future value (Section F.5.5.1).

F.5.3.2 Surface water

Usage. Surface water in the vicinity of the site is used for stock watering and for casual use by wildlife.

Value. The estimated value of stock-watering supplies can vary extensively. In years in which livestock production produces minimal profits or even losses for the producer, the value of such supplies is relatively very small. An upper bound on the value of such supplies is probably the cost of providing alternative water supplies. In the area of the proposed site this is less than \$20 per thousand gallons for hauled water. Water of lesser quality than fresh hauled water would have a lesser value.

F.5.4 ALTERNATIVE WATER SUPPLIES

There is no existing shallow ground water below the Two Road site, and it is not expected that water resources near the site would be affected by stabilization of the tailings at the site. In the event that water resources were affected, it would be possible for future water users to obtain water supplies from other sources; including deep wells into artesian aquifers or by hauling water.

F.5.5 FUTURE USAGE AND VALUE OF WATER RESOURCES

F.5.5.1 Ground water

Usage. In the immediate vicinity of the site, test borings have shown that there is no continuous shallow ground-water system. Because of the limited amount and poor quality of shallow ground water, the potential use is minimal.

Value. Shallow ground water is not present in sufficient quantity to have any but a minimal future value.

F.5.5.2 Surface water

Usage. Because of the low precipitation and high evapotranspiration in the area, the potential surface-water development in the area is probably small. Usage in the area would probably continue to be limited to stock watering and casual use by wildlife.

Value. The difficulty of establishing the future value of water resources is discussed in Section F.3.6.1. In the vicinity of the Two Road site the value of water would probably parallel the value of livestock products. On a qualitative or relative basis, it can be concluded that the value of water resources in the vicinity of the site would remain low.

F.5.6 IMPACTS IN AFFECTED HYDROGEOLOGIC ENVIRONMENT

There is no existing shallow ground water at the Two Road site. Potential impacts on humans, crops and vegetation, and wildlife are discussed only in order to meet EPA standards.

F.5.6.1 Human health risks

There is no existing use of shallow ground water at the site and future use is expected to be minimal. It can be concluded that human health risks due to ingestion of shallow ground water would be minimal.

F.5.6.2 Damage to crops and vegetation

There is no existing shallow ground water at the site. It can be concluded that damage to crops and vegetation due to uptake of shallow ground water would be minimal.

F.5.6.3 Damage to wildlife

There is no existing shallow ground water at the site, and therefore no potential way for wildlife to uptake ground

water. It can be concluded that damage to wildlife due to uptake of potentially affected ground water would be minimal.

F.5.6.4 Persistence and permanence of adverse effects

Adverse effects due to ingestion of ground water by humans, crops and vegetation, and wildlife are discussed above. Because of the absence of shallow ground water, it is concluded that persistent or permanent adverse effects associated with the ingestion of ground water would be minimal.

F.6 CONCLUSIONS - GROUND WATER

The ground-water systems of the Grand Junction tailings and potential alternate disposal sites have been studied taking into account factors indicated by EPA standards (40 CFR Part 192). Based on these studies and factors, significant conclusions have been reached with respect to the effects or potential effects of the tailings on the hydrogeologic regime:

Grand Junction existing environment

- o Ground water near the processing site is strongly influenced by the adjacent Colorado River.
- o Vertical hydraulic gradients are very close to zero. Measured gradients have indicated both upward and downward flow. There is some uncertainty about the vertical gradient due to the hydraulic characteristics of the Mancos Shale (low permeability, slow recovery after development, and sampling).
- o Background water quality in the alluvium very near the Colorado River can vary seasonally from fresh to brackish. Away from the river it varies from brackish to salty.
- o Water quality in the Mancos Shale and Dakota Sandstone also ranges from brackish to salty. The Dakota Sandstone, the uppermost potential bedrock aquifer, has low potential use near the site.
- o The Grand Junction tailings are set within a complicated hydrogeologic area. Factors such as the presence of contaminant sources other than mill tailings complicate the characterization of the site.
- o The tailings contribute contamination in the form of ammonium and uranium to the alluvial ground water.
- o There is evidence of contamination in the Mancos Shale including a plume of arsenic and sporadically distributed, elevated concentrations of aluminum, ammonium, selenium, vanadium, and zinc. There is no evidence of radionuclide migration into the bedrock.
- o Radionuclides other than uranium and radium are not contaminating the ground water. Radium-226 does not appear to be migrating away from the ground water directly below the tailings. Polonium-210 and thorium-230 were not detected in any wells. Lead-210 was detected at approximately equal levels in one background well and one well completed below the tailings.
- o There is no evidence of contamination in the Dakota Sandstone, the uppermost potential bedrock aquifer.
- o Although the tailings have caused changes in the quality of alluvial ground water, there are no known existing effects on humans due to the absence of existing use.

- o The tailings have not caused a measurable degradation in the quality of the Colorado River water; however, some degradation can be calculated. For increases in salinity only, the estimated annual loss of \$23,760 due to the tailings is relatively small when compared to the estimated annual loss of \$23 million caused by irrigation within the Grand Valley.

Aquifer restoration

- o Aquifer restoration has been evaluated for the affected ground water and rejected based on relevant considerations in EPA requirements (40 CFR Part 192). Limited measures may be needed to ensure that there is no use of water from a possibly contaminated industrial drainage well.

Stabilization on the site

- o A mixing cell model predicts the persistence of elevated concentrations of uranium in ground water. The magnitude of concentrations depends on input values for ground-water flux and ambient (background) uranium concentration; but may be 13 to 243 pCi/l ten years after remedial action, 8.8 to 253 pCi/l at 25 years after remedial action, and stabilized at 8.8 to 235 pCi/l at 50 years after remedial action. Predicted long-term concentrations are lower for a low-permeability cover than for a higher-permeability cover over the tailings.
- o Based on conditions in the existing environment, non-radioactive contaminants are expected to be flushed from the ground water relatively rapidly.

Relocation of the tailings

- o Relocation of the tailings to an alternate site would leave residual contamination in the ground water. Based on a mixing cell model, uranium may persist at levels exceeding background concentrations for up to 100 years. Contaminants other than uranium would be flushed relatively rapidly.
- o Sporadic contamination would persist in the Mancos Shale at the Grand Junction site. The same hydrogeologic conditions which cause this persistence make the use of this ground water unlikely.
- o Use of the affected ground water in the near future is unlikely.

Cheney Reservoir site

- o There is a shallow ground-water system perched on the Mancos Shale. This system is probably less than 10 feet in thickness.
- o The shallow ground water moves through low-permeability deposits, at an average velocity of approximately 0.57 to 8.67 feet per year.

- o The quality of the water ranges from fresh to brackish. The representativeness of some water-quality analyses is questioned because the residual presence of biodegradable drilling fluid is suspected. The residual presence of drilling fluid after repeated purges of the wells would indicate a very low permeability system.
- o Infiltration rates calculated using a water balance are very low, less than 1.5×10^{-2} centimeters per year. Other calculated infiltration rates indicate that a low permeability cover over the tailings would permit little net infiltration of moisture.
- o The potential yield of the ground-water system is low, 1.5 to 3.0 gallons per day. Expected use of this ground water would be minimal.

Two Road site

- o Ground water was not encountered at the site. Current and potential use of ground water would be minimal because there is none.
- o Seepage from stabilized tailings would be low due to low infiltration and drainage. There is no on-site ground water which would be impacted.

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APPENDIX G
FLOODPLAIN AND WETLANDS ASSESSMENT

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G.1 PROJECT DESCRIPTION

Materials contaminated by uranium mill tailings from the inactive processing site at Grand Junction, Colorado, are present in the floodplain of the Colorado River and in the wetlands within the floodplain. There are no floodplains or wetlands associated with the Cheney Reservoir or the Two Road sites.

The primary feature of the remedial action is the consolidation and stabilization of tailings and other contaminated soils either at the processing site or at an alternate disposal site.

Remedial action would require the following major construction activities regardless of which alternative is selected:

- o Removal of approximately 40 acres of vegetation on the 100-year floodplain prior to excavation of an estimated 126,000 cubic yards of contaminated soils (estimated average depth of excavation is six inches).
- o Grading and revegetating the floodplain where excavated, including adding any necessary soil conditioners.
- o Upon completion of the remedial action, radioactive contamination in the floodplain would be reduced to levels that comply with the EPA standards for inactive uranium processing sites (40 CFR Part 192). These areas would then be released for any use consistent with local land use controls.

G.2 FLOODPLAIN EFFECTS

Alteration of the floodplain during and after remedial action is of concern due to the potential for changes in river elevations during flood events and the resulting impacts to nearby properties and structures. These impacts are discussed in this assessment.

Other temporary impacts, such as increased sedimentation and erosion, alteration of habitat, and water-quality changes, are of additional concern. After remedial action, long-term impacts on ground-water quality and flow and surface-water quality would result from the removal of contaminated materials present in the floodplain. Temporary and long-term impacts are discussed in Sections 5.5 and 5.6 of this DEIS. Mitigation measures for these short- and long-term impacts are discussed in Sections 5.20 and G.2.2.

Effects of flooding resulting from changes in flood elevations during construction and after completion of the remedial action were calculated. Results of these analyses are summarized in Sections G.2.1 through G.2.3. Additional discussion can be found in Appendix F, Hydrology Report.

G.2.1 FLOOD ANALYSIS

During a 100-year flood event, the flow of the Colorado River at the Grand Junction site would be 61,600 cfs. The maximum water surface elevation at the site would be 4575.1 feet at the tailings pile with a mean velocity of 8.4 fps. Figure G.2.1 is a map of the 100-year floodplain at the Grand Junction site. The base of the tailings would be under approximately six feet of water. Existing erosion at the southeast corner of the pile would be accelerated during a major flood.

The 500-year flood flow would be 84,200 cfs with the water surface elevation ranging from 4574 to 4578 along the tailings pile. The base of the tailings pile would be approximately nine feet under water. Mean velocities would range between six and 12 fps. Figure G.2.2 is a map of the 500-year floodplain boundary.

The PMF, as described in Section 4.6.1, for the Colorado River at the tailings pile would be approximately 889,000 cfs and would be approximately 36 feet above baseline.

G.2.2 FLOOD CONDITIONS DURING REMEDIAL ACTION

During remedial action, aside from the tailings, approximately 40 acres (126,000 cubic yards) of contaminated soils would be removed from the Colorado River floodplain, slightly deepening the flood channel. The changes in the flood level and velocities attributable to the increased area would be undetectable from current flood levels and velocities.

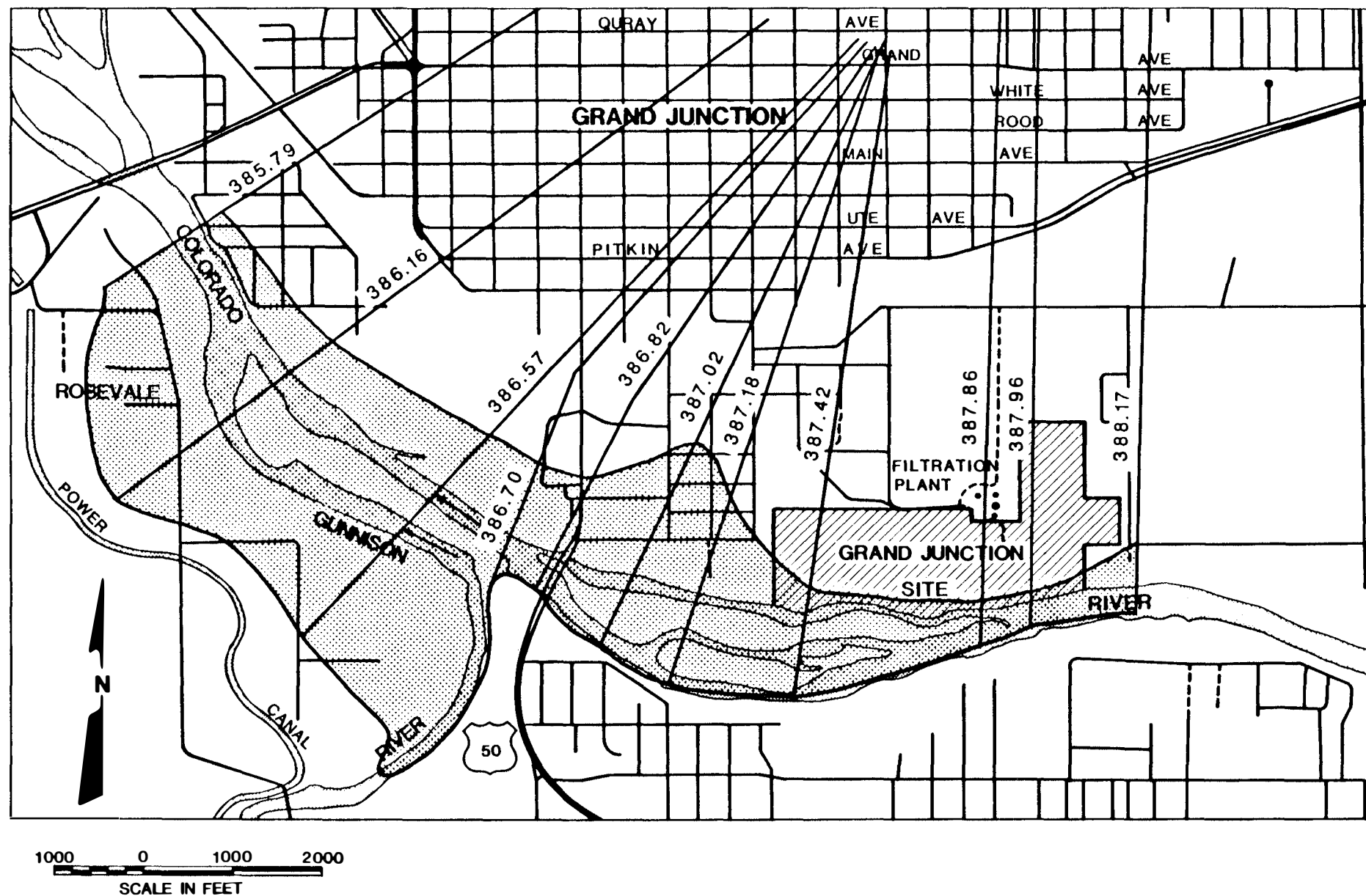


FIGURE G.2.1
LOCATION OF CROSS SECTIONS & FLOODPLAIN BOUNDARIES
OF THE 100-YEAR FLOOD EVENT

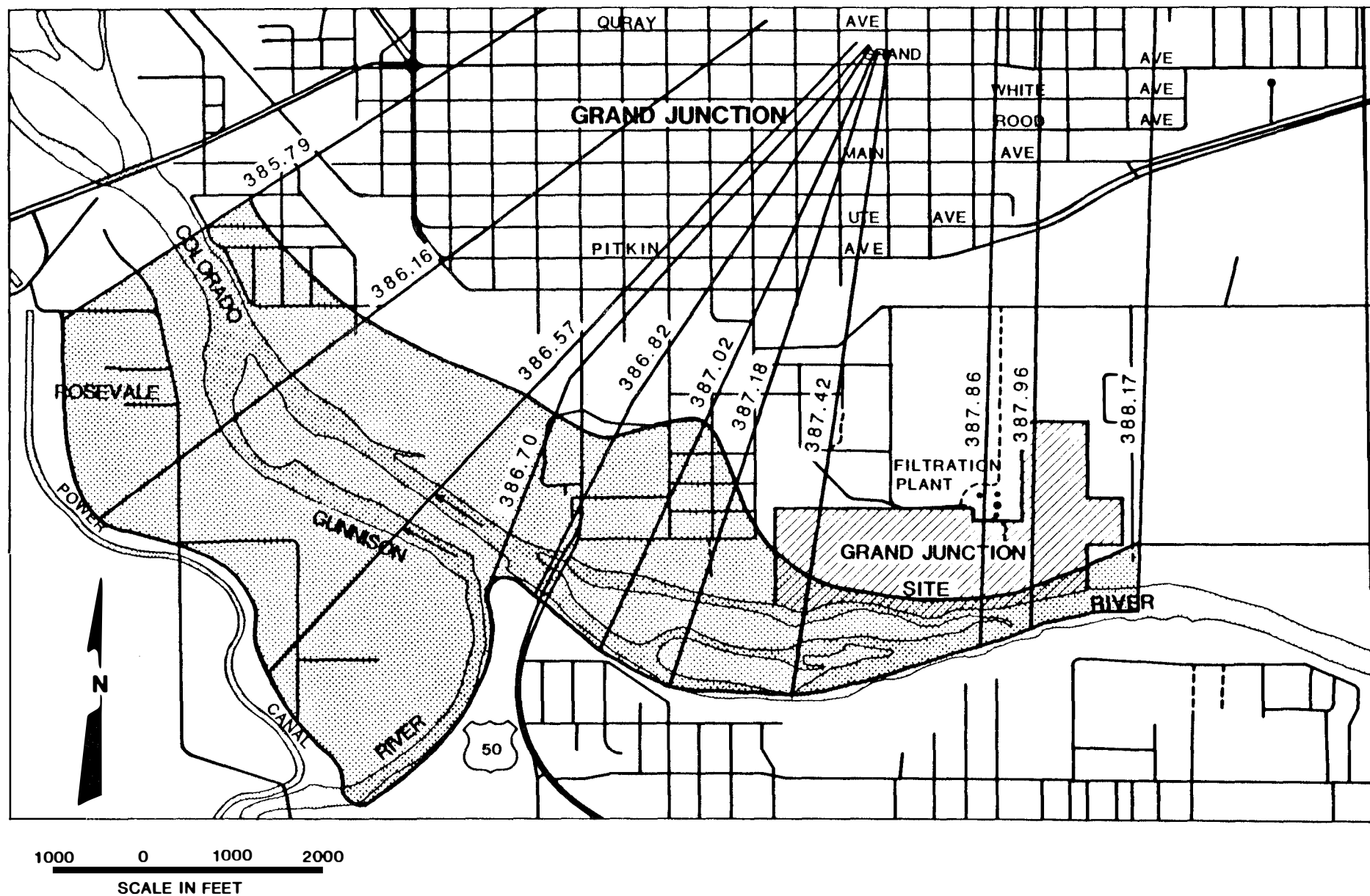


FIGURE G.2.2
LOCATION OF CROSS SECTIONS & FLOODPLAIN BOUNDARIES
OF THE 500-YEAR FLOOD EVENT

Potential impacts would be mitigated by use of the following measures during remedial action:

- o Excavation of contaminated materials in the floodplain during the seasonal dry period, when runoff is lowest.
- o Restrictions on removal of riparian vegetation adjacent to areas subject to excavation to reduce river velocities and associated erosion during flood events.
- o Initiation of revegetation efforts as soon as practicable after removal of contaminated materials.
- o Selective use of water bars, mulch, riprap, or other soil erosion controls to minimize erosion.

G.2.3 FLOOD CONDITIONS FOLLOWING REMEDIAL ACTION

Following remedial action, if the tailings are stabilized on the site, the pile would be stabilized above the 100-year floodplain. The configuration of the excavated areas within and adjacent to the river would be the same as during the remedial action until the vegetation of the floodplain is reestablished. During a 100-year or 500-year flood event, impacts to nearby property and structures would be similar to flood impacts before remedial action. The reestablishment of a vegetative cover would tend to stabilize the floodplain and minimize the impacts during floodflows. Excavated areas of the floodplain would be reclaimed by contouring the area, adding any necessary soil conditioners, and revegetating the area with native riparian plants.

If the tailings are removed from the Grand Junction site, the 100-year flood flow boundaries would change slightly from existing conditions. Figure G.2.3 shows the 100-year flood boundary without the tailings present. The elevation of the flood would be slightly higher (0.1 foot), and the mean channel velocity would be slightly higher (0.1 fps) than the conditions predicted for the 100-year flood with the tailings in place. Figure G.2.4 shows the 500-year flood boundary without the tailings present. The maximum water surface elevation during a 500-year flood event would be 4577.1 feet at the tailings pile, while the mean channel velocity would be 9.6 fps. These elevations and velocities for the 500-year event are slightly less than would occur if the tailings pile were left in place.

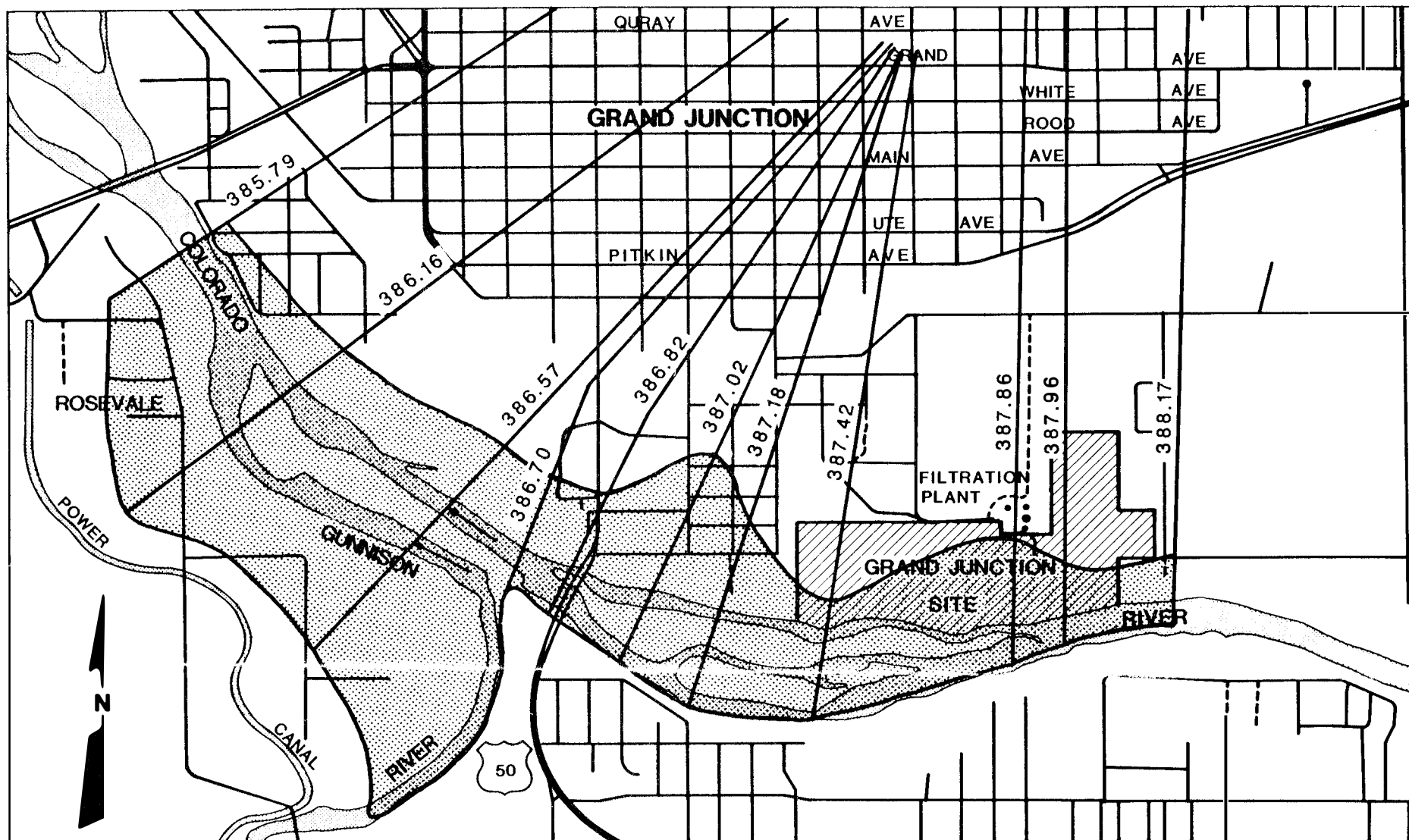


FIGURE G.2.3
LOCATION OF CROSS SECTIONS & FLOODPLAIN BOUNDARIES OF THE 100-YEAR FLOOD AFTER RELOCATION OF TAILINGS PILE

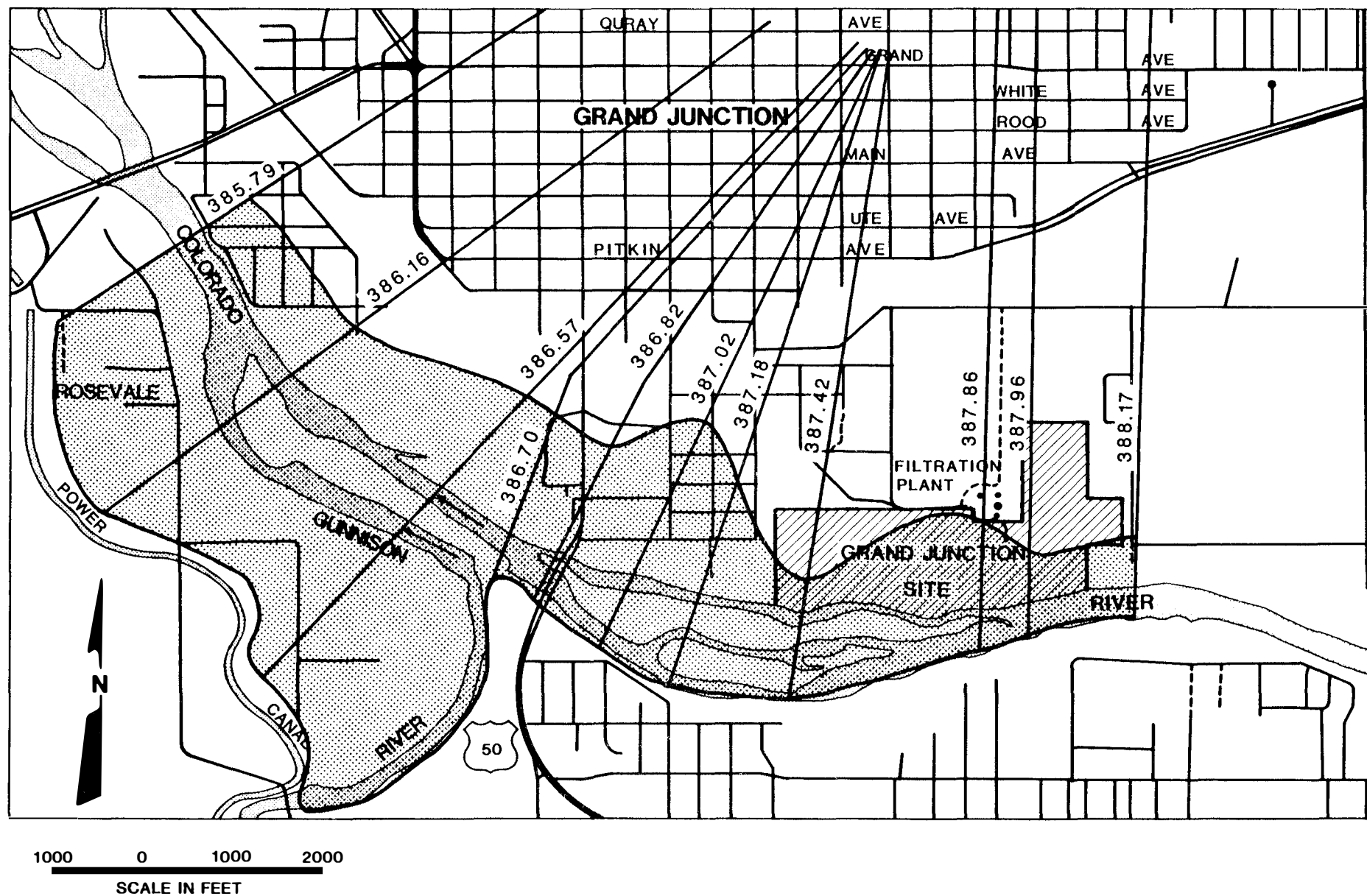


FIGURE G.2.4
LOCATION OF CROSS SECTIONS & FLOODPLAIN BOUNDARIES OF THE 500-YEAR
FLOOD AFTER RELOCATION OF TAILINGS PILE

G.3 WETLANDS EFFECTS

G.3.1 WETLANDS DESCRIPTION

The U.S. Army Corps of Engineers (COE) has determined that approximately 47 acres of the Colorado River floodplain near the existing tailings site are wetlands (COE, 1985). Figure G.3.1 shows wetlands adjacent to the site. Discharge of dredged or fill material including backfilling or recontouring in COE-designated wetlands would require a permit under Section 404 of the Clean Water Act.

The wetlands area consists primarily of palustrine scrub-shrub habitat, with some riverine unconsolidated habitat and some palustrine forested habitat. The scrub-shrub wetland is dominated by tamarisk and the forested wetland is primarily cottonwood (USFWS, 1985).

Wildlife associated with the wetlands consists of birds, small mammals, and some small furbearers (beaver and muskrat).

G.3.2 WETLANDS IMPACTS

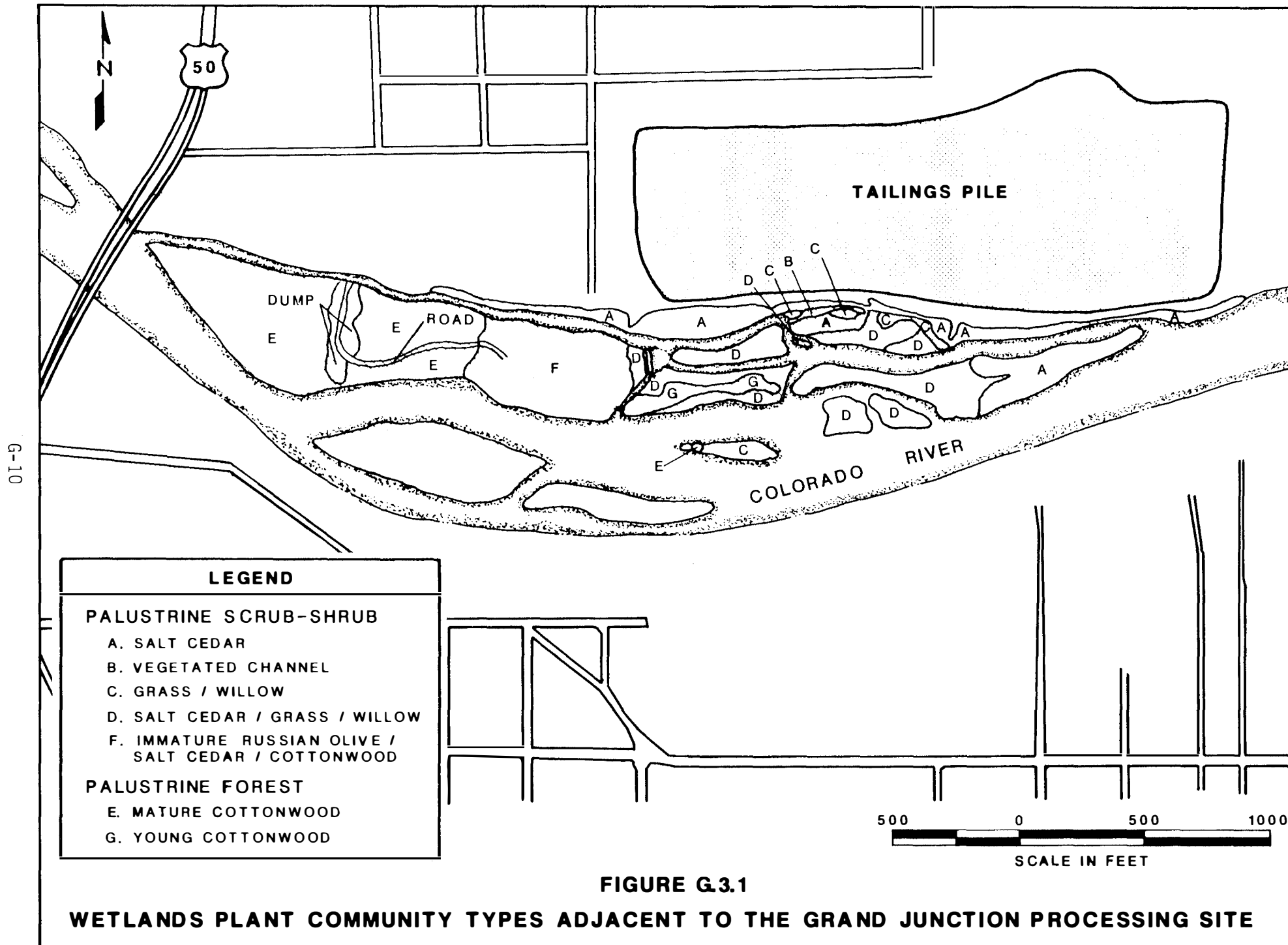
During remedial action, wetlands would be affected by excavation of approximately 40 acres of contaminated materials. The affected wetlands are fairly typical of the areas along the Colorado River in the area. Vegetation in the wetland areas would be removed prior to excavation. Habitat for birds, small mammals, and other wildlife would be lost during remedial action and afterward until vegetation is reestablished. Birds and some small mammals would probably move to similar habitats found along the Colorado River upstream and downstream of the site. Small, less mobile mammals utilizing the wetlands would be destroyed during excavation of contaminated soils.

G.3.3 WETLANDS IMPACTS MITIGATION

The potential impacts to the wetlands area would be mitigated by measures listed in Section G.2.2 and by the following actions:

- o Recontouring of excavated areas to create conditions favorable to reestablishment of scrub-shrub wetlands.
- o Revegetation of the area using plant materials that would lead to the reestablishment of palustrine scrub-shrub wetlands.
- o Selective use of water bars, mulch, riprap, or other soil-erosion controls to minimize erosion.

After vegetation has been reestablished, habitat similar to pre-remedial action conditions would develop.



G.4 ALTERNATIVES

The alternative remedial actions are discussed in Sections 1.2 and 3.2 of this DEIS. The impacts of these alternatives are discussed in Sections 5.1 through 5.17. Mitigation measures that are likely to be used are described in Sections 5.20, G.2.2, and G.3.3.

The no action alternative, which entails leaving the site in its present condition, would not be consistent with the intent of Congress in PL95-604 and would not result in DOE's compliance with the EPA standards. For the other alternatives, the construction activities and impacts that would occur are discussed in Sections G.2 and G.3.2.

REFERENCES FOR APPENDIX G

COE (U.S. Army Corps of Engineers), 1985. Written communication from G. McNure, Chief Regulatory Unit 4, Grand Junction, Colorado, to R. Peel, Jacobs Engineering Group, Inc., UMTRA Project Office, Albuquerque, New Mexico, dated May 7, 1985.

USFWS (U.S. Fish and Wildlife Service), 1985. Written communication from R. Garrison, Acting Field Supervisor, Salt Lake City, Utah, to R. Peel, Jacobs Engineering Group, UMTRA Project Office, Albuquerque, New Mexico, dated March 28, 1985.

APPENDIX H
BIOLOGICAL INFORMATION

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H.1 BIOLOGICAL INFORMATION

This appendix contains the list of animals and plants that occur in the vicinity of the Grand Junction site, alternate disposal sites, and borrow sites. The animal lists do not represent a complete inventory of species which occur at the Grand Junction site. Rather, they represent a compilation of species observed at the site or species with a high probability of occurring at the site. Probable species were derived from the references listed at the back of this Appendix. The plant species list represents species observed on the site.

Table H.1.1 Animal species observed or which may occur at the Grand Junction site, the alternate disposal sites, and borrow sites

Location	Scientific name	Common name
<u>Mammals</u>		
2, 5	<u>Ammospermophilus leucurus</u>	white-tailed antelope squirrel
2, 3	<u>Antilocapra americana</u>	pronghorn antelope
2, 3, 4, 5	<u>Canis latrans</u>	coyote
1,	<u>Castor canadensis</u>	beaver
3 5	<u>Cervus elaphus</u>	elk
1, 3	<u>Cynomys leucurus</u>	white-tailed prairie dog
2, 4 5	<u>Dipodomys ordii</u>	Ord's kangaroo rat
2 5	<u>Felis rufus</u>	bobcat
3, 4	<u>Lepus californicus</u>	black-tailed jackrabbit
2, 3, 4	<u>Lepus townsendii</u>	white-tailed jackrabbit
1, 2, 4 5	<u>Mephitis mephitis</u>	striped skunk
1, 4 5	<u>Mustela frenata</u>	long-tailed weasel
1, 2, 3, 4 5	<u>Myotis leibii</u>	small-footed myotis
3, 4	<u>Myotis volans</u>	long-legged myotis
2, 3, 4 5	<u>Odocoileus hemionus</u>	mule deer
1, 4	<u>Ondatra zibethicus</u>	muskrat
1, 2, 3, 4 5	<u>Peromyscus maniculatus</u>	deer mouse
3	<u>Peromyscus truei</u>	pinon mouse
1, 2, 3, 4 5	<u>Pipistrellus hesperus</u>	Western pipistrelle
1, 2, 3, 4 5	<u>Plecotus townsendii</u>	Townsend's big-eared bat
1	<u>Procyon lotor</u>	raccoon
1, 4 5	<u>Rattus norvegicus</u>	Norway rat
1, 2, 3, 4, 5	<u>Spilogale gracilis</u>	spotted skunk
1, 2, 3, 4 5	<u>Sylvilagus audubonii</u>	desert cottontail
1, 3, 4 5	<u>Taxidea taxus</u>	badger
3	<u>Vulpes macrotis</u>	kit fox
<u>Reptiles</u>		
1	<u>Chelydra serpentina</u>	snapping turtle
1	<u>Chrysemys picta</u>	painted turtle
1, 5	<u>Cnemidophorus velox</u>	plateau whiptail
2, 3, 4	<u>Gambelia wislizeni</u>	leopard lizard
2, 3, 4 5	<u>Phrynosoma douglassi</u>	short-horned lizard
1, 2, 3, 4 5	<u>Pituophis melanoleucus</u>	gopher snake
2, 3, 4 5	<u>Sceloporus graciosus</u>	sagebrush lizard
1, 4 5	<u>Thamnophis elegans</u>	wandering garter snake
2, 3, 4 5	<u>Uta stansburiana</u>	side-blotched lizard

Table H.1.1 Animal species observed or which may occur at the Grand Junction site, the alternate disposal sites, and borrow sites (Continued)

Location	Scientific name	Common name
<u>Amphibians</u>		
1, 4 5	<u>Ambystoma tigrinum</u>	tiger salamander
1, 4 5	<u>Bufo woodhousei</u>	woodhouse toad
1, 4	<u>Rana catesbeiana</u>	bullfrog
1, 4 5	<u>Rana pipiens</u>	leopard frog
<u>Birds</u>		
1, 3, 4, 5	<u>Accipiter cooperii</u>	Cooper's hawk
1, 2, 3, 4, 5	<u>Amphispiza belli</u>	sage sparrow
2	<u>Anas clypeata</u>	northern shoveler
1	<u>Anas platyrhynchos</u>	mallard
1, 2, 3, 4, 5	<u>Aquila chrysaetos</u>	golden eagle
1	<u>Ardea herodias</u>	great blue heron
1	<u>Asio otus</u>	long-eared owl
2, 3	<u>Athene cunicularia</u>	burrowing owl
2	<u>Aythya spp.</u>	Scaup
1	<u>Bubo virginianus</u>	great horned owl
1, 2, 3, 4, 5	<u>Buteo jamaicensis</u>	red-tailed hawk
2, 3	<u>Buteo lagopus</u>	rough-legged hawk
3	<u>Buteo regalis</u>	ferruginous hawk
2, 3	<u>Buteo swainsoni</u>	Swainson's hawk
1, 2, 3, 4, 5	<u>Callipepla gambelii</u>	Gambel's quail
3, 4	<u>Carpodacus cassinii</u>	Cassin's finch
1	<u>Carpodacus mexicanus</u>	house finch
1, 2, 3, 5	<u>Cathartes aura</u>	turkey vulture
1, 4	<u>Charadrius vociferus</u>	killdeer
1, 3, 4	<u>Chondestes grammacus</u>	lark sparrow
1, 2, 3	<u>Chordeiles minor</u>	common nighthawk
3	<u>Circus cyaneus</u>	marsh hawk (harrier)
1	<u>Colaptes auratus</u>	red-shafted flicker
1	<u>Columba livia</u>	rock dove
1	<u>Contopus sordidulus</u>	western wood pewee
1, 2, 3, 4	<u>Corvus brachyrhynchos</u>	American crow
1, 2, 3, 4	<u>Corvus corax</u>	common raven
1, 2, 5	<u>Dendroica petechia</u>	yellow warbler
1, 2, 3, 4	<u>Eremophila alpestris</u>	horned lark
1, 4	<u>Euphagus cyanocephalus</u>	Brewer's blackbird
2, 3, 5	<u>Falco mexicanus</u>	prairie falcon
5	<u>Falco peregrinus</u>	peregrine falcon
1, 2, 4, 5	<u>Falco sparverius</u>	American kestrel

Table H.1.1 Animal species observed or which may occur at the Grand Junction site, the alternate disposal sites, and borrow sites (Continued)

Location	Scientific name	Common name
<u>Birds (continued)</u>		
1, 5	<u>Haliaeetus leucocephalus</u>	Bald eagle
1, 3, 4	<u>Hirundo pyrrhonota</u>	cliff swallow
1, 4, 5	<u>Hirundo rustica</u>	barn swallow
1, 2, 3, 4, 5	<u>Junco hyemalis</u>	dark-eyed junco
2, 3, 4, 5	<u>Lanius ludovicianus</u>	loggerhead shrike
1	<u>Melospiza melodia</u>	song sparrow
1, 2, 3, 4, 5	<u>Molothrus ater</u>	brown-headed cowbird
1	<u>Nycticorax nycticorax</u>	black-crowned night heron
3	<u>Passerculus sandwichensis</u>	savannah sparrow
1	<u>Passerina amoena</u>	lazuli bunting
1, 2	<u>Phalaenoptilus nuttallii</u>	poor-will
1, 2, 3, 4, 5	<u>Pica pica</u>	black-billed magpie
1, 2, 4	<u>Pipilo chlorurus</u>	green-tailed towhee
2, 3	<u>Sayornis saya</u>	Say's phoebe
1, 2, 4, 5	<u>Selasphorus platycercus</u>	broad-tailed hummingbird
1, 2, 3, 5	<u>Sialia currucoides</u>	mountain bluebird
1, 2, 3	<u>Spizella breweri</u>	Brewer's sparrow
3	<u>Spizella passerina</u>	chipping sparrow
1, 3, 4, 5	<u>Sturnella neglecta</u>	western meadowlark
1, 4	<u>Sturnus vulgaris</u>	European starling
1, 3	<u>Tachycineta thalassina</u>	violet-green swallow
1, 4, 5	<u>Turdus migratorius</u>	robin
3	<u>Tympanuchus phasianellus</u>	sharp-tailed grouse
1, 2	<u>Tyrannus verticalis</u>	western kingbird
1, 2, 3, 4, 5	<u>Zenaida macroura</u>	mourning dove
<u>Fish</u>		
1	<u>Catostomus commersoni</u>	white sucker
1	<u>Catostomus discobolus</u>	bluehead sucker
1	<u>Catostomus latipinnis</u>	flannemouth sucker
1	<u>Catostomus latipinnis</u> x <u>C. commersoni</u>	white x flannemouth sucker
1	<u>Catostomus latipinnis</u> x <u>Xyranche texanus</u>	flannemouth x razorback sucker
1	<u>Cyprinus carpio</u>	carp
1	<u>Gila robusta</u>	roundtail chub
1	<u>Ictalurus melas</u>	black bullhead
1	<u>Ictalurus punctatus</u>	channel catfish
1	<u>Lepomis cyanellus</u>	green sunfish

Table H.1.1 Animal species observed or which may occur at the Grand Junction site, the alternate disposal sites, and borrow sites (Concluded)

Location	Scientific name	Common name
<u>Fish</u> (continued)		
1	<u>Lepomis macrochirus</u>	bluegill
1	<u>Micropterus salmoides</u>	largemouth bass
1	<u>Notropis lutrensis</u>	red shiner
1	<u>Notropis stramineus</u>	sand shiner
1	<u>Pimephales promelas</u>	fathead minnow
1	<u>Ptychocheilus lucius</u>	Colorado squawfish
1	<u>Pomoxis nigromaculatus</u>	black crappie
1	<u>Rhinichthys osculus</u>	speckled dace
1	<u>Xyrauchen texanus</u>	razorback sucker

Ref. Bissell, 1978; Hammerson and Langlois, 1981; Kingery and Gaul, 1978; Murie, 1954; NUS, 1983; Peterson, 1969; Stebbins, 1966; URS, 1983; Whitaker, 1980.

Key:

- 1 = Grand Junction site.
- 2 = Cheney Reservoir site.
- 3 = Two Road site.
- 4 = Borrow sites (Fruita and 32 and C $\frac{1}{2}$).
- 5 = Borrow sites (Unaweep Canyon).

Table H.1.2 Plant species observed at the Grand Junction site,
the alternate disposal sites, and borrow sites

Location	Scientific name	Common name
<u>Plants</u>		
1, 2	5 <u>Agropyren smithii</u>	western wheatgrass
1, 2	4 <u>Agropyron cristatum</u>	crested wheatgrass
	5 <u>Artemisia spinescens</u>	bud sagebrush
	5 <u>Artemisia tridentata</u>	big sagebrush
	5 <u>Astragalus</u> sp.	loco
2, 4, 5	<u>Atriplex canescens</u>	fourwing saltbush
2, 3, 5	<u>Atriplex confertifolia</u>	shadscale
2, 3	<u>Atriplex nattallii</u>	Nuttall's saltbush
	5 <u>Bouteloua gracilis</u>	blue grama
1, 3, 4, 5	<u>Bromus tectorum</u>	cheatgrass
	5 <u>Castilleja</u> sp.	Indian paintbrush
2, 5	<u>Ceratoides lanata</u>	winterfat
2, 3, 5	<u>Chrysothamnus viscidiflorus</u>	little rabbitbrush
1, 4	<u>Cirsium</u> sp.	thistle
1	<u>Distichlis stricta</u>	saltgrass
	5 <u>Echinocereus triglochidiatus</u>	Spineless hedgehog cactus
1	<u>Elaeagnus angustifolia</u>	Russian olive
1, 5	<u>Elymus cinereus</u>	Great Basin wildrye
1	<u>Halogeton glomeratus</u>	halogeton
2, 3	<u>Hilaria jamesii</u>	galleta grass
1	<u>Hordeum</u> sp.	barley foxtail
	5 <u>Juniperus scopulorum</u>	Rocky Mountain juniper
1	<u>Kochia americana</u>	kochia
	3 <u>Leucelene ericoides</u>	composite
	5 <u>Lupinus</u> sp.	lupine
1, 4	<u>Medicago sativa</u>	alfalfa
1, 4	<u>Melilotus</u> sp.	sweet clover
2, 3, 5	<u>Opuntia polyacantha</u>	prickly pear cactus
2, 3, 5	<u>Oryzopsis hymenoides</u>	Indian ricegrass
	5 <u>Penstemon</u> sp.	penstemon
	5 <u>Pinus edulis</u>	pinyon pine tree
	5 <u>Pinus ponderosa</u>	ponderosa pine tree
1	<u>Populus freemontii</u>	cottonwood
	5 <u>Purshia tridentata</u>	bitterbrush
1, 4	<u>Salix</u> sp.	willow
1	<u>Salsola kali</u>	Russian thistle
1	<u>Sarcobatus vermiculatus</u>	greasewood
	5 <u>Sclerocactus glaucus</u>	Uinta Basin hookless cactus
2	<u>Sitanion hystrix</u>	squirreltail
3	<u>Sphaeralcea coccinea</u>	scarlet globemallow
	5 <u>Sphaeralcea</u> sp.	globemallow
2, 5	<u>Stipa comata</u>	needle-and-thread

Table H.1.2 Plant species observed at the Grand Junction site,
the alternate disposal sites, and borrow sites (Concluded)

Location	Scientific name	Common name
<u>Plants</u>		
1, 2	4, 5 <u>Tamarix pentandra</u> <u>Tetradymia spinosa</u>	tamarisk spiny horsebrush
1,	4 <u>Typha latifolia</u>	cattail
1,	4, 5 <u>Ulmus parvifolia</u>	chinese elm

Ref. NUS, 1983; URS, 1983.

Key:

- 1 = Grand Junction site.
- 2 = Cheney Reservoir site.
- 3 = Two Road site.
- 4 = Borrow sites (Fruita and 32 and C½).
- 5 = Borrow sites (Unaweep Canyon).

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APPENDIX I
RADIATION HEALTH EFFECTS



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I.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 "activity" measured by the unit "curie." A more convenient unit for measuring the activity of radioactive atoms in 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 is the time required for the radioactive substance to lose 50 percent of its activity 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 transfers energy to matter as it travels through matter. Alpha radiation penetrates only a few millimeters into matter and beta radiation penetrates a few centimeters. However, gamma radiation can travel deeper into matter in the same way as x-rays. Alpha radiation will not penetrate through a layer of skin, whereas gamma radiation has some probability of traveling through the whole body without transferring energy.

The amount of radiation to which an individual is exposed may be expressed in terms of the amount of energy imparted to cells and tissue 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 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 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.

Radon-222 (radon) is the radionuclide of primary importance to the UMTRA Project because it represents the largest radiation exposure pathway to the general population. The half-life of radon (3.8 days) is short relative to the half-life of radium-226 (Ra-226) (1602 years). As Ra-226 decays, the newly produced radon will begin to decay, and the radon activity will become equal to the Ra-226 activity within 30 days. Similarly, the short-lived radon daughter activities will ingrow within four hours to equal the activity of radon. When the activities 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 as they are formed, they will not reach 100-percent equilibrium.

When a succession of radioactive parent atoms decay to radioactive daughter atoms, a "radioactive decay series" is formed. U-238 is such a radioactive parent atom and the U-238 decay series is shown in Figure I.1.1 (Lederer, 1978;

Nuclide	Historical name	Half-life	Major radiation energies (MeV) and intensities†		
			α	β	γ
$^{238}_{92}\text{U}$	Uranium I	$4.51 \times 10^9 \text{ y}$	4.15 (25%) 4.20 (75%)	---	---
$^{234}_{90}\text{Th}$	Uranium X_1	24.1d	---	0.103 (21%) 0.193 (79%)	0.063c# (3.5%) 0.093c (4%)
$^{234}_{91}\text{Pa}^m$	Uranium X_2	1.17m	---	2.29 (98%)	0.765 (0.30%) 1.001 (0.60%)
99.87% $^{234}_{92}\text{U}$ 0.13% $^{234}_{91}\text{Pa}$	Uranium Z	6.75h	---	0.53 (66%) 1.13 (13%)	0.100 (50%) 0.70 (24%) 0.90 (70%)
$^{234}_{92}\text{U}$	Uranium II	$2.47 \times 10^5 \text{ y}$	4.72 (28%) 4.77 (72%)	---	0.053 (0.2%)
$^{230}_{90}\text{Th}$	Ionium	$8.0 \times 10^4 \text{ y}$	4.62 (24%) 4.68 (76%)	---	0.068 (0.6%) 0.142 (0.07%)
$^{226}_{88}\text{Ra}$	Radium	1602y	4.60 (6%) 4.78 (95%)	---	0.186 (4%)
$^{222}_{86}\text{Rn}$	Emanation Radon (Rn)	3.823d	5.49 (100%)	---	0.510 (0.07%)
$^{218}_{84}\text{Po}$	Radium A	3.05m	6.00 (~100%)	0.33 (~0.019%)	---
99.98% $^{214}_{82}\text{Pb}$ 0.02% $^{218}_{85}\text{At}$	Radium B	26.8m	---	0.65 (50%) 0.71 (40%) 0.98 (6%)	0.295 (19%) 0.352 (36%)
$^{218}_{85}\text{At}$	Astatine	~2s	6.65 (6%) 6.70 (94%)	? (~0.1%)	---
$^{214}_{83}\text{Bi}$	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% $^{214}_{84}\text{Po}$ 0.02% $^{214}_{81}\text{Tl}$	Radium C'	164 μ s	7.69 (100%)	---	0.799 (0.014%)
$^{214}_{81}\text{Tl}$	Radium C''	1.3m	---	1.3 (25%) 1.9 (56%) 2.3 (19%)	0.296 (80%) 0.795 (100%) 1.31 (21%)
$^{214}_{82}\text{Pb}$	Radium D	21y	3.72 (.000002%)	0.016 (85%) 0.061 (15%)	0.047 (4%)
$^{214}_{83}\text{Bi}$	Radium E	5.01d	4.65 (.00007%) 4.69 (.00005%)	1.161 (~100%)	---
~100% $^{214}_{84}\text{Po}$.00013% $^{214}_{81}\text{Tl}$	Radium F	138.4d	5.305 (100%)	---	0.803 (0.0011%)
$^{214}_{81}\text{Tl}$	Radium E''	4.19m	---	1.571 (100%)	---
$^{206}_{82}\text{Pb}$	Radium G	Stable	---	---	---

FIGURE I.1.1

URANIUM 238 DECAY SERIES

BRH, 1980). The U-238 decay series includes Th-230, Ra-226, Rn-222 (radon), short-lived radon daughters, and other long-lived radioactive atoms. The U-238 decay series ends with Pb-206, an atom that is stable and not radioactive. When the daughters in a radioactive decay chain have shorter half-lives than the parent, the daughter activities will increase (termed "ingrowth"), until they equal the activity of the parent.

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. 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 become a source from which radon diffuses into the atmosphere. Once in the atmosphere, radon is transported downwind and, according to its 3.8-day half-life, 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; however this exposure pathway contributes 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 will decay before being removed from the lung.

Trace amounts of U-238 and its daughters are found everywhere on the earth; therefore, radon and its short-lived daughters contribute significantly to the background radiation exposure of the general population. Human exposure to radiation originates from both natural and man-made sources. The major natural radiations originate from cosmic and terrestrial external sources, and from naturally occurring radionuclides which are deposited inside the body via the ingestion and inhalation pathways. Exposure to man-made sources results primarily from medical exposures (e.g., diagnostic x-rays), weapons testing, consumer products, and technologically enhanced natural radiation (TENR).

Medical usage of radiation is responsible for the highest contribution to man's total radiation exposure (50 percent). Other man-made contributors, including airline travel, atmospheric weapons tests, and consumer and industrial products together account for approximately five percent. The remaining 45 percent of man's total radiation exposure results from exposure to natural radiation sources.

The health effects attributed to a radiation dose are categorized into two general types: somatic and genetic. Somatic effects are manifested in the exposed individual. The International Commission on Radiological Protection (ICRP, 1977) estimated the genetic effect to be less than the somatic effects; therefore, only risk of somatic effects are considered.

I.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 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. Synergistic effects of other health effect agents (e.g., chemicals), are not considered in this analysis.

There are five principal environmental pathways by which individuals could be exposed to radioactivity during and after remedial action (Figure I.2.1). These are: (1) inhalation of radon and radon daughters, (2) exposure to direct gamma radiation from the tailings pile, (3) inhalation or ingestion of windblown radioactive particulates, (4) ingestion of contaminated foods produced in areas contaminated by tailings, and (5) ingestion of ground or surface water contaminated by radioactive materials.

For the calculation of health effects, the first four pathways mentioned above are considered. Exposures via the ground- or surface-water pathways are not considered because the water sources used for human consumption do not show evidence of contamination.

The health effect estimates made in this appendix are primarily based on data and models presented in the BEIR-III report (NAS, 1980). Quantitative risk estimation of somatic effects 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, depending on the type of cancer and the age of the person exposed. The risks from radiation will vary with age and sex, but are presented as average values where variation due to age and sex is small. No data are available that indicate whether risk estimates for adults are appropriate for radiation exposure during childhood. Because the BEIR-III report does not always make firm recommendations for application of the data, health risk estimates in this appendix also make use of recommendations published in scientific journals.

I.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 then deposit energy from alpha particles in the lung. For radiation protection purposes, the ICRP (1977) proposed an individual lung-cancer risk factor of 20×10^{-6} per rem, or 20 excess cancer deaths where one million individuals each receive a one-rem lung dose equivalent from radon daughters.

Other standards-setting organizations express the excess risk of lung cancer based on the lung collective dose equivalent 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-

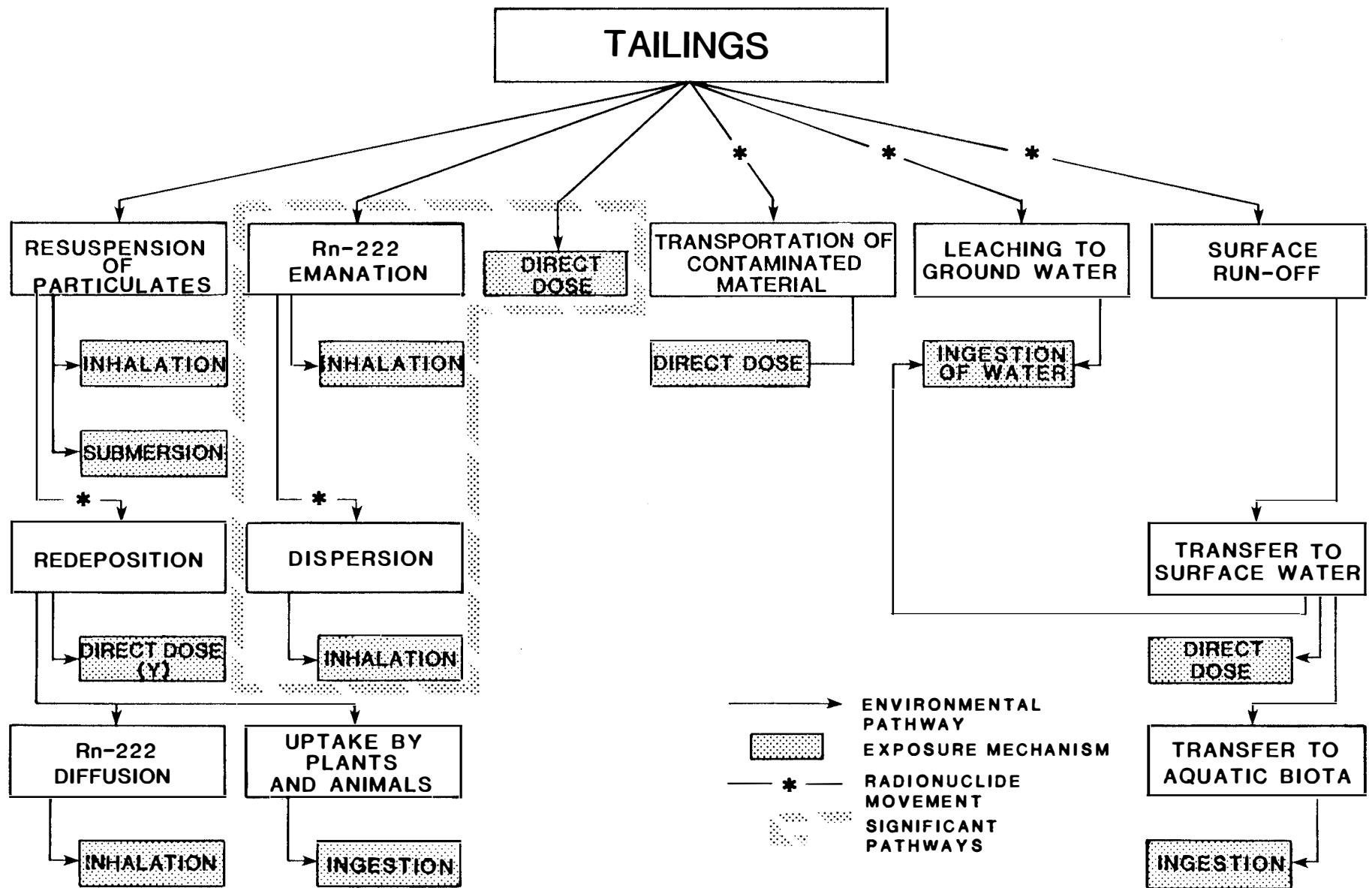


FIGURE I. 2.1
POTENTIAL RADIATION EXPOSURE PATHWAYS
TO THE GENERAL PUBLIC AND REMEDIAL ACTION WORKERS

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.

The following are estimates of excess fatal lung cancers given in terms of person-WLM. The United Nations Scientific Committee on the Effects of Atomic Radiation quoted a range of 200 to 450×10^{-6} deaths per person-WLM (UNSCEAR, 1977), while the NRC in its environmental impact statement on uranium milling quoted 360×10^{-6} deaths per person-WLM (NRC, 1980b). The BEIR-III report formulated an age-dependent model for predicting the risk of lung cancer based on several studies of uranium and fluorspar miners. Evans et al. (1981), reviewed the BEIR-III study, lung-cancer risk estimates published by other authors, and other epidemiological evidence and recommended 100×10^{-6} deaths per person WLM. For this EIS a value of 300×10^{-6} deaths per person-WLM was assumed as the lifetime lung cancer risk for the general population.

The National Council on Radiation Protection in their Report 78 (NCRP, 1984) stated that one WLM is approximately equal to a 15-rem dose equivalent commitment to the lung. The risk estimate of 300×10^{-6} deaths per person-WLM is therefore equivalent to the ICRP risk estimate, 20×10^{-6} deaths per person-rem, which is used in this appendix.

To estimate the radon daughter concentrations inhaled by the general population and remedial action workers, two methods are used: (1) atmospheric dispersion calculations for radon released from the tailings pile (the MILDOS computer code was used, Section I.3), and (2) a modification to the Gaussian sector average model that predicts atmospheric radon concentrations within one km of an area source.

In order to convert modeled radon and radon daughter concentrations in air to rem of dose equivalent commitment, conversion factors were developed for on-pile workers and the population within one km of the site based on the following calculations:

$$\frac{15 \text{ rem}}{\text{WLM}} = \frac{15 \text{ rem}}{\text{WLM (170 hr/m)(100 pCi/l/WL)}} = \frac{8.82 \times 10^{-4} \text{ rem}}{\text{hr} \times (\text{pCi/l})} \text{ (at 100\% eq.)}$$

Assuming a conservative 25 percent equilibrium of radon daughters on the site, the radon daughter dose conversion factor for workers becomes 2.2×10^{-4} rem/hr (pCi/l). The population within one km of the site is assumed to spend six hours a day outdoors and 18 hours a day indoors. Radon daughter equilibrium is assumed to be 25 percent outdoors and 50 percent indoors. This results in a time-weighted radon daughter conversion factor of 4.38×10^{-4} rem/hr/(pCi/l).

I.2.2 HEALTH EFFECTS OF EXPOSURE TO GAMMA RADIATION

Tailings piles emit gamma radiation that delivers an external exposure to the whole body of people near the pile. The BEIR-III report contains several models for estimating cancer risk resulting from exposure to gamma radiation. Health effect estimates in this appendix for excess cancer deaths due to gamma radiation use a risk factor of 120×10^{-6} deaths per person-rem (NAS, 1980; Cohen, 1981). This is equivalent to 120 excess cancer deaths in an exposed population for each 1,000,000 person-rem of collective dose equivalent. A person-rem is the product of the radiation dose equivalent multiplied by the number of people receiving that dose equivalent. A wide range of risk factors are accepted by experts who attempt to relate cancer deaths to radiation exposure. DOE has selected this as a realistic value for comparison of alternatives, after reviewing figures in the literature ranging from 50 to 500 cancer deaths per 1,000,000 person-rem.*

Health effect estimates for gamma radiation exposure were performed for remedial action workers and for the general population within one km from the tailings site. The contribution from the tailings pile to gamma radiation levels becomes negligible beyond approximately one km from the tailings pile perimeter. A health effect analysis was performed for the general population and remedial action workers to determine gamma radiation impacts during transportation of tailings material in the relocation alternative actions.

For gamma radiation, one rem is approximately equal to one roentgen (R) which is the unit for measuring gamma-radiation intensity in air. A microroentgen (uR) is 1×10^{-6} R, and typical environmental gamma radiation levels are expressed in uR/hr.

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. This is sufficiently similar to the somatic risk estimate so that protection of the individual against somatic effects will ensure adequate protection against genetic effects.

The gamma radiation exposures on and around the Grand Junction tailings pile are estimated from direct measurements and from the Ra-226 content of the tailings. The exposures to workers takes account of substantial shielding offered by the working environment.

*A more extensive discussion of these issues is provided in Appendix N, Radiologically Related Health Effects, in the Draft Environmental Impact Statement on Disposal of Hanford Defense High-Level, Transuranic and Tank Waste, U.S. Department of Energy, February, 1986, DOE/EIS-0113.

I.3 SITE RADIOLOGICAL CHARACTERISTICS

In this section the data concerning the environmental radiation conditions of the Grand Junction site, which includes the tailings pile and perimeter, ore storage area, mill yard, settling ponds, and the State of Colorado tailings repository are described. The environmental radiation conditions of the alternate disposal sites are also discussed.

I.3.1 EXISTING CHARACTERISTICS AT THE GRAND JUNCTION SITE

The Grand Junction site is a 116-acre tract located in Mesa County, Colorado, immediately south and east of the Grand Junction city limits. There are approximately 2.2 million cubic yards of contaminated material on and below the tailings pile. An additional 0.54 million cubic yards of contaminated material located within the site boundary, but off of the pile, will be included in the final stabilization.

The tailings pile covers approximately 57 acres of the site and has an average thickness of 22.3 feet. Underlying the pile is a layer of contaminated soil averaging 4.6 feet in thickness. To the north of the pile are the former ore storage area and the former mill yard. The State of Colorado tailings repository and settling ponds are located east of the pile. Approximately 280,000 cubic yards of the off-pile contamination are located in the tailings repository which has an average depth of contamination of 10.7 feet.

Physical characteristics

Physical characteristics of the tailings are described by Mountain States Research and Development (MSRD), (MSRD, 1982). The tailings consist mainly of finely ground material which is predominately sandstone with some clay. The average moisture content is 10 percent.

In-situ densities ranged from 1.4 g/cm^3 for sand tailings to 1.6 g/cm^3 for slimes tailings. A density of 1.6 g/cm^3 was used in this appendix for stabilized tailings.

The radon emanation coefficient is the fraction of radon produced within the soil or tailings grains that is released to the interstitial pore spaces. The NRC (1979) recommended a generic value of 0.20 for a tailings emanation coefficient. This value was used in this appendix.

Radionuclide content

The principal isotopes of concern in assessing the radiological impacts of the proposed alternatives are U-238, Th-230, and Ra-226. Concentrations of other radionuclides may be estimated based on these three radionuclides and the assumption of secular equilibrium. The radionuclide concentrations on the Grand Junction site are estimated based on the statistically designed drilling and sampling program of MSRD (1982) and Bendix Field Engineering Corporation (BFEC), (BFEC, 1985).

BFEC performed Ra-226 analyses on 425 of the samples which MSRD collected from 100 on-pile boreholes sampled every 2.5 feet. This resulted in a pile-average concentration of 669 pCi/g Ra-226. As a conservative measure, this concentration was increased by five percent to 702 pCi/g. In addition BFEC analyzed 358 shallow soil samples and performed down hole gamma-logging of 177 boreholes to determine the extent of Ra-226 contamination on the site in off-pile areas. This resulted in an average off-pile concentration of 90 pCi/g Ra-226. For this appendix a volume-weighted average concentration of 581 pCi/g Ra-226 is used $((90 \text{ pCi/g} \times 5.40 \times 10^5 \text{ cy}) + (702 \text{ pCi/g} \times 2.2 \times 10^6 \text{ cy})) / (5.40 \times 10^5 \text{ cy} + 2.2 \times 10^6 \text{ cy})$.

The Th-230 volume-weighted average concentration can be estimated by assuming secular equilibrium with Ra-226. Thus, 581 pCi/g is the value used for the Th-230 concentration.

The average concentration of U-238 found in the 100 on-pile boreholes sampled by MSRD was 0.018 percent. As a conservative measure, this concentration was increased by five percent to 0.019 percent. This corresponds to approximately 54 pCi/g U-238 and is based on the most complete data available. It is reasonable to assume that the concentration of U-238 in all off-pile areas except the ore storage area is proportional to the U-238/Ra-226 ratio on the pile since the bulk of the off-pile material is tailings. This results in an off-pile U-238 concentration of:

$$\frac{(54 \text{ pCi/g U-238}) (90 \text{ pCi/g Ra-226})}{(702 \text{ pCi/g Ra-226})}$$

$$= 6.9 \text{ pCi/g U-238}$$

The ore storage area has an average Ra-226 concentration of 126 pCi/g. In this area U-238 and Ra-226 are assumed to be in equilibrium. The average U-238 concentration used was 126 pCi/g for the 2.74×10^4 cy of contaminated material. A volume-weighted average on-site concentration of 46 pCi/g $((6.9 \text{ pCi/g} \times 5.13 \times 10^5 \text{ cy}) + (126 \text{ pCi/g})(2.74 \times 10^4 \text{ cy}) + (54 \text{ pCi/g} \times 2.2 \times 10^6 \text{ cy})) / ((2.74 \times 10^4 \text{ cy}) + (2.2 \times 10^6 \text{ cy}) + (5.13 \times 10^5 \text{ cy}))$ is used in this appendix.

In summary, the radionuclide concentrations used in this appendix for determining the particulate release source term are 581 pCi/g for Ra-226, 581 pCi/g for Th-230, and 46 pCi/g for U-238.

Radon flux

Radon flux at the Grand Junction site has been measured or calculated by various groups. Short-term flux measurements taken on the pile by FBDU (1981) ranged from 90 to 1340 pCi/m²s and averaged 550 pCi/m²s. Radon flux measurements on the State of Colorado tailings repository averaged 16 pCi/m²s. An average flux of 380 pCi/m²s was calculated by ORNL (1980) on the tailings pile. The NRC (1979) reported radon flux-to-radium concentration ratios of 0.35 for wet tailings, and 1.2 for dry tailings in units of pCi/m²s radon flux per pCi/g of Ra-226; however, the NRC prefers a generic value of 1.0 for this ratio. Approximately 59 acres of the site have an average Ra-226 concentration of 90 pCi/g, and

57 acres of the site have a Ra-226 concentration of 702 pCi/g. Based on these average Ra-226 concentrations, an assumed radon flux-to-radium concentration ratio of one picocurie per gram per picocurie per square meter-second would yield an area-weighted radon flux of:

$$\frac{(90 \text{ pCi/g}) (59 \text{ acres}) + (702 \text{ pCi/g}) (57 \text{ acres})}{59 + 57 \text{ acres}} \\ = 391 \text{ pCi/m}^2\text{s}$$

This value was used in this appendix.

Radon in air

On the site, ambient air radon concentrations are needed to estimate exposures of workers during remedial action. Long term radon concentration measurements made on the Grand Junction pile resulted in an annual average of 26 pCi/l with a range of eight to 66 pCi/l (EPA, 1977). By using the on-site radon flux of 391 pCi/m²s and an average wind speed of two m/s as inputs into the Gaussian sector average dispersion model modified to predict radon concentration close to an area source, an on-site radon concentration of 11 pCi/l was determined. Based on the available information, it is believed that 30 pCi/l is a reasonably conservative estimate of the average radon concentrations on the Grand Junction site.

Existing characteristics at Grand Junction

Vicinity properties. An estimated 363,825 cubic yards of uranium tailings have been moved from the Grand Junction site and used as fill material on various construction projects. Approximately 3585 properties have levels of radiation exceeding EPA standards, 3465 of which will be cleaned up during the remedial action at the Grand Junction site (Appendix L, Vicinity Property Report, contains additional details on the number of vicinity properties).

The highest annual average radon working level found indoors at a vicinity property was 1.5. Average values range from 0.005 to 0.015 working level. The average of the high indoor gamma exposure rate is approximately 29 uR/hr. A representative value for exposure rates found outdoors is 30 to 40 uR/hr (Emelia, 1985). The above values are based on experience at several hundred vicinity properties in Grand Junction. The average of the high outdoor gamma exposure rate is 74 uR/hr.

Background values for radon working levels range from 0.005 to 0.007. Background gamma exposure rates are approximately 12 uR/hr.

I.3.2 ENVIRONMENTAL RADIATION MEASUREMENTS

The environmental radiation levels for the area surrounding the Grand Junction site and alternate disposal sites have been studied (EPA 1975; FBDO, 1981; ORNL, 1980; BFEC, 1985), and are summarized here.

I.3.2.1 Grand Junction site environmental radioactivity

Radioactive airborne particulate concentrations were measured on the State of Colorado tailings repository by ORNL (1980). Three air samples were collected on asbestos fiber filters having a collection efficiency greater than 99 percent for 0.3 micrometer or larger particles during 3.2-hour periods with a high volume air sampler. The results of the sampling are shown in Table I.3.1.

Radon in air. Ambient-air Rn-222 concentrations have been measured and calculated for the area surrounding the Grand Junction pile (FBDU, 1981; Schearer and Sills, 1969; EPA 1977; ORNL, 1980). Previous estimates indicated 6.7 pCi/l at 0.08 mile from the pile edge and 2.6 pCi/l at 0.33 mile from the pile to the west. A background level of 0.8 pCi/l was measured at 1.7 miles from the pile.

Gamma radiation. Gamma radiation exposure rates away from the tailings pile have been measured at 100-yard intervals and reached background levels (11 uR/hr) at about 0.2 mile to the east and west of the site. South of the site, the exposure rate reached background across the Colorado River. North of the site the gamma radiation level reached background at 0.35 mile (FBDU, 1981). This reduction in exposure rate with distance from the pile is shown as Figure I.3.1.

Soil and sediment radioactivity. Background concentrations of radionuclides in soils have been measured in and around Grand Junction by a number of investigators. Results are generally comparable and are typified by the ORNL, 1980, results which indicate the following values (arithmetic mean plus or minus the arithmetic standard deviation): Ra-226, 2.0 ± 0.84 pCi/g; U-238, 0.7 ± 0.21 pCi/g; and Th-230, 0.6 ± 0.17 pCi/g. In addition, 12 soil samples were collected within approximately 400 to 1000 meters of the pile. These samples were collected at the ground surface and analyzed for Ra-226. Concentrations found in the off-site samples ranged from near background to 17 pCi/g.

Sediment and dry wash samples from the Colorado River, a drainage ditch east of the pile, and a dry wash west of the pile were collected and analyzed for Ra-226 (ORNL, 1980). Samples were collected at the surface and at a depth of 15 cm. All samples showed contamination above background levels. The dry wash samples taken in the western dry wash had Ra-226 concentrations ranging from three to 700 pCi/g. The two sediment samples in the east drainage ditch had concentrations of 42 and 68 pCi/g Ra-226. The Colorado River sediment samples had a range of 1.6 to 9.5 pCi/g Ra-226.

I.3.2.2 Alternate disposal site environmental radioactivity

Radiation levels currently existing at the alternate disposal site have been determined from monitoring programs con-

Table I.3.1 Concentration of radionuclides in airborne particles at the Grand Junction site

Sample	Date	Radionuclide concentration (pCi/m ³) ^a			
		Ra-226	Pb-210	Th-230	U-238
J-3HV	5-13-76	1.4 x 10(+0.95)	11 x 10(+18)	3.8 x 10(+0.66)	2.1 x 10(+0.60)
J-4HV	5-17-76	15 x 10(+2.7)	11 x 10(+18)	7.1 x 10(+1.1)	3.8 x 10(+0.88)
J-5HV	5-13-76	17 x 10(+3.1)	4.4 x 10(+1.8)	14 x 10(+1.3)	4.2 x 10(+0.88)
MPC _a ^b		2.0	4.0	0.08	3.0

^aIndicated errors associated with these concentrations are shown in parentheses and two sigma (95% confidence level).

^bMaximum permissible concentrations in air (MPC_a) for unrestricted areas, in 10 CFR Part 20, Appendix B, Table 2, Column 1. Limiting concentrations for the given radionuclides are for the soluble state except Ra-226 which is for the insoluble state.

Ref. ORNL, 1980.

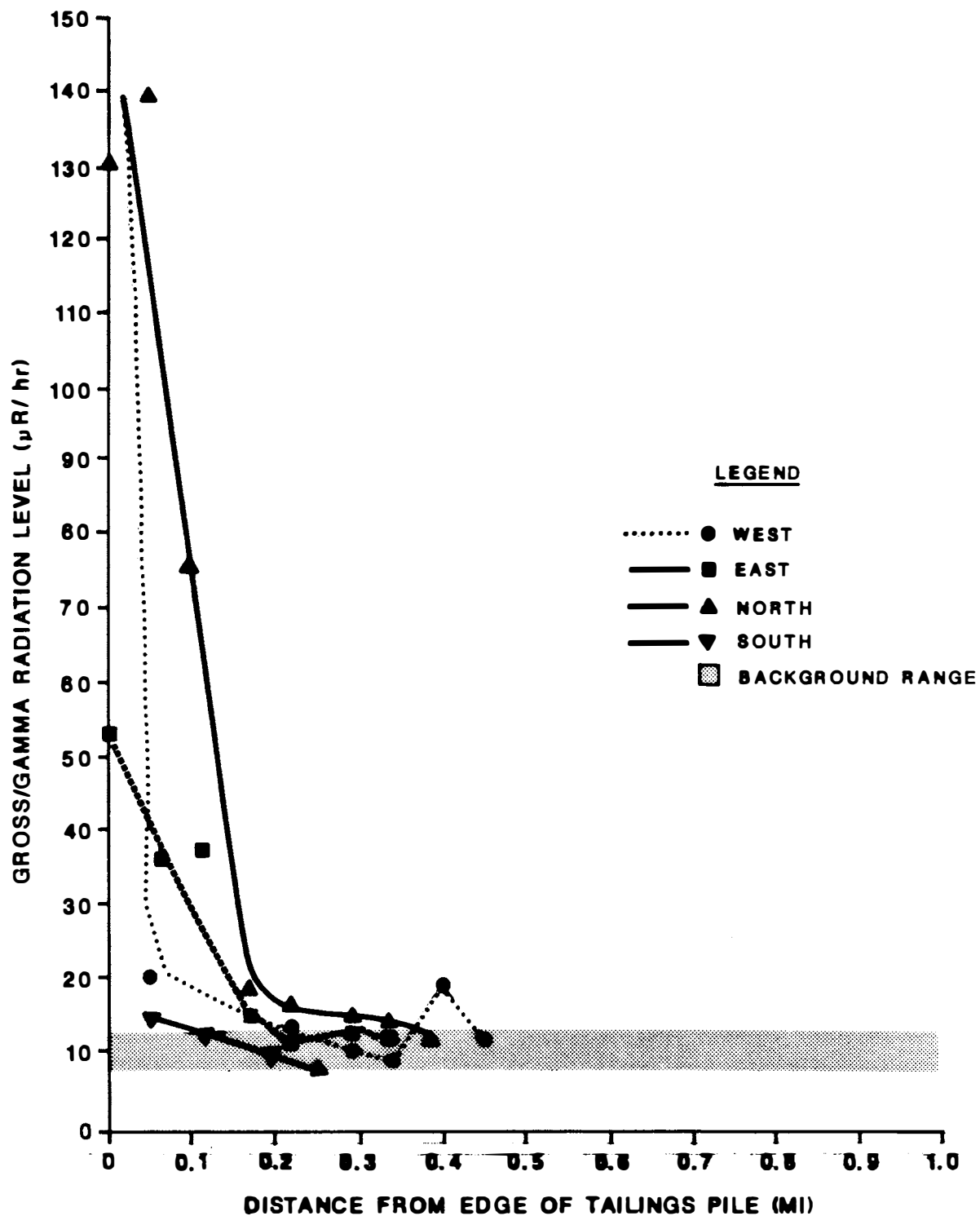


FIGURE I.3.1
REDUCTION OF EXTERNAL GAMMA RADIATION LEVELS
WITH DISTANCE FROM THE TAILINGS PILE

ducted by the Technical Assistance Contractor (TAC). The data presented below are the result of three months of monitoring. The environmental characterization program included measurements of ambient radon concentrations in air, gamma radiation exposure rates, radionuclide concentrations in surface soils, and radionuclide concentrations in ground water.

The radiological environmental sampling program formulated for the alternate disposal sites is summarized in Table I.3.2. Ground water was sampled and analyzed as part of the water-quality program (Appendix F, Hydrology Report). The lower limits of detection for the environmental radiological monitoring program were sufficiently sensitive to meet the specifications of the USNRC (NRC, 1980a).

Rn-222 in air. Radon concentrations were measured for three months by the TAC using one set of three track etch detectors at each alternate disposal site. The background concentration of Rn-222 at the Two Road site was 0.46 pCi/l. The concentration of Rn-222 at the Cheney Reservoir site will be measured for a three-month period beginning in September, 1985.

A general area survey of gamma radiation exposure rates was conducted by the TAC. The measurements averaged 13.6 uR/hr and ranged from 12.9 to 14.0 at the Two Road site. The average exposure rate at Cheney Reservoir site was 13.8 uR/hr with a range of 13.5 to 14.3.

Soil radioactivity. Soil sampling of surface soils (top 15 cm of soil) was performed at both alternate disposal sites. The four samples taken from each site were analyzed for Ra-226 using a sodium iodide gamma spectrometer. The average concentration of Ra-226 was 1.8 at the Cheney Reservoir site and 0.94 at the Two Road site. Table I.3.3 shows the sample results at the Two Road and Cheney Reservoir sites.

Table I.3.2 Summary of radiological sampling program

Sampling	Method	Number of points	Frequency
Ambient air Radon-222	Terradex Track-etch	One set of three cups	One quarter
External gamma radiation	Pressurized ionization chamber, NaI scintillometers	Four locations Four traverses	Once
Soil	Surface analyzed by gamma spectroscopy	Four	Once

Table I.3.3 Soil sample results at Two Road and Cheney Reservoir

Site	Sample number	Ra-226 concentration (pCi/g)
Two Road	GRJ001ASA	0.8
	GRJ002ASA	0.8
	GRJ003ASA	1.0
	GRJ004ASA	1.2
	GRJ005ASA	0.9
Cheney Reservoir	GRJ006ASA	1.3
	GRJ007ASA	2.6
	GRJ008ASA	2.1
	GRJ009ASA	1.0

I.4 RADIOACTIVE SOURCE TERM

In this section the calculations necessary to estimate the radiological effect of the proposed alternative remedial actions are presented. Most of the important radioactive releases occur at the Grand Junction site; however, calculations for the alternate site and the transportation corridor are also considered.

I.4.1 RADON RELEASE SOURCE TERM

Radon may be released from the tailings during four phases of the remedial action process: 1) prior to remedial action; 2) during the material moving operations; 3) after the relocation of the material but prior to installation of the cover; and 4) after the material has been covered. In Alternative 1 (no action) only phase (1) applies; in Alternatives 2 through 6 all four phases apply.

Alternative 1 - no action

For this alternative a radon flux of $391 \text{ pCi/m}^2\text{s}$ exists on the approximately 116 acres of the site ($470,000 \text{ m}^2$). The total estimated radon release is $(391 \text{ pCi/m}^2\text{s}) (470,000 \text{ m}^2) (3.15 \times 10^7 \text{ s/yr}) = 5789 \text{ Ci/yr}$.

Alternative 2 - stabilization at Grand Junction

During the material moving operations it is assumed that all interstitial radon would be released. The total quantity of Rn-222 in equilibrium with Ra-226 is estimated to be 1820 Ci. Based on an average emanation coefficient of 0.2, the total radon that could be released from the interstitial spaces is 364 Ci.

The time period from the beginning of pile stabilization to complete cover placement is estimated to be 2.3 years (28 months). If the excavation rate is uniform then the area of excavated material would decrease linearly from $470,000 \text{ m}^2$ (116 acres) to zero over the 2.3-year period. The average radon flux from the material as it is excavated would be $391 \text{ pCi/m}^2\text{s}$.

During this same 2.3-year period, the excavated tailings would be stabilized on the site on an area of $304,000 \text{ m}^2$ (75 acres). Since the cover placement will lag behind the tailings placement by two months, 2/28 of the pile area ($21,700 \text{ m}^2$) would be uncovered at any time during remedial action. The stabilized pile construction sequence would be such that the 702 pCi/g material in the tailings pile would be overlain with the 90 pCi/g material from off-pile areas. The uncovered areas of the stabilized pile would emit radon with a flux that is proportional to the volume-weighted average Ra-226 concentration of 581 pCi/g . Since a radon flux to Ra-226 ratio of one $\text{pCi/m}^2\text{s}$ per pCi/g Ra-226 is assumed, the resulting average radon flux from the uncovered tailings would be $581 \text{ pCi/m}^2\text{s}$.

The radon flux from the covered areas of the stabilized pile would be 20 pCi/m²s plus one pCi/m²s background flux. This covered pile area would increase linearly from zero to 304,000 m² in 2.3 years.

The total radon source term can be described by the following equation:

$$\begin{aligned} & \left(\frac{3.15 \times 10^7 \text{ s}}{\text{yr}} \right) \left(\frac{391 \text{ pCi}}{\text{m}^2 \text{ s}} \right) \int_0^{2.3} \left(470,000 - \frac{470,000}{2.3} t \right) dt \\ & + 364 \text{ Ci} + \left(\frac{3.15 \times 10^7 \text{ s}}{\text{yr}} \right) \left(\frac{21 \text{ pCi}}{\text{m}^2 \text{ s}} \right) \int_0^{2.3} \left(\frac{304,000}{2.3} t \right) dt \\ & + \left(\frac{3.15 \times 10^7 \text{ s}}{\text{yr}} \right) \left(\frac{581 \text{ pCi}}{\text{m}^2 \text{ s}} \right) (21,700 \text{ m}^2) (2.3 \text{ y}) \\ & = 8165 \text{ Ci, where } t \text{ is time in years.} \end{aligned}$$

After remedial action, the radon flux from the 75-acre stabilized pile would be less than or equal to the EPA standard of 20 pCi/m²s plus one pCi/m²s background soil flux, or approximately 201 Ci/yr.

Alternatives 3 and 5 - relocation and stabilization at the alternate sites by truck

The contaminated material would be removed from the 470,000 m² Grand Junction site during a 2.7-year period (32 months). Assuming that the excavation rate is uniform, the pile area would be reduced linearly from 470,000 m² to zero. Since the radon flux is 391 pCi/m²s and 364 Ci of radon would emanate from the interstitial pore spaces, then the total radon source term can be described by the following equation:

$$\begin{aligned} & \left(\frac{3.15 \times 10^7 \text{ s}}{\text{yr}} \right) \left(\frac{391 \text{ pCi}}{\text{m}^2 \text{ s}} \right) \int_0^{2.7} \left(470,000 - \frac{470,000}{2.7} t \right) dt + 364 \text{ Ci} \\ & = 8179 \text{ Ci, where } t \text{ equals time in years.} \end{aligned}$$

After remedial action, the radon flux from the decontaminated Grand Junction site would be the normal background flux of one pCi/m²s. This would result in annual releases of 15 Ci.

Tailings disposal at the alternate sites would be concurrent with application of the radon barrier. The application of the radon barrier would lag behind the tailings placement by two months. As a result 2/32 of the 251,000 m² disposal site (approximately 15,700 m²) would have an uncovered radon flux of 581 pCi/m²s at any time during the remedial

action. The covered area of the pile would increase linearly during the 2.7 years of tailings and cover placement from zero to 251,000 m². This scenario and the resulting radon release can be described by the following equation.

$$\left(\frac{3.15 \times 10^7 \text{ s}}{\text{yr}} \right) \left(\frac{21 \text{ pCi}}{\text{m}^2 \text{ s}} \right) \int_0^{2.7} \frac{251,000}{2.7} t \, dt$$

$$+ (15,700 \text{ m}^2) \left(\frac{581 \text{ pCi}}{\text{m}^2 \text{ s}} \right) \left(\frac{3.15 \times 10^7 \text{ s}}{\text{yr}} \right) (2.7 \text{ yr})$$

$$= 1000 \text{ Ci; where } t \text{ is time in years.}$$

Once the entire pile has been relocated, the pile would contribute a yearly radon source term of 166 Ci.

Alternatives 4 and 6 - relocation and stabilization at the alternate sites by train

The radon source term at the Grand Junction site and at the alternate disposal sites for the train transport alternative would be identical to the radon source term as calculated for the truck alternative. An additional radon source term is considered at the railheads in Whitewater and Mack.

When the trains are loaded in Grand Junction all of the radon in the interstitial pore spaces would be released. The following analysis assumes that, on the average, the time period from train loading at Grand Junction to train unloading at the railheads is 24 hours. Each of the 650 train trips would, on the average, transport approximately 2.8 Ci Ra-226 (1820 Ci/650 trips). Each radioactive decay of Ra-226 will produce one atom of Rn-222 resulting in (2.8 Ci) (3.7 x 10¹⁰ atoms/Ci) (24 hours) (3600s/hr) = 8.95 x 10¹⁵ atoms Rn-222. By using a radon emanating fraction of 0.2 and a radioactive decay constant for radon of 2.09 x 10⁻⁶/s, it is estimated that 0.101 Ci of radon would be released per train load of tailings at the railheads. The total radon source term at the railheads is estimated to be 65.7 Ci.

I.4.2 Particulate release source term during remedial action

This section determines the magnitude of particulate releases from the Grand Junction site and the alternate disposal sites. The health impacts caused by particulate releases is shown to be small when compared to the health impacts from exposure to radon daughter inhalation. The particulate release source term is, however, a required input for the MILDOS code and thus, the resulting health impacts from the particulates are determined.

Alternative 1 - no action

Dust suspension due to wind erosion is the mechanism for mobilization of tailings material during the no action alternative. The total particulate source terms₁ as calculated by MILDOS are: 9.81×10^{-3} Ci/yr U-238 and 1.24×10^{-1} Ci/yr for Th-230, Ra-226, and Pb-210.

Alternative 2 - stabilization at Grand Junction

The particulate release radioactive source term may be estimated from the air quality data of Appendix D, Weather, Air Quality, and Noise. For the operations involving tailings movement, the resulting dust releases are estimated at 4.25×10^5 kg/yr. This dust release includes wind erosion. Assuming all of this dust contains the average Ra-226, Th-230, and U-238 concentrations estimated for the tailings, the radionuclide release would be:

$$\begin{aligned}\text{Ra-226 } (581 \times 10^{-12} \text{ Ci/g})(4.25 \times 10^8 \text{ g/yr}) &= 0.247 \text{ Ci/yr} \\ \text{Th-230 } (581 \times 10^{-12} \text{ Ci/g})(4.25 \times 10^8 \text{ g/yr}) &= 0.247 \text{ Ci/yr} \\ \text{Pb-210 } (581 \times 10^{-12} \text{ Ci/g})(4.25 \times 10^8 \text{ g/yr}) &= 0.247 \text{ Ci/yr} \\ \text{U-238 } (46 \times 10^{-12} \text{ Ci/g})(4.25 \times 10^8 \text{ g/yr}) &= 0.020 \text{ Ci/yr}\end{aligned}$$

Alternatives 3 and 4 - disposal at Cheney Reservoir by truck and rail

Approximately 3.15 kg/yr of particulates would be released for the truck transportation alternative. The radionuclide release at the Grand Junction site would be 0.183 Ci/yr for Ra-226, Th-230, and Pb-210; and 0.015 Ci/yr for U-238.

Approximately 5.07×10^5 kg/yr of particulates would be released at the Grand Junction site for the train transport alternative. The resulting radionuclide release at the Grand Junction site would be 0.295 Ci/yr for Ra-226, Th-230, and Pb-210, and 0.023 Ci/yr for U-238.

At the Cheney Reservoir site, 3.25×10^5 kg/yr of particulates would be released for both the truck and train transport alternatives. The resulting radionuclide release is 0.189 Ci/yr for Ra-226, Th-230, and Pb-210, and 0.015 Ci/yr for U-238.

During the train transport alternative, 3.67×10^5 kg/yr would be released at the railhead in Whitewater. The radionuclide release at Whitewater is 0.213 Ci/yr for Ra-226, Th-230, and Pb-210, and 0.017 Ci/yr for U-238.

Alternatives 5 and 6 - disposal at Two Road by truck and rail

Approximately 3.11×10^5 kg/yr of particulates would be released for the truck transportation alternative at the Grand Junction site. The radionuclide release at the Grand Junction site is 0.181 Ci/yr for Ra-226, Th-230, and Pb-210, and 0.0143 Ci/yr for U-238.

Approximately 5.04×10^5 kg/yr of particulates would be released at the Grand Junction site for the train transport alternative. The resulting radionuclide release at the Grand Junction site would be 0.293 Ci/yr for Ra-226, Th-230, and Pb-210, and 0.023 Ci/yr for U-238.

At the Two Road site, 3.19×10^5 kg/yr of particulates would be released for both the truck and train transport alternatives. The resulting radionuclide release is 0.185 Ci/yr for Ra-226, Th-230, and Pb-210, and 0.015 Ci/yr for U-238.

During the train transport alternative, 3.39×10^5 kg/yr of particulates will be released at the railhead in Mack. The radionuclide release at Mack is 0.197 Ci/yr for Ra-226, Th-230, and Pb-210, and 0.016 Ci/yr for U-238.

I.4.3 GAMMA RADIATION SOURCE TERM

The gamma radiation emissions from the Grand Junction site are described in Figure I.3.1. For persons farther than one km (0.6 mile) from the site, gamma radiation exposure is negligible. The average of 44 exposure rate measurements taken by FBDU (1981) in off-site locations is five uR/hr above background. This value was used in this appendix to estimate gamma exposure health effects for the no action alternative. Since the exposure rate is likely to increase as the contamination on the site is excavated and mounded, a reasonable average value of 10 uR/hr gamma exposure due to the site is applied.

For occupational workers on the site, the gamma radiation exposure is higher. Using the 581 pCi/g concentration of Ra-226 assumed for the on-site contamination, the average gamma radiation exposure rate can be estimated by the method of Schiager (1974): the gamma exposure rate (uR/hr) is 2.5 times the radium concentration (pCi/g). In this case $(2.5 \text{ (uR/hr)/(pCi/g)}) (581 \text{ pCi/g}) = 1450 \text{ uR/hr}$. This would be the hourly exposure to an unshielded worker on the site. The majority of workers would be enclosed in the cabs of trucks or other earth moving equipment. As an inch of iron reduces the gamma radiation by a factor of 10, a more likely exposure is 145 uR/hr. Also, the placing of cover on the contamination would reduce the gamma exposure rate by a factor of 10 per foot of soil; this again leads to the gamma exposure rate of 145 uR/hr as an appropriate upper estimate.

Following remedial action, gamma exposure rates would be at background levels (about 11 uR/hr) since sufficient cover would be applied to attenuate the gamma radiation.

I.4.4 ATMOSPHERIC DISPERSION OF RN-222

Atmospheric-dispersion calculations are used as the basis for estimating the environmental radiation dose (for individuals and populations) resulting from radon and radon daughters from uranium mill tailings piles. In this report, the computer code MILDOS was utilized to calculate the atmospheric dispersion of radon, and the doses received by individuals and the population during the various phases of the proposed alternatives. The results of the MILDOS runs are used in Section I.5.

The computer code MILDOS was developed by the NRC to estimate the impacts from radioactive emission from uranium milling facilities, based on the calculation procedures outlined in Appendix G of NUREG-0706 (NRC, 1980b) and in Chapter Two of the MILDOS user's manual (NRC, 1981a).

In MILDOS, emissions of radioactive materials from fixed-point sources or area sources are modeled using a sector-averaged Gaussian plume dispersion model. Exposure rates are presented for various source and receptor point locations. In order to run the code, four categories of inputs are required: source parameters, meteorological and population parameters, translocation parameters, and receptor parameters.

The first source parameter required is the number of sources of discrete effluents. This may be an actual number if there are fixed point sources or an assumed number for area sources. The number of sources of discrete effluents used for area sources is dependent upon the area of the source.² Each source considered may be no larger than 0.1 square kilometer (km^2) when input for MILDOS. Therefore, the number of sources should be chosen or assumed such that each one has an area no greater than 0.1 km^2 . As mentioned above, approximately 116 acres of the Grand Junction site contain contaminated materials. The 116 acres were divided into nine areas (Figure I.4.1). Figure I.4.1 was drawn so that the areas and their locations were representative of the tailings pile and perimeter, the ore storage area, the mill yard, the State of Colorado tailings repository, and the settling ponds. The coordinates (x = length, y = width, and z = height) of the midpoints of the nine source areas were input into MILDOS in units of kilometers. The areas of the sources are listed on the figure and were input in units of square kilometers.

At each of the alternate disposal sites, the stabilized pile will occupy 62 acres. Figure I.4.2 shows the area sources and the coordinates that were input into MILDOS.

The source terms from the preceding sections were recalculated and entered for a two-year interval as MILDOS calculates concentrations and doses on a two-year minimum time step. For example, a source term for each nuclide was calculated by taking the mean of the first and second years, and weighting by the area of each source.

The particle-size distribution for each source was matched with the appropriate set-number provided in the code and included in the source input. For example, particle-size distribution set-number three, which represents tailings characteristics, was entered.

The second group of parameters requires population and meteorological data for the site. The meteorological data required included the joint fractional frequency distribution of wind in a certain wind direction and in specific wind speed and atmospheric stability classes. These data were entered for the Grand Junction site along with the population distribution, for 16 wind sectors, out to a radius of 80 km from the site. The wind data are presented in Appendix D, Weather, Air Quality, and Noise.

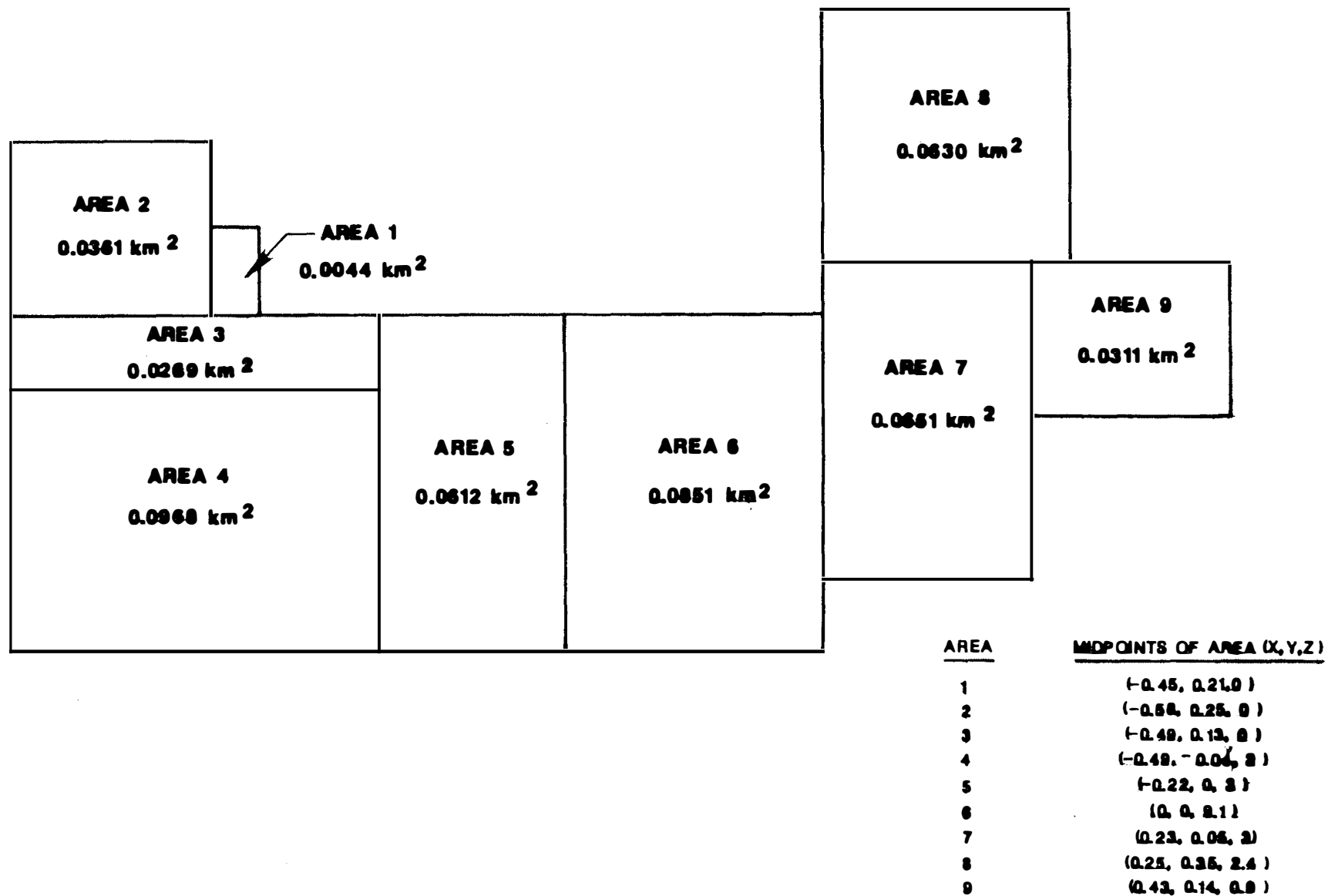


FIGURE I.4.1
SOURCE TERM GEOMETRY FOR
THE GRAND JUNCTION SITE

<u>AREA</u>	<u>MIDPOINTS OF AREA (X,Y,Z)</u>
1	-0.10988, 0.14264, 12
2	0.10988, 0.14264, 12
3	-0.10988, -0.14262, 12
4	0.10988, -0.14262, 12

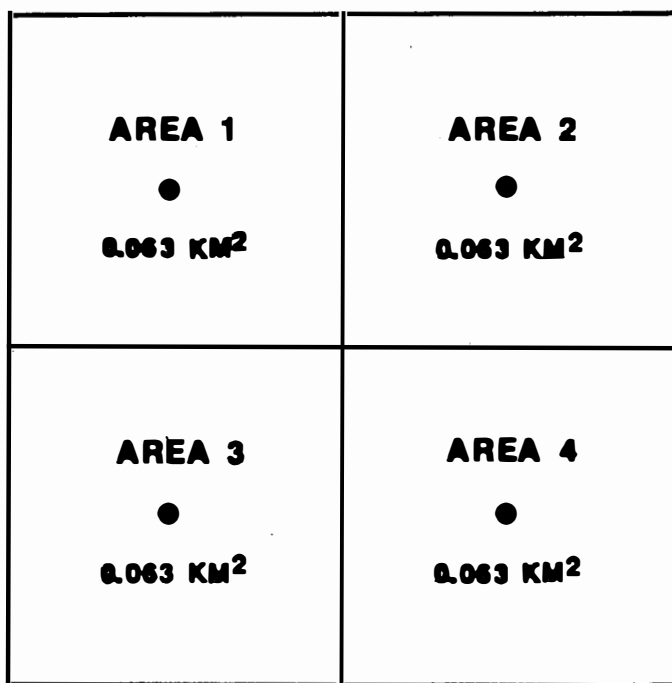


FIGURE I.4.2
SOURCE TERM GEOMETRY FOR TWO ROAD
AND CHENEY RESERVOIR

The third group of parameters required are the translocation parameters. These parameters, along with the meteorological data, determine the actual movement of the radionuclides once they leave the source. The input parameters for MILDOS that were used for food production are based on site-specific data and are listed in Table I.4.1.

The receptor parameters represent the final set of data required for the MILDOS code. Ten individual receptors for the Grand Junction site were located at a radius of approximately one km from the site boundary and compass directions of N, NE, E, SE, SSE, S, SSW, SW, W and NW.

I.4.5 ACCIDENT ANALYSES

This section considers accidents that might occur during the transport of tailings to the alternate sites. No accidents will occur in the no action alternative, and it is difficult to think of an accident occurring on the Grand Junction site which will have radiological consequences of any significance in relation to the radiological effect of the site itself. Accidents are considered explicitly for the train-transport option for moving the tailings to the alternate disposal sites; the impact of a truck transport accident is scaled according to the volume of material carried. Two kinds of accidents are considered: (1) the spill occurs on land and the tailings are dispersed by wind, and (2) the spill will fall into the Gunnison River.

I.4.5.1 Accidental spill of material on land

The potential impacts from a spill of material on land were calculated using a computer model "AIRREL" (an EPA certified computer model developed by Dames & Moore). AIRREL calculates the theoretical radiological impacts to an individual or to populations resulting from an accidental release of uranium mill tailings to the atmosphere. The particulates released in this fashion would be subject to transportation by prevailing winds to distances where they might become accessible to the surrounding population. The impacts incurred through this airborne transport mechanism are expressed in terms of the radiological dose that would be received by all individuals (cumulative dose) near the accidental release. The population dose is expressed in units of man-rem.

In the AIRREL code, the population dose is determined by multiplying the radionuclide concentration at a particular downwind distance by the dose conversion factor applicable to the radionuclide and body organ of interest and by the number of persons affected. In this program three radionuclides (U-238, Th-230, and Ra-226) and five body organs (whole body, bone, lung, liver, and kidney) are considered. Dose conversion factors obtained from the program MILDOS are used in the calculations. Up to 10 downwind locations and their respective populations can be considered in a single execution of the program.

Table I.4.1 MILDOS input parameters

Parameter	Grand Junction	Cheney Reservoir	Two Road
Fraction of annual feed that is pasture grass, for individual-dose calculations (FFORI) ^a	0.5	0.5	0.5
Fraction of annual feed that is pasture grass, for population-dose calculations (FFORP) ^a	0.5	0.5	0.5
Fraction of annual feed that is stored, for individual-dose calculations (FHAYI) ^a	0.5	0.5	0.5
Fraction of annual feed that is stored, for population-dose calculations (FHAYP) ^a	0.5	0.5	0.5
Areal vegetable production (FPR(1)) ^b	2212	2516	1602
Areal meat production (FPR(2)) ^b	2617	2918	2012
Areal milk production (FPR(3)) ^b	1497	1447	1597

^aDefault values from reference NRC, 1980a.

^bValues expressed in kilograms per year per square kilometer. Values for each site derived from county data on agricultural productivity within 80 kilometers (50 miles). Weighted productivities of vegetables, meat, and milk were calculated for each site region in terms of data for that fraction of each county that is within the region.

The radionuclide concentration at a particular location downwind from a ground-level point source is found using the basic atmospheric diffusion equation (AEC, 1967).

$$X = \frac{Q}{\sigma_y \sigma_z u \pi}$$

where

X = average centerline ground level concentration (Ci/m³)
 Q = radionuclide source term (Ci/sec)
 u = wind speed (m/sec) (u = 1 m/sec in the code)
 σ_y = horizontal standard deviation of plume (m)
 σ_z = vertical standard deviation of plume (m)
 π = 3.1416

The standard deviations sigma y and sigma z are measures of the spatial spread of the particulates plume as a function of downwind distance and meteorological stability class. In this program a Pasquill Type F stability class is assumed based on the recommendations of U.S. NRC Regulatory Guides 1.3 and 1.4. These standard deviations can be computed using the following empirical relations (NRC, 1980a).

$$\sigma_y = 0.04r (1 + 0.0001r)^{-1/2}$$

and

$$\sigma_z = 0.016r (1 + 0.0003r)^{-1}$$

where

r = the downwind distance in meters.

AIRREL expresses the population dose as follows:

$$\text{Dose}(r, n, \theta) = c(r, n) \times \text{DCF}(n, \theta) \times T/8760 \times \text{POP}(r)$$

where

Dose = radiological impact (man-rem)
 c = radionuclide concentration (pCi/m³)
 DCF = dose conversion factor (mrem/yr per pCi/m³)
 T = duration time (hours)
 POP = population count (number of individuals)
 r = downwind distance
 n = radionuclide "n"
 θ = body organ

For a land spill, a worst case accident would be a derailment of the unit train with a subsequent spill of material. As the train would contain 6200 tons of material (or a volume of 3900 m³), a full derailment was assumed to dump material over an area twice the ground area of the train. Assuming that the cars are two meters deep by three meters wide, a suspension rate as calculated by the MILDOS code of 1.44 x

10^{-5} g/m²s leads to estimated source terms for U-238, Th-230, and Ra-226 of 9300 pCi/hr, 1.18×10^5 pCi/hr, and 1.18×10^5 pCi/hr, respectively.

The one-hour doses to individuals at 0.1, 1.0, 2.0, and 10 km from this accident, as computed by AIRREL, are listed in Table I.4.2. An additional but smaller dose of less than 11 percent would be incurred if Pb-210 and Po-210 were considered (ANL, 1983).

These doses are insignificant compared to the doses received by workers on the site and by the population immediately surrounding the Grand Junction site, as could be guessed from the small quantity of tailings carried by each train and the limited time of exposure.

Scaling for a truck accident would be according to the ratio of (22 tons per truck/6200 tons per train) or 355×10^{-3} . This implies that the doses due to a truck spill would be more than 100 times smaller than the doses due to a train spill.

The probability of either accident is roughly 9×10^{-7} per mile traveled (SNL, 1982), or about 0.014 spills by rail transport to Two Road and 0.007 spills by rail transport to Cheney Reservoir during the 2.7 years of the relocation. Since these estimates are based on the frequency of injury and death accidents (SNL, 1982), it is clear that the major impact will not be radiological, but the actual injuries or deaths involved.

I.4.5.2 Surface-water transport accident

The transport of tailings by rail to Cheney Reservoir could result in a potential spill of the material carried in one or two of the gondolas into the Gunnison River since the train route is adjacent to the river for approximately 10 miles of the trip. This results in a total accident probability of 0.007 spills during the 2.7 years of relocation to the Cheney Reservoir site, which is a negligible chance.

In addition to the negligible probability, the consequences of such an accident would also be negligible. A similar accident was considered for the remedial action at the Durango uranium mill tailings site (DOE, 1984). This analysis showed that dilution and dispersion by the river would quickly reduce the insoluble radionuclide concentrations to well below the 10 CFR Part 20, Appendix B, Table B-11 maximum permissible concentrations for drinking water.

Table I.4.2 Doses due to a hypothetical accident

	Distance (m)	Dose (rem)				
		Whole body	Bone	Lung	Liver	Kidney
U-238	100	1.48E-10	2.501E-9	1.611E-8	0	5.69E-10
	500	6.74E-12	1.14E-10	7.34E-10	0	2.59E-11
	1000	1.95E-12	3.29E-11	2.12E-10	0	7.50E-12
	1500	9.88E-13	1.67E-11	1.08E-10	0	3.80E-12
	2000	5.03E-13	1.06E-11	6.82E-11	0	2.41E-12
Th-230	100	2.971E-8	9.44E-7	4.564E-7	5.432E-8	2.639E-7
	500	1.202E-9	4.298E-8	2.045E-8	2.473E-9	1.202E-8
	1000	3.47E-10	1.243E-8	6.013E-9	7.15E-10	3.475E-9
	1500	1.76E-10	6.299E-9	3.047E-9	3.63E-10	1.761E-9
	2000	1.12E-10	3.996E-9	1.932E-9	2.30E-10	1.117E-9
Ra-226	100	6.891E-9	6.891E-8	9.393E-7	8.95E-12	2.42E-10
	500	3.20E-10	3.199E-9	4.276E-8	3.92E-13	1.10E-11
	1000	9.08E-11	9.08E-10	1.237E-8	1.08E-13	3.19E-12
	1500	4.60E-11	4.60E-10	6.270E-9	5.74E-14	1.62E-12
	2000	2.92E-11	2.92E-10	3.976E-9	3.64E-14	1.03E-12

I.5 HEALTH EFFECTS

For each of the proposed alternatives for the Grand Junction tailings site, the information and calculations presented above are applied to give an estimate of the impact of the remedial action in terms of health effects in the general population and the remedial action workers.

I.5.1 ALTERNATIVE 1 - NO ACTION

Remedial action worker health effect

No remedial action workers are exposed to radiation under this alternative.

General population health effects from radon daughters and airborne particulates

Two methods are used to estimate these exposures. For the major portion of the population, the computer code MILDOS is used to provide estimates of the radon daughter and particulate exposures of the population. This code does not provide estimates within one km of the source, however. For the population within one km of the Grand Junction site, radon daughter and particulate concentrations are estimated using the Gaussian sector-average dispersion model modified to predict concentrations close to an area source.

Population within one km of the Grand Junction site

To estimate the health effects from radon daughter and particulate exposure for persons living or working within one km of the Grand Junction site, the following set of conservative assumptions were applied.

- o The entire population within one km of the Grand Junction site was exposed to the meteorological conditions of the northwest quadrant to which the winds blow the majority (44 percent) of the time.
- o The calculated site-average wind speed of two m/s was used.
- o The radon and airborne particulate concentrations at 0.5 km from the pile edge in the northwest quadrant were assumed to represent the average radon and particulate concentrations for the entire one-km distance interval.

It is believed that these assumptions will result in radon and particulate concentrations downwind that are higher than the actual concentrations.

The radon concentrations were determined by calculating the concentration for each of the six standard stability classes, weighting each

by frequency of occurrence, and summing the weighted values. The concentration 0.5 km from the northwestern pile edge was calculated by integrating the functional form of the vertical dispersion coefficient (σ_z in the Gaussian sector-average atmospheric dispersion model) as a function of distance from 0.5 km off the site back to the southeastern site boundary.

A radon flux of $391 \text{ pCi/m}^2\text{s}$ results in a radon concentration at 500 meters from the site boundary of 3.15 pCi/l . Assuming 25 percent equilibrium of the radon daughters in outdoor air and 50 percent equilibrium indoors at this close distance from the site boundary, the conversion factor $4.38 \times 10^{-4} \text{ rem/hr per pCi/l}$ may be applied (Section I.2.1).

The population living within one km of the Grand Junction site is 843 persons. Using a 2.7-year period of exposure for comparison to other alternatives, the population dose equivalent is $(843 \text{ persons})(3.15 \text{ pCi/l})(8760 \text{ hr/yr})(2.7/\text{yr})(4.38 \times 10^{-4} \text{ rem/hr per pCi/l}) = 2.75 \times 10^4 \text{ person-rem}$. Applying the lung cancer risk estimator $20 \times 10^{-6} \text{ cancer/person-rem}$ (Section I.2.1), gives an estimated excess of 0.550 lung cancer in this group.

The site-average release rate of particulates as predicted by the MILDOS code (Section I.4.2) translate into a flux of $(0.124 \text{ Ci/yr})(\text{yr}/3.15 \times 10^5 \text{ s})(10^{-12} \text{ pCi/Ci})(1/4.70 \times 10^{-5} \text{ m}^2) = 8.38 \times 10^{-3} \text{ pCi/m}^2\text{s}$ for Ra-226, Th-230, and Pb-210; and a flux of $(9.8 \times 10^{-3} \text{ Ci/yr})(\text{yr}/3.15 \times 10^5 \text{ s})(10^{-12} \text{ pCi/Ci})(1/4.70 \times 10^{-5} \text{ m}^2) = 6.62 \times 10^{-4} \text{ pCi/m}^2\text{s}$ for U-238.

Assuming that the particulates are transported in a manner similar to gaseous radon, the concentrations of particulates at 0.5 km from the Grand Junction site are $6.76 \times 10^{-2} \text{ pCi/m}^3$ for Ra-226, Th-230, and Pb-210, and $5.33 \times 10^{-3} \text{ pCi/m}^3$ for U-238. Using the dose conversion factors shown in Table I.5.1 and the site-specific particle size distribution (which indicates that at most 10 percent of the particles are smaller than 10 micron and are thus respirable), the predicted concentrations of radionuclides would result in a total individual dose equivalent to the lung of 31 mrem/yr. This results in a total health risk for the 843 persons living within one km of the Grand Junction site of $(843 \text{ persons})(31 \text{ mrem/yr})(2.7 \text{ yr})(20 \times 10^{-6} \text{ lung cancer/person-rem})(\text{rem}/1000 \text{ mem}) = 1.41 \times 10^{-3} \text{ fatal lung cancers}$. Since this risk is only 0.26 percent of the radon daughter lung cancer risk it is considered negligible and this pathway will not be considered for close-in populations for the other alternatives.

Table I.5.1 Average lung inhalation dose conversion factors
(mrem/yr per pCi/m^3)

Size	Nuclide			
	U-238	Th-230	Ra-226	Pb-210
0.5 um	1.24×10^3	1.38×10^3	2.84×10^3	3.30×10^2

Ref. NRC, 1981a.

Population beyond one km of the Grand Junction site

The computer code MILDOS was used to estimate population doses beyond one km from the Grand Junction site. The input data required for MILDOS have been described above (Section I.4.4). The output is summarized in Table I.5.2 for a 2.7-year exposure (comparable to the time for remedial action).

Table I.5.2 Summary of MILDOS results for the no action alternative for the population within 80 km of the Grand Junction site

Organ	Dose equivalent (person-rem)	Estimated excess cancer deaths
Whole body	502	0.060
Bone	820	ne ^a
Lung	629	ne ^a
Bronchial epithelium	21,400	0.427

^aNot estimated.

General population health effects from gamma radiation exposure

The population within one km of the Grand Junction site is 843 persons. The elevated gamma exposure rate is 5 uR/hr (Section I.4.3). The resulting population dose equivalent is $(843 \text{ persons})(5 \text{ uR/hr})(8760 \text{ hr/yr})(2.7 \text{ yr})(1 \times 10^{-6} \text{ rem/uR}) = 99.7 \text{ person-rem}$. The estimate of excess health effects is 0.012 cancer death.

I.5.2 ALTERNATIVE 2 - STABILIZATION AT GRAND JUNCTION

Remedial action worker health effects from radon daughter exposure

Worker exposure to radon daughters will occur at the Grand Junction site during excavation and stabilization of the tailings. A conservative assumption is that a radon concentration of 30 pCi/l will exist on the site (Section I.3.1). Radon daughter equilibrium is assumed to be 25 percent (Section I.2.1). The worker exposure hours required for this alternative total 542,020 person-hr. This worker exposure results in a dose equivalent commitment of $(542,520 \text{ person-hr})(30 \text{ pCi/l})(2.21 \times 10^{-4} \text{ rem/(hr-pCi/l)}) = 3597 \text{ person-rem}$. This corresponds to an estimated excess of 0.072 lung cancer death among the workers.

Remedial action worker health effects from gamma radiation exposures

Remedial action workers on the pile would be exposed to gamma radiation from tailings, as well as radon daughters. The estimated gamma exposure rate on the site in uR/hr is 2.5 times the average Ra-226 concentration in pCi/g (Schiager, 1974), or 1450 uR/hr based on the measured average Ra-226 concentration of 581 pCi/g (Section I.3.1). This is a highly conservative estimate and represents an upper limit which, in practice, is not expected to be reached. On a partially reclaimed portion of the tailings pile, the exposure rate would be reduced by a factor of 10 for each foot of cover material. The majority of workers will be enclosed in the cabs of earth moving equipment. This will provide shielding, reducing the exposure rate by a factor of 10 per inch of iron. A more realistic upper bound for the gamma exposure would therefore be 145 uR/hr.

It is possible to estimate the number of workers exposed during remedial action for two categories: (1) workers exposed on foot on bare tailings (1450 uR/yr), and (2) workers shielded by heavy equipment or tailings cover (145 uR/hr). It was assumed that the worker classifications of equipment operators and truck drivers will be afforded shielding equivalent to one inch of steel. The worker classifications of operator supervisors, laborers, general supervisors, and field service and supervisor/foremen will not be afforded shielding due to heavy equipment.

Table I.5.3 summarizes the number of worker hours in each of two exposure categories of the corresponding person - dose equivalents.

Table I.5.3 Worker hours per exposure category

Worker category	Worker hours	Dose equivalent (person-rem)
Unshielded (1450 ur/hr)	226,512	328
Shielded (145 ur/hr)	316,008	46
TOTAL	542,520	374

This total of 374 person-rem corresponds to an estimated excess 0.045 cancer death among the workers.

Remedial action worker exposure to particulates

Occupational exposures for remedial action workers breathing dust in the vicinity of earthmoving equipment may be estimated for comparison to the combined radon daughter exposure and gamma radiation exposure. A method proposed by NRC (1981b) was used to estimate doses from inhalation of particulates. These doses would be to the worker's lungs from inhalation of respirable particulates (<10 microns in size) that contain trace amounts of U-238, Th-230, Pb-210, and Ra-226. The equation used is:

$$H = (T_{sa} \times C_w \times PDCF_{air}) \text{ (NRC, 1981b)}$$

where

H = the 50-year dose commitment to the lung in mrem

PDCF_{air} = pathway dose conversion factor for air pathways (i.e., inhalation and direct radiation)

C_w = the radionuclide concentration in the material in pCi/m³

T_{sa} = soil-to-air transfer factor

The soil-to-air transfer factor, T_{sa}, may be expressed in terms of the geometry of the problem, the suspension flux (E), and the empirical equation (NRC, 1981b):

$$T_{sa} = \frac{ExGxfr}{uxd}, \text{ in m}^3 \text{ of soil per m}^3 \text{ of air (NRC, 1981b)}$$

where

E = suspension rate of transportation particulates (<30 microns) in units of g/m²sec

fr = fraction of suspended transportable particulates that are respirable (<10 microns)

G = geometry factor = (area subject to dusting)/(width of area x mixing height)

d = density of the soil (assume 1.6 g/cm³)

u = wind speed (m/sec); use 2.0 m/s

The following calculates the transfer factor for particulates from excavation for stabilization on the site. The total emission term for construction would be approximately 4.25 x 10⁵ kg/yr, based on the total TSP of 1053 tons for stabilization on the site divided by 2.25 years of tailings disturbance. The site consists of approximately 2116 acres of contaminated material or the equivalent of 4.7 x 10⁵ m² for the construction.

For the total particulate release rate of 4.25 x 10⁵ kg/yr, approximately 30 percent by weight would be in particles smaller than 30 microns. This assumes that the particle size distribution of initially suspended dust is proportional to the particle size distribution in the tailings and assumes that only a small fraction of the tailings mass is in particles too large to be disturbed by earthmoving equipment. The factor E is thus:

$$E = (0.3) \times (4.25 \times 10^5 \text{ kg/yr}) \times (1000 \text{ g/kg}) \times$$

$$(1 \text{ yr}/3.15 \times 10^7 \text{ sec}) \times \frac{1}{4.70 \times 10^5 \text{ m}^2} = 8.61 \times 10^{-6} \text{ g/m}^2 \text{ sec}$$

Roughly 30 percent of the particulates released will represent particles smaller than 10 microns. Thus the factor fr in this calculation is 0.3.

The geometry factor was calculated by assuming that the area of construction would be 116 acres or $4.70 \times 10^5 \text{ m}^2$, and that the mixing height would be three meters. The width of the area is best represented by the diameter of a circle whose area is $4.70 \times 10^5 \text{ m}^2$. The width of the area is then equal to 773 meters. These assumptions yield $G = 203$. Therefore:

$$T_{sa} = \frac{(8.61 \times 10^{-6} \text{ g/m}^2 \text{ sec})(203)(0.3)}{(2 \text{ m/sec})(1.6 \times 10^6 \text{ g/m}^3)} = 1.64 \times 10^{-10}$$

Table I.5.4 lists the occupational pathway dose conversion factors for the air pathways and also tailings concentrations (pCi/m^3) for Ra-226, Th-230, and U-238 at the Grand Junction site.

Table I.5.4 Occupational dose parameters

Nuclide	PDCF air (mrem-m ³ /pCi)	Concentration in soil ^a (pCi/m ³)
Ra-226	240	9.30×10^8
Th-230	106	9.30×10^8
U-238	936	7.36×10^7
Pb-210	31.2	9.30×10^8

^aAssumes a density of 1.6 g/cm^3 and concentrations of 581 pCi/g for Th-230 and Ra-226 and 46 pCi/g for U-238.

The calculated 50-year dose commitments to the lungs from Ra-226, Th-230, Pb-210, and U-238 from excavation at the Grand Junction site for the 2.3-year period are shown below. An assumption was made that a person would work eight hours a day, 240 days a year.

- a) 50-year dose commitment from Ra-226 to the lung from a one-year exposure is:

$$H = (1.64 \times 10^{-10}) \times 9.3 \times 10^8 \text{ pCi/m}^3 \times 240 \text{ mrem-m}^3/\text{pCi}$$

$$H = 36.6 \text{ mrem}$$

- b) 50-year dose commitment from Th-230 to the lung from a one-year exposure:

$$H = (1.64 \times 10^{-10}) \times 9.3 \times 10^8 \text{ pCi/m}^3 \times 106 \text{ mrem-m}^3/\text{pCi}$$

$$H = 16.2 \text{ mrem}$$

- c) 50-year dose commitment from U-238 to the lung from a one-year exposure:

$$H = (1.64 \times 10^{-10}) \times 7.36 \times 10^7 \text{ pCi/m}^3 \times 936 \text{ mrem-m}^3/\text{pCi}$$

$$H = 11.3 \text{ mrem}$$

d) $H = (1.64 \times 10^{-10}) \times 9.3 \times 10^8 \text{ pCi/m}^3 \times 31.2 \text{ mrem-m}^3/\text{Ci}$

$$H = 4.76 \text{ mrem}$$

Using the ICRP lung cancer risk factor of 20×10^{-6} per rem which is equivalent to the risk of 300×10^{-6} per WLM used for radon daughter exposure, and an average of 125 workers during the 2.3-year remedial action, the risk from a 50-year dose commitment of 68.9 mrem/person year is:

$$\left(\frac{68.9 \text{ mrem}}{\text{person yr}} \right) \left(\frac{\text{rem}}{1000 \text{ mrem}} \right) (2.3 \text{ yr}) (125 \text{ person}) \left(\frac{20 \times 10^{-6}}{\text{rem}} \right) = 3.96 \times 10^{-4}$$

This should be compared to the risks to the workers from exposure to radon daughters and gamma radiation. It was estimated in previous sections that the workers incur a total health risk of 0.117 cancer fatalities.

The calculations above show that for workers in the stabilization on site alternative, the risk from inhalation of particulates is 0.34 percent of that from the sum of the risks from exposure to gamma rays and radon daughters. Since this is considered a negligible health impact, the worker exposure to airborne particulates will not be considered for the other remedial action alternatives.

General population health effects from exposure to radon daughters and airborne particulates

The 843 persons living within one km of the Grand Junction site will be exposed to an average radon concentration of 1.93 pCi/l over the 2.3 years of tailings disturbance. This is based on an average radon flux of 240 pCi/m²s ((8165 Ci)(1/2.3 yr) (yr/3.15 x 10⁷ s) (1/470,000

m²) (10^{12} pCi/Ci)) as input into the modified Gaussian sector-average atmospheric dispersion model for this alternative. The population dose equivalent is (843 persons)(1.93₄ pCi/l)(4.38 x 10⁻⁴ rem/hr per pCi/l)(8760 hr/yr)(2.3 yr) = 1.44 x 10⁴ person-rem. Applying the lung cancer risk estimator of 20 x 10⁻⁶ cancer/person-rem gives an estimated excess of 0.287 lung cancers.

For the population beyond one km from the Grand Junction site, the population dose equivalent commitments during the 2.3-year remedial action as predicted by the MILDOS code are presented in Table I.5.5. The excess lung cancer death for this population is estimated to be 0.228.

Table I.5.5 Summary of MILDOS results for the stabilization on site alternative for the population within 80 km of the Grand Junction site

Organ	Dose equivalent (person-rem)	Estimated excess cancer deaths
Whole body	444	0.053
Bone	876	ne ^a
Lung	748	ne ^a
Bronchial epithelium	11,380	0.228

^aNot estimated.

General population health effects from gamma radiation exposure

As discussed for the no action alternative, direct gamma exposure due to the Grand Junction site is insignificant beyond one km. The gamma exposure rate for this and all action alternatives is assumed to be 10 uR/hr above background to take into account increases in exposure rate while the pile is excavated and mounded. Over the course of the 2.3 years of tailings stabilization, the excess gamma exposure rate will decrease roughly linearly to zero with time. Thus, the average excess gamma exposure rate will be approximately 5 uR/hr. The population dose equivalent is (5 uR/hr)(rem/10⁶ uR)(8760 hr/yr)(2.3 yr)(843 persons) = 84.9 person-rem. This results in a predicted 0.010 cancer death for the population within one km of the Grand Junction site.

I.5.3 ALTERNATIVES 3 AND 4 - DISPOSAL AT CHENEY RESERVOIR BY TRUCK AND BY TRAIN

Remedial action worker health effects from radon daughter exposure

Worker exposure to radon daughters will occur at Cheney Reservoir during disposal and at Grand Junction during excavation. A conservative assumption is that a radon concentration of 30 pCi/l will exist on the piles at both locations (Section I.3.1). Radon daughter equilibrium is assumed to be 25 percent (Section I.2.1). Two options are available for this alternative--truck or train transport of the tailings to Cheney Reservoir. Since the hours of worker exposure differ for the two options, the calculation of dose equivalent commitments is done separately for each option.

Truck haulage option

As given in Table I.5.6, the worker exposure hours required for this option total 938,918 person-hr. Radon daughter exposure during truck haulage of tailings is negligible due to the effective dilution and dispersion caused by the moving vehicle. The worker exposures result in dose equivalent commitments of $(938,918 \text{ person-hr})(30 \text{ pCi/l})(2.21 \times 10^{-4} \text{ rem/(hr-pCi/l)}) = 6225 \text{ person rem}$. This would result in 0.125 excess lung cancer death.

Train haulage option

As given in Table I.5.7, the worker exposure hours required for this option total 817,817 person-hr. Radon daughter exposure during train haulage of tailings is negligible due to the effective dilution and dispersion caused by the moving vehicle. The worker exposures result in dose equivalent commitments of $(817,817 \text{ person-hr})(30 \text{ pCi/l})(2.21 \times 10^{-4} \text{ rem/(hr-pCi/l)}) = 5422$. This would result in 0.108 excess lung cancer death.

Remedial action worker health effects from gamma radiation exposure

Remedial action workers on foot on bare tailings will be exposed to 1450 uR/hr and those afforded shielding by heavy equipment or cover will be exposed to 145 uR/hr as discussed above for Alternative 2.

For tailings transport by truck or train, workers on the vehicles will be exposed to elevated levels of gamma radiation. Exposures during transport may be conservatively estimated by using an exposure rate of 145 uR/hr in the occupied areas of a vehicle. This is based on assuming that the estimated 145 uR/hr near a large volume of tailings applies to a train or truck, and allowing a factor of 10 reduction to account for vehicle shielding of the workers.

Table I.5.6 Worker hours per exposure category for truck transport

Worker category	Worker hours	Dose equivalent (person-rem)
Unshielded (1450 uR/hr)	432,846	628
Shielded (145 uR/hr)	506,071	73
TOTAL	938,918	701

This total of 701 person-rem corresponds to an estimated excess 0.084 cancer death among the workers.

Table I.5.7 Worker hours per exposure category for train transport

Worker category	Worker hours	Dose equivalent (person-rem)
Unshielded (1450 uR/hr)	448,878	650
Shielded (145 uR/hr)	368,938	53
TOTAL	817,817	703

This total of 703 person-rem corresponds to an estimated excess 0.084 cancer death among the workers.

Truck haulage option

Table I.5.6 details the number of worker hours in each exposure category and the corresponding dose equivalents for the truck transport option.

Train haulage option

Table I.5.7 details the number of worker hours in each exposure category and the corresponding dose equivalents for the train transport option.

General population health effects from radon daughter and airborne particulate exposure

There are no residents within one km of the Cheney Reservoir site, thus population doses are predicted entirely by the MILDOS code. These

doses are summarized in Table I.5.8 for the truck transport and Table I.5.9 for train transport.

Table I.5.8 Summary of MILDOS results for the Cheney Reservoir truck transport alternative for the population within 80 km of the Cheney Reservoir site

Organ	Dose equivalent (person-rem)	Estimated excess cancer deaths
Whole body	30.4	0.004
Bone	190	ne ^a
Lung	52.3	ne ^a
Bronchial epithelium	257	0.005

^aNot estimated.

The excavation and transport of the tailings will take approximately 2.7 years. Over the course of this period, the tailings radon source term will decrease at the Grand Junction site as described in Section I.4.1. The average yearly radon flux of 205 pCi/m²s

$$((8179 \text{ Ci})(\frac{1 \text{ yr}}{1/2.7 \text{ yr}})(3.15 \times 10^7 \text{ s})(\frac{1}{470,000 \text{ m}^2})(1 \times 10^{12} \text{ pCi/Ci}))$$

will expose the 843 persons living within one km of the Grand Junction site to an average radon concentration of 1.65 pCi/l. The population dose equivalent is (843 persons)(1.65 pCi/l)(4.38 x 10⁻⁴ rem/hr/pCi/l)(8760 hr/yr)(2.7 yr) = 1.44 x 10⁴ person-rem. This would result in an estimated excess of 0.288 lung cancer death.

For the population beyond one km from the Grand Junction site, the population dose equivalent commitments predicted by the MILDOS code are presented in Table I.5.10 for the truck alternative and Table I.5.11 for the train alternative.

General population health effects from gamma radiation

Since no one lives close to the Cheney Reservoir site, only those persons living within one km of the Grand Junction site will be exposed to excess gamma radiation from the tailings. As discussed for the stabilization on site alternative, the excess gamma exposure rate will average 5 uR/hr above background. This results in a population exposure of (5 uR/hr)(8760 hr/yr)(2.7 yr)(843 persons)(rem/10⁶ uR) = 99.7 person-rem. The resulting number of excess cancer fatalities is 0.012.

Table I.5.9 Summary of MILDOS results for the Cheney Reservoir
train transport alternative for the population within
80 km of the Cheney Reservoir site

Organ	Dose equivalent (person-rem)	Estimated excess cancer deaths
Whole body	176	0.021
Bone	546	ne ^a
Lung	306	ne ^a
Bronchial epithelium	708	0.014

^aNot estimated.

Table I.5.10 Summary of MILDOS results for the Cheney Reservoir truck transport alternative for the population within 80 km of the Grand Junction site

Organ	Dose equivalent (person-rem)	Estimated excess cancer deaths
Whole body	356	0.043
Bone	704	ne ^a
Lung	597	ne ^a
Bronchial epithelium	10,940	0.219

^aNot estimated.

Table I.5.11 Summary of MILDOS results for the Cheney Reservoir train transport alternative for the population within 80 km of the Grand Junction site

Organ	Dose equivalent (person-rem)	Estimated excess cancer deaths
Whole body	559	0.067
Bone	1100	ne ^a
Lung	946	ne ^a
Bronchial epithelium	11,530	0.231

^aNot estimated.

General population health effects from transportation of tailings to Cheney Reservoir by truck and train

The exposure rate for people living along the shipping route during normal transport conditions can be determined according to the following equation (AEC, 1972; Dames & Moore, 1975; NRC, 1981b):

$$D(d) = \frac{2 K}{V} I(d)$$

where

$D(d)$ = total integrated dose at distance d , in mrem
 K = dose rate factor in mrem-ft² per hour
 V = shipment speed in feet per hour
 d = perpendicular distance of an individual from the shipment path, in feet

where

$$I(d) = \int_0^{\infty} \frac{(\exp(-ur)) B(r) dr}{dr (r^2 - d^2)^{1/2}}$$

and where u is the linear absorption coefficient for air in reciprocal feet (taken to be 0.00118 ft⁻¹ in this appendix), and $B(r)$ is the dimensionless Berger buildup factor in air given by the formula

$$B(r) = (1 + 0.0006 r)$$

where

r = is distance expressed in feet

For the transportation of the uranium tailings, the dose rate (K) was assumed to be 1.45 mrem-ft²/hr. This rate was based on the assumed EGR dose rate of about 1450 uR/hr (or 1.45 mrem/hr). The shielding effect of the truck or railroad-car sides was ignored.

A computer program TRADOS was developed to solve the integral and evaluate the population exposures.

For the truck alternative, the doses were calculated based on an average population density of 1098 person/mi², a vehicle speed of 10 mph, a transport distance of 20.3 miles, and 169,880 loaded truck trips. These assumptions yield a population dose equivalent of 0.906 person-rem which results in 1.09×10^{-4} total excess health effects for the population along the transportation corridor.

The train transport alternative actually involves 9.8 miles of truck transport and 10.5 miles of train transport. The average population density along the train route is 1276 persons/mi². Along the truck route the average population density is 106 persons/mi². Six hundred fifty train trips would be required and 169,880 truck trips would be necessary. Both truck and train are assumed to average 10 mph.

These assumptions yield a population dose equivalent of 0.044 person-rem which would result in 5.31×10^{-6} total excess cancer deaths from gamma radiation.

I.5.4 ALTERNATIVES 5 AND 6 - DISPOSAL AT TWO ROAD BY TRUCK AND BY TRAIN

Remedial action worker health effects from radon daughter exposure

Worker exposure to radon daughters would occur at Two Road during disposal and at Grand Junction during excavation. A conservative assumption is that a radon concentration of 30 pCi/l would exist on the piles at both locations (Section I.3.1). Radon daughter equilibrium is assumed to be 25 percent (Section I.2.1). Two options are available for this alternative--truck or train transport of the tailings to the alternate sites. Since the hours of worker exposure differ for the two options, the calculation of dose equivalent commitments is done separately for each option.

Truck haulage option

As given in Table I.5.12, the worker exposure hours required for this option total 933,502 person-hr. Radon daughter exposure during truck haulage of tailings is negligible due to the effective dilution and dispersion caused by the moving vehicle. The worker exposures result in dose equivalent commitments of $(933,502 \text{ person-hr})(30 \text{ pCi/l})(2.2 \times 10^{-4} \text{ rem/(hr-pCi/l)}) = 6189 \text{ person-rem}$. This results in 0.124 excess lung cancer death among workers.

Train haulage option

As given in Table I.5.13, the worker exposure hours required for this option total 868,510 person-hr. Radon daughter exposure during train haulage of tailings is negligible due to the effective dilution and dispersion caused by the moving vehicle. The worker exposures result in dose equivalent commitments of $(868,510 \text{ person-hr})(30 \text{ pCi/l})(2.21 \times 10^{-4} \text{ rem/(hr-pCi/l)}) = 5758 \text{ person-rem}$. This results in 0.115 excess lung cancer death among workers.

Remedial action worker health effects from gamma radiation exposure

Remedial action workers on foot on bare tailings will be exposed to 1450 uR/hr and those afforded shielding by heavy equipment or cover will be exposed to 145 uR/hr as discussed above for Alternative 2.

For tailings transport by truck or train, workers on the vehicles would be exposed to elevated gamma radiation. Exposures during transport may be conservatively estimated by using an exposure rate of 145 uR/hr in the occupied areas of a vehicle. This is based on assuming that the estimated 1450 uR/hr near a large volume of tailings applies to a train or truck, and allowing a factor of 10 reduction to account for vehicle shielding of the workers.

Table I.5.12 Worker hours per exposure category for truck transport

Worker category	Worker hours	Dose equivalent (person-rem)
Unshielded (1450 uR/hr)	415,949	603
Shielded (145 uR/hr)	517,553	75
TOTAL	933,502	678

This total of 678 person-rem corresponds to an estimated excess 0.0814 cancer death among the workers.

Table I.5.13 Worker hours per exposure category for train transport

Worker category	Worker hours	Dose equivalent (person-rem)
Unshielded (1450 uR/hr)	452,994	657
Shielded (145 uR/hr)	517,553	60
TOTAL	868,510	717

This total of 717 person-rem corresponds to an estimated excess 0.086 cancer death among the workers.

Truck haulage option

Table I.5.12 details the number of worker hours in each exposure category, for the truck transport option and the corresponding dose equivalent.

Train haulage option

Table I.5.13 details the number of worker hours in each exposure category, and the corresponding dose equivalents for the train transport option.

General population health effects from radon daughter and particulate exposure

As was the case at the Cheney Reservoir site, there are no residents within one km of the Two Road site, thus population doses are predicted entirely by the MILDOS code. These doses are summarized in Table I.5.14 for the truck alternative and Table I.5.15 for the train alternative.

Since the radon source term for this alternative is the same as the radon source term for the Cheney Reservoir alternative, the population dose equivalent of 1.44×10^4 person-rem is estimated for the population within one km of the Grand Junction site.

For the population beyond one km from the Grand Junction site, the population dose equivalent would be virtually the same as was predicted by the MILDOS code for the disposal at Cheney Reservoir alternative. This is because the time intervals for remedial action are the same, the radon source term which contributes the majority of the health risk is the same, and the particulate source term is only 1.15 percent less for the truck alternative or 0.645 percent less for train alternatives. These population dose equivalents are shown in Table I.5.16 for the truck transport alternative and Table I.5.17 for the train transport alternative.

General population health effects from exposure to gamma radiation

The general population dose equivalent from gamma radiation is 99.7 person-rem, the same as for the Cheney Reservoir disposal alternative. This is because no one lives within one km of the Two Road site, and the population exposure near the Grand Junction site occurs over the same time period of 2.7 years.

General population health effects from transportation of tailings to Two Road

The same model as was used for the Cheney Reservoir alternative is used to predict health effects for this alternative.

Table I.5.14 Summary of MILDOS results for the Two Road truck transport alternative for the population within 80 km of the Two Road site

Organ	Dose equivalent (person-rem)	Estimated excess cancer deaths
Whole body	23.7	0.003
Bone	221	ne ^a
Lung	30.2	ne ^a
Bronchial epithelium	411	0.008

^aNot estimated.

Table I.5.15 Summary of MILDOS results for the Two Road train transport alternative for the population within 80 km of the Two Road site

Organ	Dose equivalent (person-rem)	Estimated excess cancer deaths
Whole body	51.2	0.006
Bone	374	ne ^a
Lung	80.9	ne ^a
Bronchial epithelium	553	0.011

^aNot estimated.

Table I.5.16 Summary of MILDOS results for the Two Road truck transport alternative for the population within 80 km of the Grand Junction site

Organ	Dose equivalent (person-rem)	Estimated excess cancer deaths
Whole body	356	0.043
Bone	704	ne ^a
Lung	597	ne ^a
Bronchial epithelium	10,940	0.219

^aNot estimated.

Table I.5.17 Summary of MILDOS results for the Two Road train transport alternative for the population within 80 km of the Grand Junction site

Organ	Dose equivalent (person-rem)	Estimated excess cancer deaths
Whole body	559	0.085
Bone	1100	ne ^a
Lung	946	ne ^a
Bronchial epithelium	11530	0.340

^aNot estimated.

For the truck alternative, the doses were calculated based on an average population density of 1013 persons per square mile, a transport distance of 33 miles, an average vehicle speed of 10 mph, and 169,880 loaded truck trips. These assumptions yield a population dose equivalent of 1.36 person-rem which results in 1.63×10^{-4} total excess health effects for the population along the transportation corridor.

The train transport alternative actually involves 10.5 miles of truck transport and 22.6 miles of train transport. The average population density along the train route is 1396 persons/mi². Six hundred fifty train trips are required and 169,800 truck trips will be necessary. Both truck and train are assumed to average 10 mph. These assumptions yield a population dose equivalent of 0.074 person-rem which results in 8.88×10^{-6} total excess cancer deaths from gamma radiation.

I.5.5 HEALTH EFFECTS AFTER REMEDIAL ACTION

The estimated excess cancer deaths among members of the general population after remedial action are shown in Tables I.5.18 through I.5.23. The number of expected excess cancer fatalities are shown for 10, 100, and 1000 years following remedial action. These estimates do not include the health effects incurred during remedial action.

I.5.6 MAXIMALLY EXPOSED RESIDENT

The maximally exposed resident during remedial action would be one who lives about 200 feet from the northwestern corner of the Grand Junction site. The person might be exposed to 25 uR/hr in addition to background gamma radiation. This would yield a dose equivalent of $(25 \text{ uR/hr})(8760 \text{ hr/yr})(1 \times 10^{-6} \text{ rem/uR}) = 0.22 \text{ rem/yr}$.

The radon daughter exposure may be estimated to be 4.68 pCi/l. For a resident living full-time at this location, the radon concentration would result in a dose equivalent commitment of $(4.68 \text{ pCi/l})(2.21 \times 10^{-4} \text{ rem/(hr-pCi/l)})(8760 \text{ hr/yr}) = 9.1 \text{ rem/yr}$.

Health effects to a hypothetically maximally exposed individual

This section assesses the dose to an individual who at sometime in the future, builds a home on the unremediated tailings pile. It is assumed that this individual would eat only food raised on the pile, would drink water from a well in the shallow alluvium, and would spend 24 hours a day on the pile (eight hours indoors and 16 hours outdoors).

Health effects from radon daughter exposure

Radon and radon daughter products are assumed to be in 25 percent equilibrium in outdoor air; however, inside the house, the working level ratio is assumed to be 50 percent due to air stagnation. The dose equivalent from radon daughter inhalation would be $(30 \text{ pCi/l})(2.21 \times 10^{-4})$

Table I.5.18 Estimated excess cancer deaths in the general population after 10, 100, and 1000 years of no action

Time period (years)	Estimated excess cancer deaths
10	3.89
100	38.9
1000	389.0

Table I.5.19 Estimated excess cancer deaths after remedial action for the stabilization on site alternative^{a,b}

Time period (years)	Excess cancer deaths
10	0.161
100	1.61
1000	16.1

^aBased on a radon flux of 21 pCi/m²s from the Grand Junction site.

^bAssumes no elevated gamma exposure rate from the Grand Junction site.

Table I.5.20 Estimated excess cancer deaths after remedial action for the relocation to Cheney Reservoir by truck alternative^{a,b,c}

Time period (years)	Excess cancer deaths
10	0.011
100	0.106
1000	1.06

^aBased on a radon flux of 21 pCi/m²s from the Cheney Reservoir site.

^bAssumes no elevated gamma exposure rate from the Cheney Reservoir site.

^cAssumes a background radon flux from the Grand Junction site.

Table I.5.21 Estimated excess cancer deaths after remedial action for the relocation to Cheney Reservoir by train alternative^{a,b,c}

Time period (years)	Excess cancer deaths
10	0.011
100	0.106
1000	1.06

^aBased on a radon flux of 21 pCi/m²s from the Cheney Reservoir site.

^bAssumes no elevated gamma exposure rate from the Cheney Reservoir site.

^cAssumes a background radon flux from the Grand Junction site.

Table I.5.22 Estimated excess cancer deaths after remedial action for the relocation to Two Road by truck alternative^{a,b,c}

Time period (years)	Excess cancer deaths
10	0.019
100	0.187
1000	1.87

^aBased on a radon flux of 21 pCi/m²s from the Two Road site.

^bAssumes no elevated gamma exposure rate from the Two Road site.

^cAssumes a background radon flux from the Grand Junction site.

Table I.5.23 Estimated excess cancer deaths after remedial action for the relocation to Two Road by train alternative^{a,b,c}

Time period (years)	Excess cancer deaths
10	0.019
100	0.187
1000	1.87

^aBased on a radon flux of 21 pCi/m²s from the Two Road site.

^bAssumes no elevated gamma exposure rate from the Two Road site.

^cAssumes a background radon flux from the Grand Junction site.

rem/hr/pCi/l) (8 hrs/day) (365 day/yr) + (30 pCi/l) (4.42×10^{-4} rem/hr/pCi/l) (16 hrs/day) (365 day/yr) = 96.8 rem/yr. The estimated health risk from radon daughter inhalation would be (98.6×10^{-6} rem/yr) (20×10^{-6} lung cancer/person-rem) (1 person) = 1.94×10^{-3} lung cancer death per year.

Health effects from gamma radiation

While the individual is outdoors he would be exposed to 1450 uR/hr. If it is assumed that his house is made of six-inch-thick brick, then the indoor exposure rate would be approximately 440 uR/hr. The dose equivalent from direct gamma radiation would be (1450 uR/hr) (1×10^{-6} rem/uR) (8 hr/day) (365 day/yr) + (440 uR/hr) (1×10^{-6} rem/uR) (16 hr/day) (365 day/yr) = 6.80×10^{-6} rem/yr. The estimated health risk would be (6.80×10^{-6} rem/yr) (120×10^{-6} cancer/person-rem) (1 person) = 8.16×10^{-4} excess cancer death.

Health effects from inhalation of particulates

The dose to the individual living on the pile can be determined by scaling the dose received by a worker during the stabilization on the site alternative. The total particulate release to which the on-site individual would be subjected would be 1.69×10^4 kg/yr - the same as for no action. This release is ($1.69 \times 10^4 / 4.25 \times 10^5$) = 3.98 percent of the particulate release during stabilization on site. The workers, during stabilization on site, were assumed to be exposed during 24 percent of a year. The individual would be on the site all the time, therefore the appropriate scaling factor would be 4.17. Since the workers received a yearly dose equivalent commitment of 68.9 mrem the dose equivalent to the on-site individual would be (0.0689 rem)(4.17)(0.0398) = 1.14×10^{-2} rem/yr. The estimated health risk would be (1.14×10^{-2} rem/yr) (20×10^{-6} cancer/person-rem) (one person) = 2.29×10^{-7} lung cancer death per year.

Health effects from the consumption of contaminated food

In this section the dose to the hypothetical, maximally exposed adult individual from the ingestion of contaminated food is calculated. It is assumed that a single individual consumes vegetables, meat, and milk produced only on contaminated soil and that washing and cooking vegetables removes half of the radioactive contamination (NRC, 1980a). Only the doses from Ra-226, Th-230, and U-238 are considered since these nuclides generate the majority of the dose.

The whole body dose equivalent received from ingestion of plant material results from the concentration of radionuclides incorporated in plant tissue through root uptake and from particulate deposition on foliage from airborne dust. Radioactive concentrations in plants from root uptake are estimated from soil concentration data measured during the Grand Junction site radiological characterization and an adapted model from the U.S. Nuclear Regulatory Commission (NRC, 1980a). The dose equivalent from the dusting effect due to remedial action is established

by the model developed for radon concentrations close to the pile and the NRC model.

Wind action is expected to generate 1.69×10^4 kilograms per year (kg/yr) of particulates. Assuming that the particulates have the pile's average concentration of radionuclides, the flux of Ra-226 and Th-230 that is generated on the $470,000 \times 10^5 \text{ m}^2$ pile is:

$$1.69 \times 10^4 \frac{\text{kg}}{\text{yr}} \times \frac{\text{year}}{3.145 \times 10^7 \text{ sec}} \times \frac{1000 \text{ g}}{\text{kg}} \times \frac{581 \text{ pCi}}{\text{g}} \\ \times \frac{1}{470,000 \text{ m}^2} = 6.64 \times 10^{-4} \frac{\text{pCi}}{\text{m}^2 \text{ sec}}$$

and the flux of U-238 is:

$$1.69 \times 10^4 \frac{\text{kg}}{\text{yr}} \times \frac{\text{year}}{3.145 \times 10^7 \text{ sec}} \times \frac{1000 \text{ g}}{\text{kg}} \times \frac{46 \text{ pCi}}{\text{g}} \\ \times \frac{1}{470,000 \text{ m}^2} = 5.26 \times 10^{-5} \frac{\text{pCi}}{\text{m}^2 \text{ sec}}$$

The on-pile particulate concentrations were estimated by the Gaussian sector-average model modified to predict pollutant concentrations close to an area source. This resulted in particulate concentration values of $2.70 \times 10^{-2} \text{ pCi/m}^3$ for Ra-226 and Th-230, and $2.14 \times 10^{-3} \text{ pCi/m}^3$ for U-238.

The amount of radioactivity that is deposited on plant foliage plus the amount of radioactivity incorporated in plant tissue can be calculated by the following equation (equations 7 and 8 modified from NRC, 1980a):

Equation I.5.1

$$C_{vi} = X_i V_p \text{ Fr Ev} \left(\frac{1 - \exp(-w t_v)}{Y_v w} \right) + C_{si} BV_i$$

where

C_{vi} = the resulting concentration of isotope i in and on vegetation v (pCi/kg)

Ev = the fraction of the foliar deposition reaching edible portions of vegetation v

- Fr = the fraction of the total deposition retained on plant surfaces, 0.2 (NRC, 1980a)
- t_v = the assumed duration of exposure while growing for vegetation v (sec)
- Y_v = the assumed yield density of vegetation v, (kg/m²)
- w = the decay constant accounting for weathering losses, 6.73×10^{-7} /sec (NRC, 1980a)
- V_p = deposition velocity of particle size p, (m/sec)
- C_{si} = average concentration of the radionuclide in soil (pCi/kg)
- B_{vi} = soil-to-plant transfer factor
- X_i = air concentration of the ith radionuclide (pCi/m³)

The value of Ev is assumed to be 1.0 for all above-ground vegetation, and 0.1 for all below-ground vegetation. The value t_v is taken to be 60 days, except for pasture grass where a value of 30 days is assumed. The yield density, Y_v , is taken to be 2.0 kg/m² except for pasture grass where a value of 0.75 kg/m² is applied. The deposition velocity, V_p , is conservatively assumed to be 0.0883 m/sec for all particles. This corresponds to the settling velocity for particles ranging in size from 10 to 80 micro cm which represents the majority of the particles (NRC, 1980a). Soil-to-plant transfer factors, B_{vi} , are listed in Table I.5.24.

The concentrations on and in vegetation obtained from applying the appropriate parameters in Equation I.5.1 are listed in the first four columns of Table I.5.25. It is assumed that these concentrations in vegetables, hay, and pasture grass are uniform over the field where food for the maximally exposed individual is raised.

The yearly whole body dose equivalent to the maximally exposed adult individual due to consumption of contaminated plant material is calculated by multiplying the radioactive concentrations in Table I.5.25 by the food ingestion rates shown in Table I.5.26 and the dose conversion factors in Table I.5.27. This value is then divided by two since half the radionuclides are assumed to be removed during food preparation. Table I.5.28 shows the resultant whole body dose equivalents in mrem per year (mrem/yr).

The concentrations of radionuclides in meat and milk can be determined by the following equation (modified from NRC, 1980a):

Equation I.5.2

$$C_{bi} = 0.5 F_{bi} Q (C_{pgi} + C_{hi})$$

Table I.5.24 Environmental transfer coefficients

	U	Th	Ra
I. Plant/soil (B_{vi} 's) ^a			
a) edible above ground:	2.5×10^{-3}	4.2×10^{-3}	1.4×10^{-2}
b) potatoes:	2.5×10^{-3}	4.2×10^{-3}	3.0×10^{-3}
c) other below ground:	2.5×10^{-3}	4.2×10^{-3}	1.4×10^{-2}
d) pasture grass:	2.5×10^{-3}	4.2×10^{-3}	1.8×10^{-2}
e) stored feed (hay):	2.5×10^{-3}	4.2×10^{-3}	8.2×10^{-2}
II. Beef/feed (F_{bi} 's)			
pCi/kg per pCi/day:	3.4×10^{-4}	2.0×10^{-4}	5.1×10^{-4}
III. Milk/feed (F_{bi} 's)			
pCi/l per pCi/day:	6.1×10^{-4}	5.0×10^{-6}	5.9×10^{-4}

^aThese transfer coefficients are the dimensionless ratios of the concentrations of the radionuclides in vegetation (pCi/g) to the concentrations of the *i*th radionuclides in vegetation (pCi/g) to the concentrations of the *i*th radionuclides in soils (pCi/g).

Ref. NRC, 1980a.

Table I.5.25 Concentrations of radionuclides on and in vegetation, meat, and milk

	C_{vi} above- ground vegetables (pCi/kg)	C_{vi} below- ground vegetables (pCi/kg)	C_{pgi} pasture grass (pCi/kg)	C_{hi} hay (pCi/kg)	C_{bi} meat (pCi/kg)	C_{bi} milk (pCi/l)
Ra-226	8477	1777	11248	47985	755.1	873.5
Th-230	2784	2475	3220	2783	30.02	0.7504
U-238	142	117.7	176.8	142	2.711	4.685

Table I.5.26 Food ingestion rates

	Ingestion rates by age group			
	Infant	Child	Teen	Adult
I. Vegetables - total: (kg/yr) =	--	48	76	105
a) edible above ground:	--	17	29	40
b) potatoes:	--	27	42	60
c) other below ground:	--	3.4	5.0	5.0
II. Meat - beef, fresh pork, and lamb (kg/yr):	--	28	45	78
III. Milk (l/yr):	208	208	246	130

Ref. NRC, 1980a.

Table I.5.27 Ingestion dose conversion factors

Age group	Organ	Internal dose conversion factors by organ, mrem per pCi ingested		
		U-238	Th-230	Ra-226
Adult	whole body	4.54E-05	5.70E-05	4.60E-03
	bone	7.67E-04	2.06E-03	4.60E-02
	liver	0.00	1.17E-04	5.74E-06
	kidney	1.75E-04	5.65E-04	1.63E-04

Ref. NRC, 1980a.

Table I.5.28 Whole-body dose equivalents (mrem/yr)

	Above ground vegetables	Below ground vegetables	Meat	Milk
Ra-226	779.9	265.7	270.9	522.4
Th-230	3.173	4.584	0.1334	0.0056
U-238	0.1291	0.1737	0.0096	0.0287

where

C_{bi} = resulting average concentration of isotope i in meat or milk (pCi/kg)

C_{pgi} = concentration of isotope i in pasture grass (pCi/kg)

C_{hi} = concentration of isotope i in hay (pCi/kg)

F_{bi} = feed-to-meat or feed-to-milk transfer factor for isotope i (see Table I.5.24)

Q = assumed feed ingestion rate, 50 kilograms per day (NRC, 1980a)

0.5 = the fraction of annual feed requirement assumed to be satisfied by pasture grass or locally grown, stored feed (NRC, 1980a)

The results of applying the appropriate data in Equation I.5.2 are shown in columns five and six of Table I.5.25, and the resulting whole-body dose equivalents are listed in columns three and four of Table I.5.28. Dose equivalents are obtained by multiplying the values in Table I.5.25 by the annual adult consumption rates in Table I.5.26 and the whole-body dose conversion factors in Table I.5.27.

The total dose to the hypothetical, maximally exposed adult individual from Ra-226, ²³⁴Th-230, and U-238 is 1850 mrem/yr. The excess health risk is 2.22×10^{-4} .

Health effects from consumption of contaminated water

The following is one assessment of the radiological risk to the maximally exposed individual from drinking water drawn from beneath the tailings pile. The maximum radionuclide concentrations found in a well drilled through the pile were 305 pCi/l U-238 and U-234, and 18 pCi/l Ra-226. Lead-210 and thorium-230 were below the one pCi/l detection limit.

In the calculation, 50-year dose commitments were determined per year of exposure for all pertinent organs, which were total bone, endosteum, liver, kidney, and lung. An F_1 uptake to blood factor for uranium-238 and uranium-234 of 0.05 (Dunning, 1981; ICRP, 1981) was used. The F_1 factors used for other radionuclides were: radium-226 (0.2); thorium-230 (0.0002); and lead-210 (0.08) (Dunning, 1981; ICRP, 1959, 1981). The average daily water intake for an individual was assumed to be one liter/day. Dose conversion factors (DCF) in rem/microCi were taken from the report by Dunning (1981) and are summarized in Table I.5.29 for each target organ, using a radiobiological effectiveness factor (RBE) of 20 for alpha emitters. Table I.5.30 presents the 50-year dose commitments (DC-50) per year of consumption for each target organ, as calculated using the following formula:

Table I.5.29 Dose conversion factors for target organs (rem per microCi)

Target organ	U-238	U-234	Ra-226	Th-230	Pb-210
Total bone	7.0	7.8	43.0	1.2	21.0
Endosteum	2.8	3.6	20.0	16.0	9.6
Liver	0.013	0.016	0.60	0.22	1.4
Kidney	1.5	1.7	0.60	0.0043	0.94
Lung	0.015	0.017	0.60	0.0046	0.30

Table I.5.30 Fifty-year dose commitments per year of consumption of radionuclides in drinking water (mrem/yr)

Target organ	U-238	U-234	Ra-226	Th-230	Pb-210	Total
Total bone	779	868	283	0	0	1930
Endosteum	312	401	131	0	0	844
Liver	1.45	1.78	3.94	0	0	7.17
Kidney	167	189	3.94	0	0	360
Lung	1.67	1.89	3.94	0	0	7.50

$$DC-50 = (\text{concentration pCi/l}) \times \left(\frac{1 \text{ liter}}{\text{day}} \right) \times \left(\frac{365 \text{ days}}{\text{year}} \right) \times$$

$$\frac{(1 \text{ microCi})}{10^6 \text{ pCi}} \times (DCF) \times \frac{(1000 \text{ mrem})}{\text{rem}} = \frac{\text{mrem}}{\text{yr}}$$

Table I.5.31 presents the lifetime risk coefficients used for each target organ (NAS, 1980; Millard and Baggett, 1984) and also the resulting risk estimates from ingestion of the ground water in terms of individual organ risk per year of consumption. The individual organ risk was determined from multiplying the 50-year dose commitment per year of consumption (Table I.5.30) times the lifetime risk coefficient.

The total dose equivalent of 7.50 mrem/yr results in an estimated excess of 7.62×10^{-8} cancer fatalities. The resulting total risk to the maximally exposed individual from all exposure pathways is 2.99×10^{-3} cancer deaths per year of exposure. For an assumed lifetime of 70 years this individual would have approximately a one in five chance of dying from cancer.

I.5.7 HEALTH EFFECTS IN PERSPECTIVE

The health effects calculations presented in this appendix are summarized in Section 5.1.4 of the main text. For comparison to the impacts of remedial action, estimates of the collective dose equivalents due to natural radioactivity (which would result from continuous exposure at background levels) are presented in Table I.5.4. It is quickly seen that the incremental radiation dose equivalents due to remedial action are small by comparison to the dose equivalents resulting from natural radioactivity.

Table I.5.31 Summary of drinking water risk analysis

Target organ	Lifetime risk coefficient (risk/ 10^6 person-rem)	Individual organ risk per year of consumption (excess health effect $\times 10^{-6}$ per year)
Total bone ^a	1.9	3.67
Endosteum	1.9	1.60
Liver	30	0.215
Kidney	5.5 ^b	1.98
Lung	20 ^c	1.50
Total		7.62

^aTotal bone and endosteum risk coefficients were taken from the BEIR III report for a 7000 g bone, and modified to given average skeletal doses for a 5000 g bone by multiplying BEIR coefficient by 5000/7000.

^bThe risk coefficient for kidney was obtained by taking a ratio of low LET risk rate coefficients reported in the BEIR III report and multiplying by the high LET risk coefficient for liver.

^cThis risk coefficient was taken from Evans et al. (1981) and is equivalent to the lifetime risk coefficient of 300×10^{-6} deaths per person-WLM, where one WLM is approximately equal to a 15-rem dose equivalent commitment to the lung.

I.6 HEALTH EFFECTS AT VICINITY PROPERTIES

Inhalation of radon daughter products and direct exposure to gamma radiation are the exposure pathways considered in this section. Increases in airborne particulate concentrations are expected; however, the dose to individuals caused by this pathway would be insignificant when compared to radon daughter inhalation and direct gamma exposure. Just as for the on-site remedial action, exposures via ground or surface water will not have a significant impact on the general population.

I.6.1 RADIOLOGICAL IMPACTS OF THE REMEDIAL ACTION

The work called for in the remedial action would be similar to ordinary construction work and would consist of soil removal, decontamination of surfaces, and possibly demolition and replacement of some sidewalks and other structures. These activities might cause a small temporary increase in radioactivity levels by raising dust and bringing contaminated materials to the surface.

The storage of materials from the vicinity properties at the Grand Junction site would not appreciably increase the impacts of radiation already being emitted from the tailings site. The radioactivity-per-unit volume of the vicinity property materials would, in most cases, be lower than that of the material in the tailings pile.

The Grand Junction vicinity includes 2478 residences, 696 commercial properties, 13 complex properties, and 278 open lands that will be remediated during the 2.7-year Grand Junction site remedial action. Structural contamination occurs in 1038 of these properties. It is assumed that an average of four people spend 24 hours each day on each property. Therefore, 4152 people live on a property having structural contamination and 8596 people live on a property without structural contamination. It is further assumed that each person spends six hours a day outdoors and 18 hours a day indoors.

I.6.2 GENERAL POPULATION HEALTH EFFECTS FROM EXPOSURE TO GAMMA RADIATION

The excess dose equivalent due to gamma radiation is based on 17 uR/hr above background indoors and 62 uR/hr above background outdoors. These values represent the average of the high indoor gamma exposure rate and the average of the high outdoor gamma exposure rate once background exposure rates have been subtracted. It is assumed that the vicinity properties are remediated at a uniform rate and therefore the number of persons exposed on vicinity properties are estimated to decrease linearly from 12,748 to zero during the 2.7 years (23,652 hours) of remedial action. Since the time-weighted exposure rate indoors and outdoors is 28.3 uR/hr $((0.25 \times 62 \text{ uR/hr}) + (0.75 \times 17 \text{ uR/hr}))$ the excess dose equivalent received by the general population would be:

$$(28.3 \text{ uR/hr})(\text{rem}/1 \times 10^6 \text{ uR}) \int_0^{23,652} (12,748 \text{ persons} - \frac{17,748 \text{ persons}}{23,652 \text{ hours}} t) dt$$

= 4266 person-rem. This would result in 0.512 excess cancer death.

I.6.3 HEALTH EFFECTS TO REMEDIAL ACTION WORKERS FROM GAMMA RADIATION

The 654 workers are assumed to be exposed to gamma radiation 2000 hours per year for 2.7 years for a total of 5400 hours. Thirty percent of the properties have structural contamination, and it is estimated that these properties would take three times as long to remediate as those properties without structural contamination. Therefore, approximately 3035 hours would be spent on properties with structural contamination and 2365 hours would be spent on properties without structural contamination.

On properties without structural contamination, the workers would be exposed to a gamma exposure rate of 62 uR/hr. The worker dose equivalent commitment would be:

$$\frac{\text{rem}}{(62 \text{ uR/hr})(1 \times 10^6 \text{ uR})(654 \text{ persons})(2365 \text{ hours})}$$

= 95.9 person-rem.

On properties with structural contamination it is assumed that a worker is exposed to the indoor exposure rate half the time and the outdoor exposure rate half the time. The worker dose equivalent would be:

$$[(0.5)(62 \text{ uR/hr}) + (0.5)(17 \text{ uR/hr})] \times \frac{\text{rem}}{(654 \text{ persons})(3035 \text{ hours})(1 \times 10^6 \text{ uR})}$$

= 78.4 person-rem.

The excess health effects received on both categories of property would be:

$$(78.4 \text{ person rem} + 95.9 \text{ person rem}) \left(\frac{120 \times 10^{-6} \text{ cancer death}}{\text{person-rem}} \right)$$

= 0.021 cancer death.

I.6.4 GENERAL POPULATION HEALTH EFFECTS FROM RADON DAUGHTER INHALATION

The average radon daughter working level in properties with structural contamination is 0.013 above background. Assuming all properties are remediated at a uniform rate, then the 4152 exposed persons who occupy the structure 75 percent of the time would be reduced linearly to zero during the 23,652 hours of remedial action. The resulting population exposure would be:

$$(0.75)(0.013 \text{ WL})\left(\frac{\text{WLM}}{170 \text{ WL hr}}\right) \int_0^{23652} \left(4152 \text{ persons} - \frac{4152 \text{ persons}}{23652 \text{ hours}} t\right) dt$$

= 2816 person-WLM.

Using a risk estimate of 300×10^{-6} lung cancer deaths per person-WLM the total excess lung cancer risk for the general population would be:

$$(300 \times 10^{-6} \frac{\text{lung cancer}}{\text{person-WLM}}) (2816 \text{ person-WLM})$$

= 0.845 lung cancer death.

I.6.5 REMEDIAL ACTION WORKER HEALTH EFFECTS FROM RADON DAUGHTER INHALATION

The 654 remedial action workers would be exposed at structurally contaminated properties for 1518 hours assuming they work half of the time indoors. The resulting worker radon daughter exposure would be:

$$(0.013 \text{ WL})(654 \text{ persons})\left(\frac{\text{WLM}}{170 \text{ WL hr}}\right)(1518 \text{ hours}) = 75.9 \text{ person-WLM}$$

The estimated excess lung cancer among the workers would be:

$$(300 \times 10^{-6} \frac{\text{lung cancer}}{\text{person-WLM}}) (75.9 \text{ person-WLM}) = 0.023.$$

The average of the high indoor gamma exposure rate and the average working level on vicinity properties is already below the EPA standard before remedial action. After the contamination on these properties is removed, it is estimated that exposure to radiation on vicinity properties would not exceed background levels.

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APPENDIX J
SCENIC, CULTURAL, AND HISTORIC INFORMATION



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J.1 VISUAL RESOURCES

J.1.1 VISUAL CLASSIFICATION SYSTEM

The Bureau of Land Management (BLM) instituted a visual resource management (VRM) program in 1975 and has developed a system for evaluating visual resources and determining what degree of protection, rehabilitation, or enhancement is desirable and possible.

The VRM system is based on research that has produced methods of assessing the aesthetic qualities of the landscape in objective terms. Whatever the terrain and whoever the observer, the perception of visual quality in a landscape is based on several common principles:

- o The character of a landscape depends mainly on four basic visual elements: form, line, color, and texture. Although all four elements are present in every landscape, they exert varying degrees of influence.
- o The stronger the influence exerted by these elements, the more interesting the landscape.
- o The more visual variety in a landscape, the more aesthetically pleasing the landscape. Variety without harmony, however, is unattractive, particularly when changes in the landscape are made without care.

The inventory process in the VRM program consists of assessing three items:

- o The landscape's scenic quality.
- o The human sensitivity to changes in the landscape.
- o The viewing distance.

The information is then combined to identify areas with similar factors. These areas are assigned one of four VRM classes and maps are prepared of contiguous areas sharing the same VRM class. The Bureau of Land Management uses these maps to assess the visual impact of proposed developments. The four management classes as defined by the Bureau of Land Management (DOI, 1980) are briefly described below.

Class 1

Natural ecological changes and very limited management activity are allowed. Any contrast created within the characteristic landscape must not attract attention. This classification is applied to wilderness areas, wild and scenic rivers, and other similar landscapes.

Class 2

Changes in any of the basic elements (form, line, color, texture) caused by a management activity should not be evident in the characteristic landscape. Contrasts are seen; however, they must not attract attention.

Class 3

Contrasts to the basic elements caused by a management activity are evident; however, they should remain subordinate to the existing landscape.

Class 4

Any contrast attracts attention and is a dominant feature of the landscape in terms of scale; however, it should repeat the form, line, color, and texture of the characteristic landscape.

J.1.2 VISUAL CLASSIFICATION OF DISPOSAL AND BORROW SITES

The Colorado River Valley, and therefore the Grand Junction site, has a VRM classification of Class 4 assigned by the BLM.

The Cheney Reservoir site has been assigned to VRM Class 3 by the BLM, with Class 2 lands surrounding the area.

The Two Road site has been designated Class 3.

Vicinity properties include residential and commercial structures. The scenic values of the vicinity properties are typical of an urban setting. There are no formal VRM classifications for these properties.

The scenic values of the borrow sites vary. Those that are more remote are typical of rural scenic values in the area. Sites closer to communities are more typical of urban settings. The Colorado River Valley is considered by BLM to be VRM Class 4. Therefore, all the borrow sites, except the Unaweep site, would be Class 4. Unaweep Canyon is an area with high quality visual resources and has been assigned to VRM Class 2.

J.2 ARCHAEOLOGIC, CULTURAL, AND HISTORIC RESOURCES

J.2.1 PREHISTORY AND HISTORY

The cultural history of west-central Colorado is divided into the following periods (Viola and Firebaugh, 1983, Reed, 1984):

- Paleo-Indian (10,000 - 5500 B.C.)
- Archaic (5500 B.C. - 500 A.D.)
- Formative (500 - 1200 A.D.)
- Proto-historic (1200 - 1820)
- Historic (1820 - 1932)

During the Paleo-Indian Period, the area was used by small nomadic bands of people who hunted large game animals of the ice age, such as the woolly mammoth. Paleo-Indian hunters used distinctive, large-sized lanceolate or leaf-shaped projectile points (spear tips). Seasonal migration from place to place was characteristic of their lifestyle. Ground stone implements used to mill gathered seeds and vegetables may also be found at Paleo-Indian sites. In the study region, evidence of the Paleo-Indian Period consists of very limited fragmentary or isolated projectile-point finds. More extensive remains have been discovered elsewhere in North America. Sites of Paleo-Indian occupation may be present in the area but have yet to be discovered in the study region.

In the Archaic Period, nomadic groups continued to hunt and gather plant and animal foodstuffs; however, they explored a wider variety of species on a specialized seasonal cycle of migration. This shift in lifestyle is presumed to have resulted from a warmer and drier climate, probable higher population densities, the extinction of large game animals, and the appearance of different vegetation communities after the ice age. The Archaic people used large-sized projectile points, and stone-ground implements that are believed to indicate a greater reliance on a wide variety of plants. Evidence dating to the Archaic Period is plentiful in the study region. Small and large size artifacts consisting of chipped stone debris, tools, and hearths have been found, as have isolated artifacts. Habitation sites are rare. Archaic stage sites in west-central Colorado typically occur as open lithic scatters or rock shelters.

The Formative Period lifestyle consisted of growing such crops as corn, beans, and squash to supplement foodstuffs procured by hunting and gathering. The Formative people made discrete types of ceramics and lived in masonry or jacal surface structures or pithouses. There has been considerable discussion (Reed, 1984) as to which traditions (Anasazi or Fremont) influenced the inhabitants during this period. Reed rules out both Anasazi and Fremont traditions in west-central Colorado. The former is ruled out due to great variations in artifacts and architecture, and the latter due to lack of Fremont ceramics in the area. The quality of the data base on this period is considered poor (Reed, 1984). Formative sites yielding ceramics, masonry structures, or cultigens number less than 100.

The disappearance of the Formative Period brought a re-emergence of the nomadic Archaic-like lifestyle in the Proto-historic Period. Hunting and gathering were the primary subsistence base. The material culture was similar to the Archaic Period, except that the bow and arrow were used. The Ute lifestyle used temporary brush structures for protection. Later in the Proto-historic Period, the use of horses had a significant impact on the Utes, eventually permitting the use of the tipi and greater mobility. The Numic-speaking Ute reached the region between A.D. 1200 and 1400. The first Euroamerican observation of the Utes was in 1776 on the Dominguez-Escalante expedition. The Utes were the sole occupants of the area until their move to reservations in 1881. Ute artifact assemblages are similar to Archaic in terms of tools represented. It appears the Ute collected artifacts from pre-historic sites for reutilization. This, along with the use of horses which changed settlement patterns, and current land ownership patterns in the area, have been proposed as the reasons behind the relatively few definitive Ute sites.

After expulsion of the Utes to reservations, full scale settlement by Euroamericans ensued during the remainder of the historic period. Communities like Grand Junction were established in the latter part of the 19th century as ranches, farms, and irrigation networks were developed along major river valleys. Railroads and roads were built along the Colorado River and other routes by the early 20th century. Various cycles of mining and milling have taken place in the area. In the 1880s and later years, coal was important. Uranium and vanadium began to be mined and milled in the 20s and 30s. Euroamerican sites of this period include dwelling structures, rail and road beds, water control structures, and mining prospects.

J.3 PLACES OF ARCHAEOLOGIC AND HISTORIC INTEREST

An intensive review (Class I Inventory) of file data was conducted to identify known cultural resources in the vicinities of the proposed remedial action sites. In addition, pedestrian inventories (Class III Inventory) were conducted on the alternate sites. The data on cultural resources have been assembled by Viola and Firebaugh (1983) and GRI (1985).

J.3.1 GRAND JUNCTION SITE

A total of 74 cultural resources are known for the Grand Junction study area, a tract of nine square miles around the tailings pile. All of the resources are sites from the Historic Period. Most are structures (i.e., residences, stores, churches, and factories) and are associated with the city of Grand Junction or farming in the area. Other sites include parks, a monument, a tomb, railways, and the routes of Utes, a trapper, and explorers. Only six of the cultural resources have been evaluated in terms of eligibility for nomination to the National Register of Historic Places (NRHP). The building that houses the Grand Junction Post Office and the Mesa County Court House is listed on the NRHP. Three farm residences are considered eligible for nomination to the Register. The first sugar-beet refinery in Colorado was constructed in 1899 and portions were later converted to the uranium mill that produced the Grand Junction tailings pile. Information available to the present study indicates that the original site structures were demolished or extensively altered. The location itself, which also has been extensively disturbed, may be eligible for inclusion on the NRHP since the sugar industry was of major economic importance to Colorado. Additional, as yet unrecorded, historical sites are believed to exist near the Grand Junction site, as the area was involved in the early development of the city of Grand Junction.

The remains of the sugar beet factory and the site itself would be impacted by the remedial action. The SHPO has yet to determine the eligibility of the site for inclusion to the NRHP. A data recovery plan would be designed and implemented, in consultation with the SHPO, to mitigate any impacts if the site is eligible.

J.3.2 CHENEY RESERVOIR SITE

Two concentrations of cultural materials occur in the Cheney Reservoir study area. One occupies a low ridge that cuts diagonally (SW-NE) through the center of the site, and the other occurs in the southeast corner. The northern concentration is relatively sparse (a possible check dam suggests use of the area for horticulture). The southern concentration has a greater artifact density and includes numerous previously recorded sites.

Due to the continuous scatter between sites, a cluster approach for the southern sites has been recommended (GRI, 1985). This approach has been recommended due to the difficulty in defining individual sites. The

SHPO has determined that four lithic scatters need additional data. The other 19 sites are ineligible for inclusion to the NRHP. The four sites will be investigated for additional data to determine their significance. The additional data will be submitted to the SHPO for determination of eligibility. If the sites are eligible and if the Cheney Reservoir site is selected as the disposal site, a data recovery plan would be developed and implemented in consultation with the SHPO and BLM. This program would consist of mapping, collecting, and excavation of the eligible sites.

The Euroamerican cultural resources in the vicinity of the Cheney Reservoir site consist of an irrigation system that may be eligible for the NRHP; farm equipment and a related trail or ditch, which are probably not eligible for the NRHP; and a farm, a stock tank, and two reservoirs that have yet to be evaluated. The Euroamerican sites represent agricultural efforts during the Historic and Recent Periods. Large areas have been explored for cultural resources, and a high density of potentially significant cultural resources has been recorded in the vicinity of the Cheney Reservoir site. These sites would not be impacted by the remedial action, as they are outside the designated area to be used for disposal.

J.3.3 TWO ROAD SITE

Within the immediate vicinity of the Two Road site is one site determined by SHPO as eligible to the NRHP. The site consists of a campsite with lithic scatter and generally overlooks the east fork of Bitter Creek. No cultural resources would be impacted by disposal at the Two Road site.

J.3.4 VICINITY PROPERTIES

The majority of vicinity properties are younger than 50 years and are therefore ineligible to the NRHP. A cultural resource evaluation will be conducted for any vicinity property older than 50 years. Consultation with the SHPO will be conducted, as appropriate.

J.3.5 BORROW SITES

Cultural resource surveys have not been conducted for borrow sites. The 32 and C $\frac{1}{2}$ borrow sites are at existing commercial locations and these areas are not expected to yield cultural artifacts, since the areas have been previously disturbed. The borrow site in Unaweep Canyon has not been disturbed. Prior to surface disturbance, a Class III survey would be conducted at any borrow site. If cultural resources are present, the appropriate consultation with SHPO would be made. If cultural resources are determined to be eligible to the NRHP and if the sites would be impacted by excavation activities, a data recovery program would be designed and implemented.

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APPENDIX K
SOCIOECONOMICS AND LAND USE INFORMATION



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K.1 EXISTING SOCIOECONOMICS

K.1.1 POPULATION

In 1980 the population of the State of Colorado was 2,889,964, or 30.8 percent higher than the 1970 population. The urban population, 2,329,869, was 80.6 percent of the total and represented an increase of 34.4 percent since 1970. The Denver-Boulder Standard Metropolitan Statistical Area (SMSA), the largest population center in the state, had a 1980 population of 1,620,902, which was 56.1 percent of the state's population and represented an increase of 30.8 percent over 1970. About 28.8 percent of Colorado's population resides in the other four SMSAs (Greeley, Fort Collins, Colorado Springs, and Pueblo) which are in the center of the state near Denver (USDOC, 1981a).

Mesa County had a total 1980 population of 81,530 which was 2.8 percent of the state's population. As Table K.1.1 shows, the population of the county grew by about 50 percent during the 1970s. Estimates of the 1982 population by the Colorado West Area Council of Governments indicate continued rapid growth during 1980 and 1981. This growth may have abated, however, as the energy-related activity in the area has slowed. Grand Junction, with a 1980 population of 28,144, is the largest city in Mesa County. The populations of all the incorporated and census-designated places in the county are listed in Table K.1.1. The latest available Mesa County (Grand Junction) population estimate placed the county (city) population at 96,400 (31,500) in July, 1983 (USDOC, 1985; Colorado Department of Local Affairs, 1985).

Table K.1.2 displays population estimates and projections to the year 2000 for Mesa County; these data were developed by the State of Colorado Division of Local Government, using the Planning and Assessment System (PAS). These numbers indicate that current and future growth rates are not expected to keep pace with the 1970s. The average annual growth rate of 5.0 percent maintained during the 1970s is expected to fall to 2.3 percent and 0.4 percent for the 1980s and 1990s, respectively (Planning and Assessment System, 1984).

In 1980, the median age in Mesa County was 29.0 years. About 28.6 percent of the county's population was less than 18 years old, 60.7 percent was between the ages of 18 and 64, and 10.7 percent was 65 and older. Among the Spanish population, which constitutes 7.0 percent of the total, these figures were 41.7, 53.8, and 4.5 percent, respectively. Only 0.3 percent of the population is black. Although the numbers of males and females were about equal (49.5 versus 50.5 percent), the percentages differed substantially within age groups. Among those less than 18, males and females accounted for 51.7 and 48.1 percent, respectively; among those 18 to 65, these percentages were 49.7 and 50.3 percent; and among those 65 and older, they were 42.4 and 57.6 percent. The age, sex, and racial distribution of Mesa County is presented in Table K.1.3 (USDOC, 1981b).

The average household size in Colorado declined from 3.08 in 1970 to 2.65 in 1980. This trend was also reflected in Mesa County, where the average household size decreased from 2.97 in 1970 to 2.67 in 1980. Table K.1.4 summarizes household sizes for incorporated and census-designated places in the county (USDOC, 1971, 1982a).

Table K.1.1 Populations of Mesa County and incorporated and census-designated places in the county, 1982, 1980, and 1970

Place	1982 ^{a,b}	1980 ^c	1970 ^{b,c}
Mesa County			
Total	93,263 (+14.4%) ^d	81,530 (+49.9%) ^e	54,374
Urban	NA	59,664 (73.2%) ^f	25,994 (47.8%) ^f
Rural	NA	21,866 (26.8%) ^f	28,380 (52.2%) ^f
Clifton ^g	NA	5,223	ND
Collbran	380	344	225
DeBeque	326	279	155
Fruita	3,283	2,810	1,822
Grand Junction	29,556	28,144	20,170
Orchard Mesa ^g	NA	4,876	5,824
Palisade	1,746	1,551	874

^aEstimates for 1982 from the Colorado West Area Council of Governments (1982).

^bNA = not available; ND = not defined.

^cData for 1980 and 1970 from the 1980 Census of Population (USDOC, 1981a).

^dPercentage of increase over 1980 population.

^ePercentage of increase over 1970 population.

^fPercentage of total population in Mesa County.

^gCensus-designated place.

Table K.1.2 Population estimates and projections for Mesa County
1983-2000^a

	1983	1984	1985	1990	1995	2000
County total	95,223	95,183	96,174	100,419	103,008	104,478
Average annual change	-	(-0.04%)	(+1.04%)	(+0.88%)	(+0.51%)	(+0.29%)

^aEstimates and projections from Planning and Assessment System, State of Colorado, Division of Local Government, Department of Local Affairs, Demographic Section (1984).

Table K.1.3 Age, sex, and race distribution of the population of Mesa County, 1980^a

Age group	Total ^b			White ^b			Black ^b			Others ^c		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
Under 18	23,333	12,054	11,279	22,059	11,376	10,683	71	43	28	1,203	635	568
18-64	49,462	24,593	24,869	47,430	23,506	23,924	134	95	39	1,898	992	906
65 and over	8,735	3,704	5,031	8,601	3,642	4,959	9	4	5	125	58	67
Total	81,530	40,351	41,179	78,090	38,524	39,566	214	142	72	3,226	1,685	1,541

^aFrom U.S. Department of Commerce (USDOC, 1981b, Tables 44 and 45).

^bIncludes the population of Spanish origin, which totals 5743 in Mesa County.

^cIncludes American Indian, Asian, Pacific Islander, and others.

Table K.1.4 Average household size for Mesa County and for the incorporated and census-designated places with populations of 1000 or over in 1980^a

Place ^b	Average household size
Mesa County	2.67
Clifton	2.81
Fruita	2.88
Grand Junction	2.30
Orchard Mesa	2.93
Palisade	2.50

^aFrom U.S. Department of Commerce (USDOC, 1982a, Tables 34, 39, 43, and 44).

^bData for Collbran and DeBeque are not available because their 1980 populations were below 1000.

K.1.2 SOCIAL AND ECONOMIC STRUCTURE

Table K.1.5 presents a comparison of income by major industrial source for the State of Colorado and the United States. For the United States, the total earned income in 1980 was \$1.6 trillion. (Earned income is equal to labor and proprietors' income.) Colorado income during the same year was \$21 billion, or about 1.3 percent of the U.S. figure. In contrast with U.S. percentages, mining represents a much larger portion of the state's income than manufacturing. The percentages of all other industries are similar to those for the United States (USDOC, 1982b).

Table K.1.6 presents personal income (earned income plus dividends, interest, rent, and transfer payments) for the U.S. and Colorado. Total income is presented by place of work, whereas personal income is presented by place of residence (note residence adjustment). In 1980, the U.S. personal income was \$2.16 trillion, or \$9,511 per capita; in Colorado, it was \$29.1 billion, or \$10,033 per capita. Thus, Colorado per capita personal income was 5.5 percent higher than that of the United States (USDOC, 1982b).

As indicated in Tables K.1.7 and K.1.8 and Figure K.1.1, the economic structure of Mesa County differs substantially from that of Colorado and the United States as a whole. Earned income totaled nearly \$525 million, or 2.3 percent of the state total, and personal income was \$705 million, 2.4 percent of state personal income. Mining is a large income sector in Mesa County; it represents 11.4 percent of earned income compared with 4.9 percent for the state as a whole. Manufacturing is a very small segment of the economy in comparison with the state and national fractions (USDOC, 1982b). Table K.1.9, which shows retail sales in Mesa County and in the entire State of Colorado, indicates similar patterns in terms of the contribution of each industry to the local economic base; retail sales patterns additionally indicate that Mesa residents on average spend a larger share of their retail dollars on food and automobiles than do residents of the state as a whole. Grand Junction accounted for 78.5 percent of the county's \$1,016.7 million in retail sales during the July 1, 1982, to June 30, 1983, period (Colorado Department of Revenue, 1983).

The per capita personal income in Mesa County was \$8,630 in 1980, considerably below the state average of \$10,033 (USDOC, 1982b). Table K.1.10 shows projected indices for personal income and per capita personal income in Mesa County through the year 2000. In real terms, per capita personal income in Mesa County is expected to be below the 1980 level until 1990, then achieving a 5.1 percent increase by 2000 (Planning and Assessment System, 1984.)

Table K.1.11 displays data on commercial bank deposits in Mesa County over the 1970-1983 period. Total deposits increased by 464 percent over the period (from \$70.7 million to \$398.8 million), and the number of banks doubled. Per capita commercial bank deposits rose from \$1,300 to \$4,344 (234 percent) over the period (Denver Research Institute, 1984).

Table K.1.5 Labor and proprietors' income by place of work for the United States and the State of Colorado, 1975 and 1980^a (in thousands of dollars)

Income category	United States			Colorado		
	1975	1980	Percent	1975	1980	Percent
BY TYPE						
Wage and salary disbursements	800,828,000	1,348,605,000	--	9,973,922	19,027,041	--
Other labor income	64,489,000	137,058,000	--	671,845	1,632,794	--
Proprietors' income	89,327,000	126,032,000	--	1,360,641	1,994,569	--
Farm	23,927,000	18,858,000	--	472,527	375,768	--
Nonfarm	65,400,000	107,174,000	--	888,114	1,618,801	--
BY INDUSTRY						
Farm	30,264,000	29,247,000	1.8	560,566	507,432	2.2
Nonfarm	924,380,000	1,582,448,000	98.2	11,445,842	22,146,972	97.7
Private	750,299,000	1,320,946,000	82.0	8,741,361	18,036,441	79.6
Agricultural services, forestry, fisheries, and other	3,638,000	7,074,000	0.4	41,928	88,148	0.4
Mining	13,592,000	8,910,000	0.6	357,908	1,101,748	4.9
Construction	55,470,000	93,575,000	5.8	825,036	1,665,157	7.3
Manufacturing	240,674,000	416,136,000	25.8	1,835,319	3,747,337	16.5
Nondurable goods	89,057,000	146,245,000	9.1	690,164	1,178,125	5.2
Durable goods	151,617,000	269,891,000	16.7	1,145,155	2,569,212	11.3
Transportation and public utilities	70,293,000	124,745,000	7.7	924,204	1,937,878	8.6
Wholesale trade	63,961,000	111,235,000	6.9	796,724	1,536,167	6.8
Retail trade	98,135,000	156,114,000	9.7	1,342,615	2,386,700	10.5
Finance, insurance, and real estate	49,429,000	97,927,000	6.1	629,790	1,519,374	6.7
Services	155,107,000	285,230,000	17.7	1,988,837	4,053,932	17.9
Government and government enterprises	174,081,000	261,502,000	16.2	2,703,481	4,110,531	18.1
Federal, civilian	41,976,000	60,850,000	3.8	722,555	1,041,939	4.4
Federal, military	17,906,000	23,506,000	1.4	475,353	513,395	2.3
State and local	114,199,000	177,146,000	11.0	1,505,573	2,555,197	11.3

^aData from U.S. Department of Commerce (USDOC, 1982b, Tables 1 and 5).

Table K.1.6 Personal income for the United States and the State of Colorado, 1975 and 1980^a
(in thousands of dollars)

Income category	United States		Colorado	
	1975	1980	1975	1980
Total labor and proprietors' income ^b	954,644,000	1,611,695,000	12,006,408	22,654,404
Personal contributions for social insurance	-50,118,000	-87,370,000	-574,872	-1,127,363
Residence adjustment	-336,000	-439,000	-4,499	-7,486
Net labor and proprietors' income	904,190,000	1,523,886,000	11,427,037	21,519,555
Dividends, interest, and rent	176,145,000	342,503,000	2,183,356	4,366,690
Transfer payments	178,308,000	294,240,000	1,858,762	3,166,294
Personal income	1,258,643,000	2,160,629,000	15,469,155	29,052,539
Total population (thousands)	215,456.6	227,166.7	2,586.1	2,895.7
Per capita personal income (dollars)	5,842	9,511	5,982	10,033

^aData from U.S. Department of Commerce (USDOC, 1982b, Tables 1 and 5).

^bSee Table K.1.5.

Table K.1.7 Labor and proprietors' income by place of work for Mesa County, 1975 and 1980^a (in thousands of dollars)

Income category	1975	1980	Percent of 1980 Total
BY TYPE			
Wage and salary disbursements	198,440	446,451	--
Other labor income	14,387	40,053	--
Proprietors' income	23,458	38,124	--
Farm	4,762	2,904	--
Nonfarm	18,696	35,220	--
Total	236,285	524,628	--
BY INDUSTRY			
Farm	7,289	6,695	1.3
Nonfarm	228,996	517,933	98.7
Private	183,596	441,521	84.2
Agricultural services, forestry, fisheries, and others	816	1,459	0.3
Mining	13,509	60,074	11.4
Construction	24,346	56,338	10.7
Manufacturing	20,454	40,303	7.7
Nondurable goods	6,494	12,497	2.4
Durable goods	13,960	27,806	5.3
Transportation and public utilities	25,200	55,399	10.6
Wholesale trade	13,168	27,683	5.3
Retail trade	38,420	71,999	13.7
Finance, insurance, and real estate	7,712	22,344	4.2
Services	39,971	105,922	20.2
Government and government enterprises	45,400	76,412	14.6
Federal, civilian	11,883	21,445	4.1
Federal, military	543	652	1.2
State and local	32,974	54,315	10.4
Total	236,285	524,628	100.0

^aData from U.S. Department of Commerce (USDOC, 1982b, Tables 1 and 5).

Table K.1.8 Personal income for Mesa County, 1975 and 1980^a
(in thousands of dollars)

Income category	1975	1980
Total labor and proprietors' income	236,285	524,628
Personal contributions for social insurance	-12,022	-26,734
Residence adjustment	<u>-185</u>	<u>-3,221</u>
Net labor and proprietors' income	224,448	501,115
Dividends, interest, and rent	51,443	119,142
Transfer payments	<u>48,945</u>	<u>85,015</u>
Personal income	324,836	705,272
Total population (thousands)	63.3	81.7
Per capita personal income (dollars)	5,135	8,630

^aData from U.S. Department of Commerce (USDOC, 1982b, Table 5).

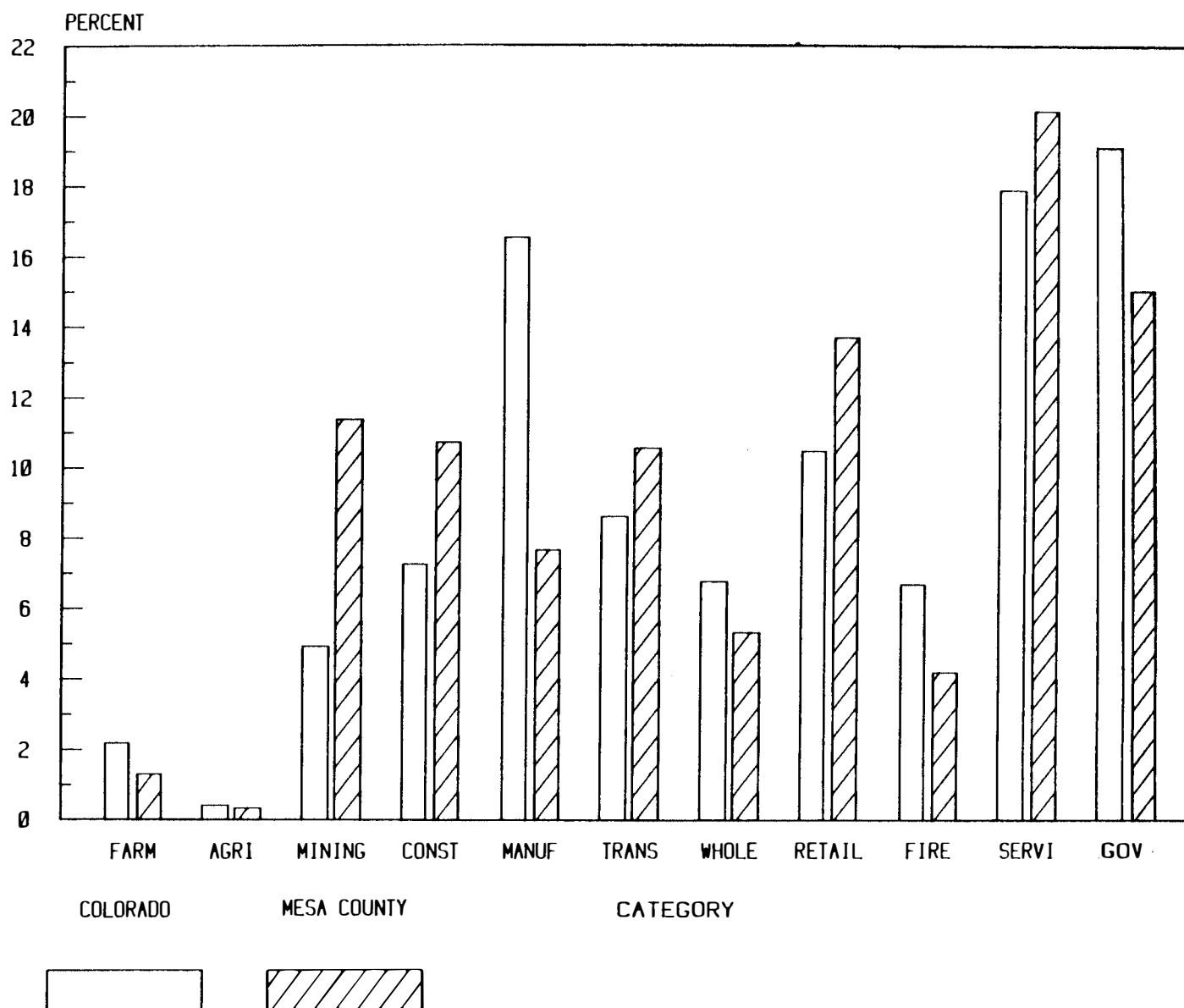


FIGURE K.1.1
STRUCTURE OF THE ECONOMY IN MESA COUNTY AND THE STATE OF COLORADO, 1980

Table K.1.9 Retail sales by business class for Colorado and Mesa County, July 1, 1982, to June 30, 1983^a

Business class	Colorado		Mesa County	
	Amount ^b	Percent ^c	Amount ^b	Percent ^d
Agriculture, forestry, and fisheries	\$ 95,329	0.29	\$ 1,112	0.10
Mining	185,637	0.56	7,303	0.72
Contract construction	673,230	2.06	53,371	5.25
Manufacturing	3,052,669	9.35	47,507	4.67
Transportation communication, electric, gas, and sanitary services	2,824,656	8.66	74,934	7.37
Wholesale trade	2,654,585	8.13	109,310	10.75
Building materials and farm equipment	1,561,826	4.79	54,617	5.37
General merchandise	1,967,613	6.03	51,131	5.03
Food stores	3,805,884	11.66	146,159	14.38
Auto dealers and service stations	4,983,963	15.27	165,195	16.25
Apparel and accessory stores	759,016	2.33	31,854	3.13
Furniture and home furnishings	903,606	2.77	28,091	2.76
Eating and drinking places	2,063,091	6.32	50,669	4.98
Miscellaneous retail stores	4,111,488	12.60	132,730	13.06
Finance, insurance, and real estate	183,780	0.56	1,764	0.17
Hotels and other lodging places	545,118	1.67	13,606	1.34
Services other than lodging	2,231,103	6.84	47,339	4.66
Government facilities	25,268	0.08	0	0
Nonclassifiable establishments	4,241	0.01	0	0
Total	\$32,632,103	100.0	\$ 1,016,691	100.0

^aFrom Colorado Department of Revenue, Annual Report, 1983.

^bThousands of dollars.

^cPercent of state total.

^dPercent of Mesa County total.

Table K.1.10 Index of personal income and per capita personal income
for Mesa County, 1980-2000 (1980=100)^a

	1980	1985	1990	1995	2000
Total personal income ^b	100.0	111.9	122.8	129.7	134.6
Per capita income ^b	100.0	94.8	99.7	102.7	105.1

^aObtained from data produced by the Planning and Assessment System, State of Colorado Division of Local Government, Department of Local Affairs, Demographic Section (1984).

^bIndices are based on 1983 dollars.

Table K.1.11 Commercial bank deposits in Mesa County, 1970-1983
(millions of dollars)^a

Commercial banks	June 30				December 31, 1983
	1970	1975	1980	1982	
IntraWest of Grand Junction ^b	\$25.9	\$ 44.0	\$100.3	\$119.9	\$111.1
First National	29.9	50.8	84.4	93.7	108.2
Mesa United	7.7	21.1	54.1	69.9	70.6
First National North	--	5.8	26.3	35.7	31.3
Colorado National - Orchard Mesa ^c	--	--	18.6	26.6	25.9
Fruita	4.3	7.8	15.3	22.0	20.3
Palisade National	2.9	4.2	8.6	15.8	18.2
Bank of Clifton	--	--	--	8.0 ^d	8.7
Bank of Grand Junction	--	--	--	--	3.3
Grand Valley National Bank	--	--	--	--	1.2
Total	\$70.7	\$133.7	\$307.3	\$383.6	\$398.8

^aFrom Polk's Bank Directory, selected years; Denver Research Institute, Facilitating Private Sector Capital Availability in Rapid Growth Communities, March, 1982; Denver Research Institute, Comparative Colorado Commercial Bank Deposits, January, 1984.

^bFormerly U.S. Bank of Grand Junction.

^cFormerly Bank of Orchard Mesa.

^dAs of December 31, 1982.

K.1.3 WORK FORCE

As shown in Table K.1.12, total employment grew by 13,789,300 (14.9 percent) in the United States and 304,300 (25.8 percent) in Colorado between 1975 and 1980. In this period, Colorado's share of national employment grew from 1.28 to 1.40 percent. Employment in Mesa County grew even more rapidly, rising from 27,684 to 38,105 (a 37.6 percent increase). In percentage of total state employment, the county grew from 2.3 percent in 1975 to 2.6 percent in 1980. Table K.1.13 summarizes employment by broad industrial sources in the county. In general, employment patterns reflect the income patterns described in Section K.1.2 (USDOC, 1982b).

Table K.1.14 presents trends in unemployment rates for Mesa County and the State of Colorado. The average annual unemployment rates for the county and state in 1983 were 11.7 percent and 6.6 percent, respectively. The unemployment rate in Mesa County was lower than that for the state as a whole during the 1975-1978 period. However, between 1979 and 1983 the county rate increase by 6.5 percentage points, while the rate for the state increased 1.8 percentage points. The large increase in the county rate during 1982 was due primarily to a slow down of oil shale development (U.S. Bureau of Labor Statistics, 1985).

The U.S. Department of Labor, Bureau of Labor Statistics, conducts monthly surveys to determine the unemployment rate in the county and in the state and counties. Because the sample is too small to provide direct local estimates for any but the 10 largest states, the Bureau uses a complicated procedure to estimate unemployment rates in states like Colorado. The estimated non-seasonally adjusted unemployment rate in Colorado for December, 1984, was 5.2 percent versus the U.S. rate of 7.0 percent. The corresponding rate for Mesa County was 10.0 percent. Thus, while unemployment in Colorado was substantially below that of the United States, the rate in Mesa County was considerably higher. This is due, in part, to the decline in the energy industry in the area (U.S. Bureau of Labor Statistics, 1985).

Table K.1.15 shows labor force and employment projections for Mesa County through the year 2000. Despite an expected rise in the labor participation rate from 47 percent to 49 percent, the rate of unemployment is projected to decline to a reasonably steady level of five percent by 1989 (Planning and Assessment System, 1985).

Table K.1.16 displays projections (on a percentage basis) for employment by sector in Mesa County through the year 2000. Wholesale/retail trade is expected to continue to employ the largest share of workers in the county. Mining and manufacturing sectors are expected to make the largest proportionate employment gains, while the proportions employed in the agriculture and government sectors are expected to make the largest declines (Planning and Assessment System, 1984).

The Colorado Division of Employment and Training collects data on the pay scales for more than 600 occupations and publishes them quarterly. Table K.1.17 presents the minimum, average, and maximum hourly wages offered for job openings in 13 occupations in Colorado State Planning Region 11 between July, 1984, and December, 1984; this region in-

Table K.1.12 Employment by type and broad industrial sources
in the United States and Colorado, 1975 and 1980^a

Type	United States		Colorado	
	1975	1980	1975	1980
Farm proprietors	2,888,000	2,771,000	29,617	28,488
Nonfarm proprietors	5,830,000	7,007,000	91,808	119,517
Total proprietors	<u>8,718,000</u>	<u>9,778,000</u>	<u>121,425</u>	<u>148,005</u>
Farm employees	1,360,000	1,336,300	18,077	20,068
Nonfarm employees				
Private				
Agricultural services	362,000	565,000	4,422	7,730
Mining	748,000	1,029,000	19,442	35,923
Construction	3,573,000	4,332,000	53,259	76,242
Manufacturing	18,320,000	20,375,000	138,013	179,852
Nondurable goods	7,626,000	8,124,000	55,843	63,496
Durable goods	10,674,000	12,251,000	80,170	116,356
Transportation and public utilities	4,550,000	5,156,000	59,547	77,726
Wholesale trade	4,427,000	5,291,000	57,239	75,498
Retail trade	12,715,000	15,086,000	179,106	230,631
Finance, insurance, and real estate	4,264,000	5,268,000	57,201	80,901
Services	15,882,000	19,395,000	201,112	265,999
Total private employees	<u>64,841,000</u>	<u>76,497,000</u>	<u>767,341</u>	<u>1,030,502</u>
Government				
Federal, civilian	2,895,000	2,988,000	49,562	51,654
Federal, military	2,566,000	2,451,000	56,625	45,842
State and local	12,243,000	13,362,000	168,467	189,725
Total government employees	<u>17,704,000</u>	<u>18,801,000</u>	<u>274,654</u>	<u>287,221</u>
Total nonfarm employees	<u>82,545,000</u>	<u>95,298,000</u>	<u>1,041,995</u>	<u>1,317,723</u>
Total employees	83,905,000	96,634,300	1,060,072	1,337,791
Total employment	92,623,000	106,412,300	1,181,497	1,485,796

^aFrom the U.S. Department of Commerce, Bureau of Economic Analysis (USDOC, 1982b).

Table K.1.13 Employment by type and broad industrial sources
in Mesa County, 1975 and 1980^a

Type	1975	1980
Farm proprietors	1,358	1,306
Nonfarm proprietors	<u>2,618</u>	<u>3,722</u>
Total proprietors	3,976	5,027
Farm employees	532	590
Nonfarm employees		
Private		
Agricultural services	106	117
Mining	884	2,354
Construction	1,678	2,738
Manufacturing		
Nondurable goods	604	711
Durable goods	1,605	1,911
Transportation and public utilities	1,744	2,343
Wholesale trade	1,128	1,592
Retail trade	4,830	6,747
Finance, insurance, and real estate	771	1,343
Services	<u>4,744</u>	<u>7,185</u>
Total private employees	18,094	27,041
Government		
Federal, civilian	776	1,038
Federal, military	275	226
State and local	<u>4,031</u>	<u>4,183</u>
Total government employees	5,082	5,447
Total nonfarm employees	<u>23,176</u>	<u>32,488</u>
Total employees	23,708	33,078
Total employment	27,684	38,105

^aFrom U.S. Department of Commerce (USDOC, 1982b). Bureau of Economic Analysis.

Table K.1.14 Percent unemployed in Mesa County and the State
of Colorado: 1975-1983

Year	Mesa County	State of Colorado
1983	11.7	6.6
1982	10.7	7.7
1981	5.9	5.5
1980	6.4	5.9
1979	5.2	4.8
1978	5.4	5.5
1977	5.4	6.2
1976	5.5	5.9
1975	6.1	6.9

Ref. U.S. Bureau of Labor Statistics, 1985.

Table K.1.15 Labor force and employment projections for Mesa County,
1985-2000^a

Item	1985	1986	1987	1988	1989	1990	1995	2000
Labor force	39,798	40,196	40,453	40,668	40,993	41,808	43,557	45,459
Employment	36,298	36,822	37,508	38,236	38,979	39,735	41,420	43,230
Unemployment	3,500	3,374	2,945	2,431	2,014	2,073	2,137	2,229
Unemployment rate	8.8%	8.4%	7.3%	6.0%	5.0%	5.0%	5.0%	5.0%
Labor partici- pation rate	47.4%	47.5%	47.4%	47.3%	47.3%	47.4%	47.6%	49.2%

^aFrom the Planning and Assessment System, State of Colorado, Division of Local Government, Department of Local Affairs, Demographic Section, 1985.

Table K.1.16 Projected employment by sector for Mesa County,
1985-2000, by percent of total employment^a

Sector	1985	1990	1995	2000
Agricultural proprietors	2.8	2.4	2.2	2.0
Agricultural labor	1.7	1.5	1.3	1.3
Mining	5.5	6.0	7.3	7.1
Construction	6.3	7.1	6.9	6.9
Manufacturing	6.3	6.7	6.7	6.9
Trans./comm./public utilities	6.2	6.0	6.0	6.0
Wholesale/retail trade	23.8	23.9	23.4	23.6
Finance/insurance/real estate	4.0	3.8	3.8	3.8
Services	19.2	18.8	18.7	18.9
Government	14.3	13.6	13.3	12.9
Other	<u>9.9</u>	<u>10.1</u>	<u>10.3</u>	<u>10.6</u>
Total	100.0	100.0	100.0	100.0

^aFrom the Planning and Assessment System, State of Colorado, Division of Local Government, Department of Local Affairs, Demographic Section, September 7, 1984.

Table K.1.17 Hourly wages for occupations that will be required for remedial action, Colorado State Planning Region 11, July, 1984-December, 1984^{a, b}

Occupation	Pay scale (dollars per hour) ^c		
	Minimum	Average	Maximum
Machinist	9.91	9.91	9.91
Construction-equipment mechanic	6.50	7.25	8.00
Diesel mechanic	1.92	4.21	6.50
Bulldozer operator I	12.50	12.50	12.50
Power-shovel operator	7.00	8.50	10.00
Operating engineer	4.00	8.72	10.00
Pipe fitter (construction)	13.50	13.50	13.50
Plumber (construction)	10.00	10.00	10.00
Construction worker I	3.13	5.44	12.33
Dump-truck driver	8.00	8.50	9.00
Tractor-trailer-truck driver	6.00	6.60	8.00
Heavy-truck driver	4.50	7.18	12.00
Front-end-loader operator	12.00	12.00	12.00

^aFrom Colorado Division of Employment and Training (1985, Table V, pp. 56-61).

^bColorado State Planning Region 11 encompasses Garfield, Mesa, Moffet, and Rio Blanco Counties.

^cThe amounts are based on the rates offered in the job openings received by the Division of Employment and Training for the July 1984 to December 1984 period.

cludes Mesa County. The average wage offer for a tractor-trailer truck driver, which will be one of the main occupations involved in the remedial action, was \$6.60 per hour. Other important occupations and their wage offers are construction-equipment mechanic, \$7.25 per hour, and bulldozer operator, \$12.50 per hour. In projects funded by the Federal Government, labor wages are determined by the U.S. Department of Labor under the Davis-Bacon Act (Colorado Division of Employment and Training, 1985).

K.1.4 HOUSING

There were 32,573 housing units in Mesa County in 1980, and about 4340 new units have been constructed recently, bringing the total to about 36,900 units (Table K.1.18). Rental units accounted for about 26 percent of the 1980 total, and the median rental price was \$225, compared with \$223 for the state. The rental vacancy rate in the county was 9.2 percent, slightly above the state rate of 8.8 percent (USDOC, 1982a; Colorado West Area Council of Governments, 1982).

The 1980 median values of owner-occupied housing for the state and Mesa County were \$64,100 and \$56,700, respectively. The vacancy rate was 3.4 percent in the county and 3.0 percent in the state. According to the Colorado West Area Council of Governments, the vacancy rate in the county for new units (rental and homeowner) was 3.5 percent (USDOC, 1982a; Colorado West Area Council of Governments, 1982).

The fact that the 1980 vacancy rates for both rental and owner-occupied housing were above the state rates indicates that there was a substantial supply of housing in the area at the time of the 1980 Census. Since then, the housing stock has increased by about 13 percent, partly in response to energy-related activities in the area. Because of the recent decline in the energy industry and the resulting drop in the demand for housing, vacancy rates may have increased.

K.1.5 GOVERNMENT

K.1.5.1 Government structure

All incorporated towns and census-designated places in Mesa County are listed in Table K.1.1. Census-designated places are unincorporated population centers that meet the Census Bureau's criteria for population density. The county government provides services for census-designated places as it does for all unincorporated areas. The county seat of Mesa County is Grand Junction.

Mesa County has three county commissioners and a clerk, treasurer, and assessor, and each official serves a four-year term of office. A county manager oversees finances and the provision of county services. The services provided include law enforcement, road construction and maintenance, planning and zoning, building and sanitary inspections, and a county-

Table K.1.18 1980 characteristics of housing in Mesa County and estimated new construction between 1980 and 1982^a

Place ^b	Total number of units	Number of year-round units	Number of occupied units	Owner occupied		Renter occupied		Vacant						Estimated new construction 1980-1982
				Number	Median value	Number	Median rent	Total	For sale		For rent		Other	
									Number	%	Number	%		
Mesa County	32,573	32,265	29,668	21,353	\$56,700	8,315	\$225	2,597	747	3.4	840	9.2	1,039	\$4,338
Clifton	2,053	2,048	1,861	1,512	49,400	349	259	187	56	36.0	57	14.1	74	NA ^c
Fruita	1,025	1,025	947	741	45,400	206	215	78	14	1.9	27	11.6	37	170
Grand Junction	12,706	12,692	2,706	16,493	49,700	10,567	217	926	193	1.2	467	4.2	226	646
Orchard Mesa	1,807	1,805	1,664	1,402	56,400	262	261	141	100	6.7	17	6.1	24	NA
Palisade	657	657	629	375	49,800	210	254	28	NA	NA	NA	NA	NA	86
State	1,194,253	1,168,681	1,061,249	684,408	64,100	376,841	223	107,432	21,255	3.0	36,222	8.8	49,955	NA

^aFrom U.S. Department of Commerce (USDOC, 1982a, Tables 1, 5, 31, 36, 37, 41, 45, and 46). New-construction estimates from the Colorado West Area Council of Governments (1982, p.3).

^bCensus data for places with 1980 populations of 1000 or more. These data are not available for Collbran and DeBeque because their 1980 populations were below 1000. New construction (1980-1982) for Collbran and DeBeque estimated at 15 and 19 units, respectively.

^cNA = Not available.

operated welfare program. The county also has a private museum, a library department, and a parks and recreation department (Norman, 1985).

Of the cities and towns in Mesa County, Grand Junction, Fruita, and Palisade have a council-manager form of government. DeBeque and Collbran share a manager and have separate councils. DeBeque and Palisade have governments organized according to Colorado statutes; Grand Junction and Fruita have developed home-rule charters. In addition to a mayor or manager, all of the towns have six council members. The council members are elected at large and serve a four-year term of office. The city managers and mayors also serve four years, except in Fruita, where the mayor serves for two years (Norman, 1985).

K.1.5.2 Fiscal characteristics

Local government revenues and expenditures for Mesa County are presented for fiscal year 1982 in Tables K.1.19 and K.1.20, respectively. Local governments include county, city, and special district governments in the geographical area. The data in Table K.1.19 provide a general understanding of revenue sources and types of expenditures within Mesa County and the city of Grand Junction. The total figures for all local governments in the state are also given for comparison.

The amount of general revenue received in 1982 by local governments in Colorado was approximately \$4.7 billion. Local government general revenues in Mesa County totaled \$105.7 million. For the state as a whole, local governments received 28.7 percent of all general revenues in the form of intergovernmental grants. In Mesa County, local governments received 36.1 percent of all general revenues in the form of intergovernmental grants (USDOC, 1984a). Grand Junction received 9.4 percent of its municipal revenues through state and Federal intergovernmental grants (USDOC, 1984b).

The tax structure affecting residents of Grand Junction is built primarily on sales and property taxes. The city sales tax rate is two percent; combining this rate with the Mesa County rate (two percent) and the state rate (three percent) results in a total sales tax rate in Grand Junction of seven percent. The nearby towns of Fruita and Palisade also have city sales tax levies in effect; however, the rate is one percent (Cleaver, 1985).

The property tax mill levies for the Mesa County government and Grand Junction City government are 17.64 and 8.00 mills, respectively. The mill levies for the city governments of Fruita, Palisade, DeBeque, and Collbran are 17.80, 17.84, 15.0, and 17.0 mills, respectively. The mill levy for the Mesa County Valley School district, the district serving Grand Junction, is 52.11 mills. Other special districts have mill

Table K.1.19 General revenues for local governments in Colorado,
Mesa County, and Grand Junction, fiscal year 1982

Type of revenue	Total for state ^a	Mesa County area ^{a,b}	Grand Junction ^c
Intergovernmental revenues			
Total (millions of dollars)	1,344.2	38.1	1.6
Portion received from the Federal Government (percent)	19.1	15.0	46.3
Taxes			
Total (millions of dollars)	1,752.4	38.5	9.6
Property tax, per capita (dollars)	417.0	357.0	N/A
Total (millions of dollars)	4,686.1	105.7	17.1

^aData from U.S. Department of Commerce (USDOC, 1984a).

^bFrom U.S. Department of Commerce (USDOC, 1984b).

^cIncludes only the Grand Junction municipal government revenues; data from U.S. Department of Commerce (1984b).

Table K.1.20 Direct general expenditures for local governments
in Colorado, Mesa County, and Grand Junction,
fiscal year 1982

Type of expenditure	Total for state ^a	Mesa County area ^{a,b}	Grand Junction ^c
Total (millions of dollars)	4,372.2	106.1	14.1
Per capita (dollars)	1,324.0	1,306.0	505.9
Education (percent)	34.5	41.6	--
Highways (percent)	5.4	6.5	17.5
Public welfare (percent)	5.6	7.3	--
Health and hospitals (percent)	5.4	1.7	--

^aData from U.S. Department of Commerce (USDOC, 1984a).

^bFrom U.S. Department of Commerce (USDOC, 1984b).

^cIncludes only the Grand Junction municipal government expenditures; data from U.S. Department of Commerce (USDOC, 1984b).

levies designed to meet specific needs; however, they are restricted to small geographical areas (Cleaver, 1985).

Total local government expenditures in Colorado in 1982 were over \$4.7 billion. In Mesa County, local government expenditures were \$106.4 million. The county local government expenditure of approximately \$1,306 per person was lower than the statewide figure of \$1,324. The Grand Junction municipal government spent \$506 per city resident. The government in Mesa County allocated 41.6 percent of 1982 expenditures to education, 6.5 percent to highways, and 7.3 percent to public welfare. The percentage of 1982 funds allocated to health and hospitals statewide was larger than the percentage allocated by the local governments in Mesa County (USDOC, 1984a,b).

The 1982 budget figures for Mesa County showed a deficit, with \$36.5 million in revenues and \$37.4 million in expenditures. Property taxes in 1985 were estimated to be \$8.1 million, or 22 percent of revenues (Morgan, 1985). The 1985 budgetary revenues and expenditures for Grand Junction were estimated at \$47.9 million and \$33.8 million, respectively; the total revenue figure includes \$9.6 million designated as reserves or earmarked for projects beyond 1985 (Cleaver, 1985).

K.1.6 COMMUNITY SERVICES

K.1.6.1 Education

While the number of primary and secondary school teachers in the United States fell by 2.5 percent, from 2,171,753 to 2,117,057 between the 1974-75 and the 1983-84 school years, the number in Colorado grew from 26,279 to 28,417, an increase of 8.1 percent. During the same period, average salaries rose from \$11,650 to \$22,019 in the United States, an 89.0 percent increase, and from \$10,930 to \$23,276 in Colorado, a 113.0 percent increase (Colorado Department of Education, 1984a, p.1). For the three school districts in Mesa County, average teacher salaries for the 1983-1984 school year varied from \$17,306 in the DeBeque School District to \$20,382, in the Mesa County Valley District (Table K.1.21).

The state student-to-teacher ratio during the 1983-1984 school year was 17.1; it was 8.6 in DeBeque, 13.8 in Plateau Valley, and 19.0 in Mesa County Valley. The number of students enrolled during the 1984-1985 school year was lowest in DeBeque (113) and highest in Mesa County Valley (15,581); the total number of students in the county was 16,053, which was 2.9 percent of the state total (Colorado Department of Education, 1985, 1984a).

The revenue sources for the three school districts in Mesa County and for all the school districts in Colorado for the calendar year 1983 are presented in Table K.1.22. For the state's school districts as a whole, property taxes provided

Table K.1.21 Selected statistics for students, teachers, and professional staff
in the school districts of Mesa County^a

School district	Fall membership			Teachers 1983-84		Professional staff		Student:teacher ratio (1983-84)
	1984	1983	1981	Number ^b	Average salary (\$)	Number ^b	Average salary (\$)	
DeBeque	113	126	168	14.6	17,306	17.1	18,381	8.6
Plateau Valley	359	358	417	26.0	18,358	31.0	19,170	13.8
Mesa County Valley	15,581	16,460	15,826	863.7	20,382	993.7	21,698	19.0
County total	16,053	16,944	16,411	904.3	19,747	1,011.8	21,568	18.7

^aData from Colorado Department of Education (1982, 1984b).

^bNumber of full-time-equivalent (FTE) personnel.

Table K.1.22 Revenues for school districts in Mesa County, calendar year 1983^a

School district ^b	Source of revenue					Total
	Local property tax	Other local taxes	County total	State total	Federal total	
DeBeque						
Revenues (\$)	528,265	149,116	0	126,255	10,751	814,387
Amount per ADAE (\$)	3,980	1,123	0	951	81	6,137
Portion of all funds (%)	64.8	18.3	0	15.5	1.3	100.0
Plateau Valley						
Revenues (\$)	665,458	183,165	3,210	429,218	59,058	1,340,109
Amount per ADAE (\$)	1,732	476	8	1,117	153	3,488
Portion of all funds (%)	49.6	13.6	(c)	32.0	4.4	100.0
Mesa County Valley						
Revenues (\$)	17,383,923	4,828,130	48,400	21,950,547	2,047,191	46,258,191
Amount per ADAE (\$)	1,136	315	3	1,435	133	3,025
Portion of all funds (%)	37.5	10.4	(c)	47.4	4.4	100.0
State total						
Revenues (\$)	819,499,392	228,344,076	1,614,767	767,224,134	86,176,853	1,902,859,222
Amount per ADAE (\$)	1,617	450	3	1,514	170	3,756
Portion of all funds (%)	43.0	12.0	(c)	40.3	4.5	100.0

^aData from Colorado Department of Education (1984, Table 1).^bADAE = average daily attendance entitlement.^cLess than 0.5 percent.

43.0 percent of revenues; the state government, 40.3 percent; the Federal Government, 4.5 percent; and other local sources, the remaining 12.2 percent. The importance of the property tax in the Mesa County school districts varied considerably; property taxes provided 49.6 percent of the revenues in the Plateau Valley School District, 37.5 percent in the Mesa County Valley School District, and 64.8 percent in DeBeque. The state's contribution ranged from 15.5 percent in DeBeque to 47.4 percent in Mesa County Valley; the Federal contribution was under five percent in all school districts. The average revenue per pupil varied from \$3,025 in Mesa County Valley to \$6,137 in DeBeque. The state average revenue per pupil was \$3,756 (Colorado Department of Education, 1984b).

Table K.1.23 shows school-district expenditures by major function. The largest percentage of expenditures for all school districts in the state, 51.9 percent, is for instruction. This consists mainly of salaries (40.6 percent of total expenditures), employee benefits (7.2 percent), purchased services (1.4 percent), supplies and materials (2.0 percent), and capital outlay (0.5 percent). Support services--pupil services, instruction services, general and school administration, operations and maintenance, pupil transportation, and food services--accounted for 35.9 percent of total expenditures. The percentage distribution of expenditures by major function for each of the three districts was similar to the state distribution. The average expenditure per pupil varied from \$3,043 in Mesa County Valley to \$5,134 in DeBeque. The state average per pupil expenditure was \$3,695 (Colorado Department of Education, 1984b).

K.1.6.2 Hospitals and health services

Table K.1.24 lists the hospitals, the number of licensed beds, and the average number of outpatients provided hospital care each day in Mesa County. Three of the four hospitals are in Grand Junction. The largest is St. Mary's Hospital and Medical Center, which has 264 licensed beds and treats approximately 130 outpatients per day (Colorado West Improvement, Inc., 1982; American Hospital Association, 1984). The total number of licensed hospital beds in the county is 461.

The number of hospital beds available to serve a population is an indicator of the adequacy of medical care in a region. Mesa County has approximately 5.0 hospital beds per 1000 people. This ratio is higher than the 1979 national average of 4.5 and the 1979 Colorado ratio of 4.3 (U.S. Department of Health and Human Services, 1981). The high ratio for the county, and for Grand Junction in particular, indicates that the county provides hospital services to people in the surrounding region.

Table K.1.23 Expenditures by function for school districts in Mesa County,
calendar year 1983^a

School district ^b	Instruction	Support services	Community services	Other	Total
DeBeque					
Expenditures (\$)	379,023	222,457	98	79,727	681,285
Amount per ADAE (\$)	2,856	1,676	1	600	5,134
Portion of all funds (%)	55.6	32.6	0	11.7	100.0
Plateau Valley					
Expenditures (\$)	653,845	524,242	0	133,521	1,311,608
Amount per ADAE (\$)	1,702	1,364	0	347	3,414
Portion of all funds (%)	49.8	39.9	0	10.1	100.0
Mesa County Valley					
Expenditures (\$)	24,822,451	16,691,089	53,847	4,964,007	46,531,400
Amount per ADAE (\$)	1,623	1,091	3	324	3,043
Portion of all funds (%)	53.3	35.8	0.1	10.6	100.0
State Total					
Expenditures (\$)	972,762,622	673,131,484	3,060,722	222,786,985	1,871,741,863
Amount per ADAE (\$)	1,920	1,328	6	439	3,695
Portion of all funds (%)	51.9	35.9	0.1	11.9	100.0

^aData from Colorado Department of Education (1984b, Table 3).

^bADAE = average daily attendance entitlement.

Table K.1.24 Characteristics of hospitals in Mesa County, 1982-1983

Name/facility	City	Number of licensed beds ^a	Admissions ^a	Average number of outpatients per day ^b	Occupancy rate ^a	Births ^a	Personnel ^a	Type of services ^a
St. Mary's Hospital and Medical Center	Grand Junction	264	11,519	130	65.5%	1,313	906	General, acute, and long-term care
Grand Junction Osteopathic Hospital	Grand Junction	78	3,267	30	51.3%	535	204	General care
U.S. Veterans Administration Medical Center	Grand Junction	99	2,542	NA	NA	--	261	General, acute, and long-term care
Nursing facility	Grand Junction	42	19	NA	NA	--	17	
Total	Grand Junction	141	2,561	50	86.8%	--	278	
Lower Valley Hospital:								
Hospital	Fruita	20	341	NA	NA	28	33	General care
Nursing facility	Fruita	120	61	NA	NA	--	86	Long-term care
Total	Fruita	140	402	6	77.9%	28	119	

^aData for year ending September 30, 1983, from American Hospital Association, 1984.

^bFrom Colorado West Improvement, Inc. (1982) and Harry Moon, Assistant Administrator, Lower Valley Hospital, December 21, 1982.

Other health facilities and programs available in Mesa County are listed in Table K.1.25. The county provides public-health services and family-planning programs that are funded by Federal, state, and local monies and some fees. A mental-health center in Grand Junction provides various types of therapy and counseling. Support groups are also available for alcoholics and drug abusers and members of their families (Human Services Directory, 1981).

Services for developmentally disabled persons are also available in Grand Junction, and the county has four nursing homes. Programs to assist low-income persons with food supplies and legal services are available; however, they are funded by various Federal Government agencies and face an uncertain future because of reductions in Federal aid (Human Services Directory, 1981).

K.1.6.3 Water supplies, waste-water treatment, and public utilities

Most of the residents of Mesa County are supplied with water from wells, springs, creeks, and surface-water sources, as indicated in Table K.1.26. Grand Junction, Palisade, and the Ute Water Conservancy District collect surface water off Grand Mesa and obtain some water from the Colorado and Gunnison Rivers during dry weather periods. Clifton and DeBeque obtain water from the Colorado River. Collbran obtains water from springs (Bowman, 1985).

The water-treatment process for all places not having wells and springs is rapid sand filtration with chemical coagulation. High salinity levels in the Colorado River near Grand Junction make treatment and use of water from the river less desirable in that area (Bowman, 1985).

Water-consumption figures for Mesa County are estimates provided by the Colorado Department of Health. Domestic water consumption in summer and in winter is estimated at 350 and 150 gallons per person per day, respectively. The higher summer rate includes water used for the irrigation of crops.

The waste-water treatment plants in Mesa County are listed in Table K.1.27. The most common type is a lagoon system. In Grand Junction, waste water is currently treated at a new activated-sludge plant. The Grand Junction waste-water treatment plant is the largest in the county, with a capacity of 20.0 million gallons per day, and is operating well below capacity. Other towns and developments along the Colorado River also appear to be operating well below capacity (Bowman, 1985).

Electricity is supplied to the Grand Junction area by the Public Service Company of Colorado and by Grand Valley Rural Power lines. Telephone service is provided by Mountain Bell. Natural gas service is provided by the Public Service Company of Colorado. According to John Kenney, acting Public Works Director of the City of Grand Junction, the area's utilities

Table K.1.25 Major health services by type in Mesa County, 1982^a

Type of service	Program, institution, or facility ^b
Community health	Mesa County Health Department Child and Migrant Services, Inc. Medical Assistance for Indigent Persons Mesa County Family Planning
Mental health	Family Counseling and Learning Center Mesa County Mental Health Center, Inc. Residential Health Care Facility
Alcohol and drug abuse	Alcoholics Anonymous/Al-Anon/Alateen Alternatives to Drug and Alcohol Abuse Bridge House, Inc. Clearview, Inc.
Care and training of developmentally disabled persons	Colorado State Home and Training School Hilltop House Rehabilitation Center
Care of, and aid to, aged persons	Bethesda Care Center Hilltop House Rehabilitation Center La Villa Grand Care Center Mesa Manor
Aid to low-income persons	Colorado West Community Action Programs (food and nutrition) Colorado Rural Legal Services, Inc.

^aInformation from Crisis Intervention and Suicide Prevention Center, Human Services Directory for Mesa County Residents, January, 1981.

^bAll services are located in Grand Junction.

Table K.1.26 Sources of water and estimated domestic water consumption in Mesa County, 1985^a

City	Water source	Number of people served	Estimated domestic water consumption (mgd) ^b	
			Summer	Winter
Fruita	Ute Water Conservancy	--	--	--
Clifton	Colorado River	15,000	5.35	2.25
Grand Junction	Grand Mesa surface water; Colorado and Gunnison River can be used	28,500 ^c	9.98	4.28
Ute Water Conservancy District	Grand Mesa surface and Colorado River water	45,000	15.80	6.80
Palisade	Grand Mesa surface	3,000	1.05	0.45
DeBeque	Colorado River	350	0.12	0.05
Collbran	3 springs	370	0.13	0.06

^aData from Dick Bowman, Colorado Department of Health, Water Quality Control Division, February, 1985.

^bmgd = million gallons per day. Consumption estimated to be 350 gallons per person per day in summer and 150 gallons per person per day in winter.

^cTotal consists of 28,000 resident users and 500 non-resident users.

Table K.1.27 Waste-water treatment plants in Mesa County, 1985^a

City operating plant	Type	Treatment capacity (mgd) ^b	Average flow (mgd)
Fruita	Lagoons	1.25	0.49
Grand Junction	Activated	20.00	6.0
Clifton			
Sanitation District 1	Evaporation	0.14	0.30
Sanitation District 2 East	Lagoons	0.41	0.06
Sanitation District 2 West	Lagoons	1.4	0.41
Palisade	Lagoons	0.52	0.15
DeBeque	Lagoons	0.07	0.02
Collbran (on Plateau Creek)	Lagoons	0.200 ^c	0.06

^aData from Dick Bowman, Colorado Department of Health, Water Quality Control Division, February, 1985.

^bMillion gallons per day.

^cEstimated by Dick Bowman, Colorado Department of Health, Water Quality Control Division, February, 1985.

would be able to accommodate any additional demand associated with remedial action (Kenney, 1985).

K.1.6.4 Police and fire protection

The Grand Junction Police Department has 67 sworn police officers, 33 of whom are authorized civilians, and 30 police vehicles (Evers, 1985). The Mesa County Sheriff's Department has 27 road deputies, six sergeants, a staff of 83 people, and 40 vehicles. The deputies patrol the entire county, and arrangements can be made for county assistance in Grand Junction, Palisade, and Fruita, all of which have their own police department, and also in Collbran and DeBeque, each of which has a deputy marshal. A central communications center in Grand Junction serves as a dispatch center for the emergency services of the police, sheriff's, and fire departments (Mesa County Sheriff's Department, 1985).

The Grand Junction Fire Department provides fire protection for Grand Junction and for rural areas surrounding Grand Junction; the total service area includes 84 square miles. The fire department staff consists of 60 full-time firefighters. Fire fighting equipment includes six 1250-gallon pumpers, one 750-gallon pumper, a 3500-gallon tanker, one 85-foot aerial platform, two rescue units, and one hazardous chemical unit (Campbell, 1985).

K.1.7 TRANSPORTATION

The average daily volumes of traffic on selected highways in the vicinity of Grand Junction are given in Table K.1.28. A map displaying the major highways is shown in Figure K.1.2. The volume of traffic varies from 1100 vehicles per day on U.S. Highway 6 & 50 between Mack and Two Road to 21,200 vehicles per day on U.S. Highway 50 between Unaweep and South Avenues. Cars and pickups account for most of the traffic on all highways. In general, Interstate 70 carries the greatest number and percentage of large trucks.

Traffic volumes for county roads and city streets that may be used in the remedial action project are given in Table K.1.29. These numbers are for the year 1983, and the traffic volumes have probably decreased slightly since then (Trainor, 1985).

The numbers of fatal, injury, and property traffic accidents have been declining in Mesa County recently. In 1981, there were a total of 3683 accidents: 33 fatal, 801 injury, and 2849 property damage accidents. In 1984, the accident total dropped to 1964: 11 fatal, 496 injury, and 1457 property damage accidents. The 1984 countywide fatal accident rate was 0.02 accidents per 10^6 vehicle-miles travelled. The 1984 countywide injury accident rate was 0.72 accidents per 10^6 vehicle-miles travelled. The total accident rate for Mesa County in 1984 was 2.85 accidents per 1,000,000 vehicle-miles travelled (Smith, 1985).

Table K.1.28 Average daily traffic on selected highway routes in Grand Junction and vicinity^{a, b}

Highway	Route segment	Average daily traffic
U.S. 50	Mesa-Delta County Line to Whitewater	3,800 ^c
U.S. 50	Whitewater to 32 Road (State Road 146)	4,600
U.S. 50	32 Road (State Route 146) to 30 Road	5,425
U.S. 50	30 Road to 28½ Road	7,800
U.S. 50	28½ Road to B½ Road	9,100
U.S. 50	B½ Road to 27½ Road	13,800
U.S. 50	27 Road to Unawep Avenue	16,400
U.S. 50	Unawep Avenue to South Avenue	21,500
U.S. 50	South Avenue to Pitkin Avenue	20,200
U.S. 50	Pitkin Avenue to Ute	12,000
U.S. 50, Loop 70 (Ute Ave)	5th Street to 1st Street	9,400
U.S. 50, Loop 70 (Pitkin Ave)	5th Street to 1st Street	12,000
U.S. 50, Loop 70	Ute to State Route 340	18,900
U.S. 50, Loop 70	State Route 340 to North (U.S. 6)	13,100
U.S. 50, U.S. 6 Loop 70	North (U.S. 6) to 25 Road	22,000
U.S. 50, U.S. 6 Loop 70	24½ Road to 24 Road	11,000
U.S. 50, U.S. 6 Loop 70	24 Road to 6 Road	10,700
U.S. 50, U.S. 6 Loop 70	6 Road to I-70/Loop 70 Junction	10,400
I-70 ^d	Loop 70 to Fruita Exit	5,100
I-70 ^d	Fruita Exit to Loma Exit	3,400
I-70 ^d	Loma Exit to Mack Exit	3,000
U.S. 50, U.S. 6 ^c	Mack to Two Road	1,100

^aData from Trainor, 1985, unless otherwise noted.

^bAverage number of vehicles passing during a 24-hour period at a point along the road segment.

^cData from Mesa County Engineer and Grand Junction City Engineer, 1983.

^dData from Colorado Department of Highways, 1980.

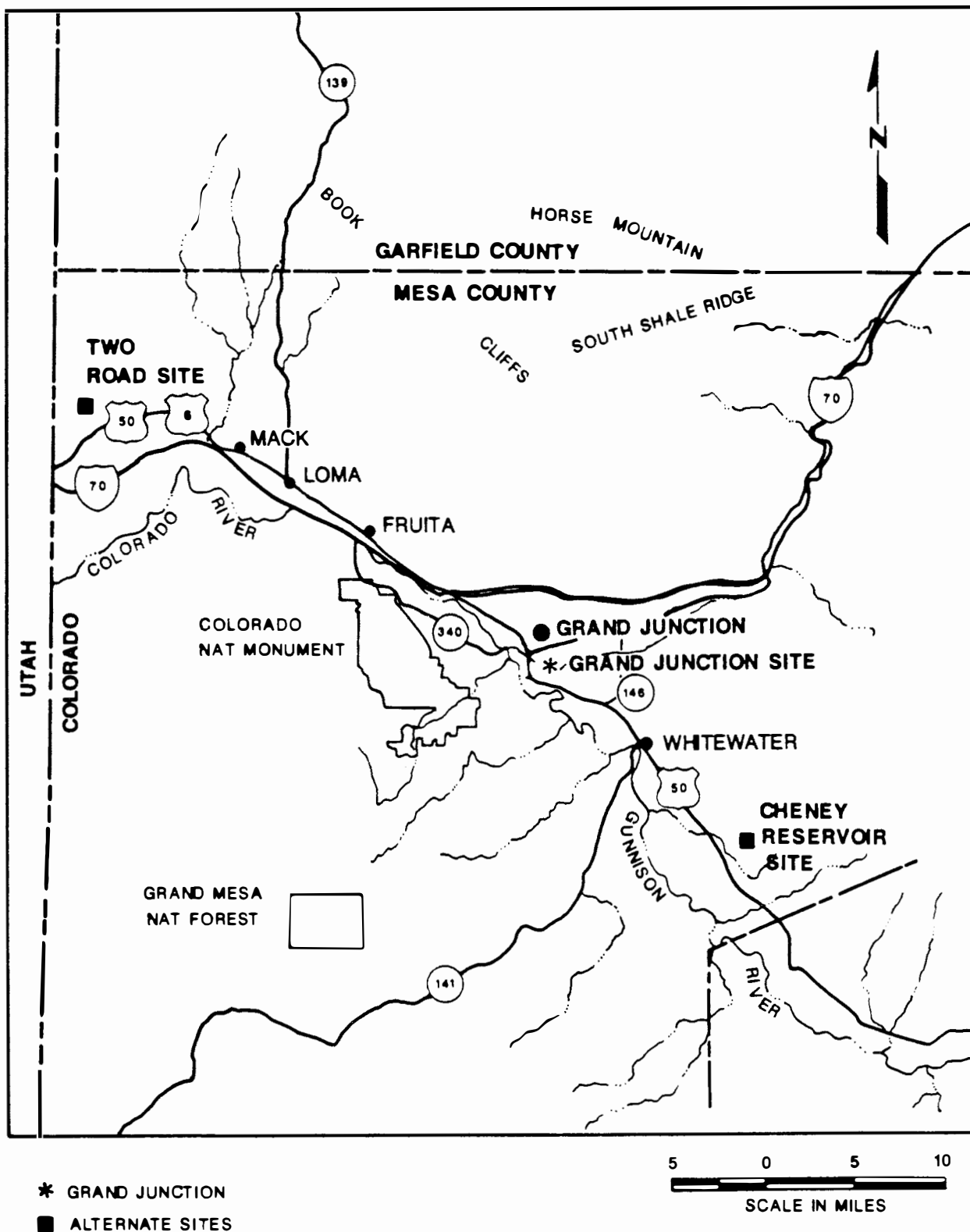


FIGURE K.1.2
MAJOR HIGHWAYS IN THE VICINITY OF GRAND JUNCTION

Table K.1.29 Average daily traffic on selected city and county roads in Grand Junction and vicinity^a

Road	Road segment	Average daily traffic
Struthers Avenue	7th Street to processing site	650
9th Street	Struthers to 4th Avenue	1,100
9th Street	4th Avenue to Ute Avenue	8,950
12th Street	Kimball to D Road	less than 1,100 ^b
15th Street	Processing site to D Road	less than 1,100 ^b
Ute Avenue	9th Street to 5th Street (one-way)	12,800
Ute Avenue	5th Street to 1st Street (one-way)	9,400
Pitkin Avenue	1st Street to 5th Street (one-way)	7,900
Pitkin Avenue	5th Street to 9th Street (one-way)	12,000
D Road	9th Street to 27½ Road	6,900
D Road	27½ Road to 28 Road	4,650
D Road	28 Road to 29 Road	3,650
D Road	29 Road to 32 Road (State Route 146)	3,700
32 Road (State Route 146)	D Road to B½ Road	8,050
32 Road (State Route 146)	B½ Road to U.S. 50	3,700
Noland Avenue	U.S. 50 to 7th Street	570
4th Avenue	9th Street to 7th Street	1,450
4th Avenue	7th Street to Riverside Park Drive	400
4th Avenue	Riverside Park Drive to U.S. 50	550
7th Street	Noland to Struthers	1,050

^aData from Trainor, 1985.

^bEstimated by Trainor, 1985.

Specific accident rates for routes which may be used during remedial action are presented in Section 5.15 of Volume I - Text (Table K.1.30).

The Denver and Rio Grande Western Railroad follows the Colorado River and connects Grand Junction with Mack 10 miles to the northwest, which is near the Two Road site. The Montrose branch of the Denver and Rio Grande Western follows the Gunnison River out of Grand Junction and runs through Whitewater, which is near the Cheney Reservoir site. The main line to Mack is a single track with several loop sidings parallel to the main line. It is used by 25 to 30 freight trains per day and a passenger train that runs three days per week. Shipments in 1981 averaged an estimated 29 million gross tons. There are approximately 23 grade crossings between Grand Junction and Mack; most of them are equipped with active warning devices. The Montrose branch rail line, which runs to Whitewater, is a single heavy-duty track used primarily for coal trains and a freight train that runs to Montrose three or four times per week. The 1981 volume for this section of the railroad was estimated at nine million gross tons. There are approximately nine grade crossings along the Grand Junction-Whitewater route (DOE, 1983).

A summary of railroad accidents for 1980 and 1981 is given in Table K.1.31, which compares the rates for the Denver and Rio Grande Western Railroad with those reported for all railroads in the United States (USDOT, 1981, 1982).

Table K.1.30 Accident data for major roads in Mesa County, 1981^a

Highway	Segment		Length (miles)	Average daily traffic	Property damage accidents	Injury accidents	Fatal accidents	Total accidents
	From	To						
Interstate 70	Mack	State Rt. 139	3.95	3,000	1	0	0	1
	State Rt. 139	W. Fruita	4.16	3,400	2	4	0	6
	W. Fruita	State Rt. 340	0.32	3,400	7	2	0	9
	State Rt. 340	E. Fruita	1.10	4,400	1	2	0	3
	E. Fruita	State Rt. 6	5.02	4,400	13	9	3	25
Loop 70	State Rt. 6	State Rt. 340	0.745	11,700	21	4	0	25
	State Rt. 340	5th St.	0.708	17,000	96	20	0	116
State Rt. 340	W. Grand Junction	Loop 70	0.564	21,000	19	4	0	23
U.S. Rt. 50	Pitkin St.	Unawee Ave.	1.21	20,000	39	11	0	50
	Unawee Ave.	B½ Rd.	1.19	13,500	31	12	2	45
	B½ Rd.	S. Grand Junction	0.08	8,400	2	2	0	4
	S. Grand Junction	30 Rd.	2.80	7,400	10	7	0	17
	30 Rd.	State Rt. 146	1.33	4,500	3	0	0	3
	State Rt. 146	State Rt. 141	2.62	5,000	1	1	0	2
	State Rt. 141	Mesa County line	11.91	3,800	12	13	1	26
State Rt. 146	U.S. Route 50	B½ Rd.	2.66	3,000	9	2	0	11
	B½ Rd.	Loop 70	2.67	7,700	50	18	1	69

^aFrom Mesa County Engineer and Grand Junction City Engineer, 1983.

Table K.1.31 Railroad accident and incident data for 1980 and 1981^a
(per million train miles)

Railroad	Year	Accidents and incidents	Injuries	Fatalities	Damages (\$1000) ^b
Denver and Rio Grande Western	1980	17.82 ^c	10.8	0.76	74.3
	1981	13.39 ^c	7.97	1.18	21.8
	Avg.	15.61	9.39	0.97	48.1
All U.S. railroads	1980	29.45	19.04	1.87	381.7
	1981	24.05	16.37	1.80	351.2
	Avg.	26.75	17.71	1.84	366.5

^aData and definitions provided by U.S. Department of Transportation (USDOT, 1981, 1982).

^bData limited to accidents involving operation of on-track equipment that resulted in damages exceeding a reporting threshold: \$2900 in 1980 and \$3600 in 1981.

^cNumber of incidents not reported by the railroad. Statistic based on the assumption that the ratio of injuries to accidents and incidents is the same for the Denver and Rio Grande Western as it is for all U.S. railroads.

K.2 SOCIOECONOMIC IMPACTS

K.2.1 IMPACTS ON POPULATION AND WORK FORCE

The impacts described in the following section are based primarily on output from the Planning and Assessment System (PAS) economic and demographic model, maintained by the State of Colorado - Division of Local Government. The PAS model is composed of three modules which are linked together by an extensive data base. The first module of PAS is a data base manager which keeps track of critical basic activities (projects or economic activities which form the basis of a local economy). The second module uses data from the first module along with other county economic and demographic data and produces projections at the county level. The third module allocates county level projections to subcounty areas.

The impacts of each of the remedial action alternatives and the vicinity properties cleanup on the population and employment of the Grand Junction area and Mesa County are displayed on Tables K.2.1 and K.2.2, respectively. The terms "population impact" and "employment impact" will be used to describe the difference between baseline or no action population and employment levels, and the population and employment levels resulting from the adoption of a particular remedial action alternative or the vicinity properties cleanup.

K.2.1.1 No action alternative

Population and employment trends would be unaffected by the no action alternative. There is a substantial amount of industrial land available in Grand Junction which is capable of supporting further development. Therefore, the loss of the Grand Junction site as a potential site for economic development would not be expected to affect local population or employment levels.

K.2.1.2 Stabilization on site alternative

The stabilization on site alternative would involve an average of 125 project workers over the proposed 33-month construction period starting in 1987. An estimated 101 of these workers would come from the local Mesa County work force, while the remainder (primarily supervisory and field staff workers), would be obtained from outside the county. During the peak construction period, a total of 185 project workers would be employed.

Local nonlabor purchases (i.e., material, equipment, and services) would create indirect employment, as increased local sales could support a larger work force. A similar secondary effect on employment would be induced as project worker income is spent and respent in the local economy (an estimated \$10.1

Table K.2.1 Population impacts of remedial action on Mesa County and Grand Junction
by alternative and vicinity properties cleanup^a

Year	Stabilization on site		Cheney truck		Cheney train and truck		Two Road truck		Two Road train and truck		Vicinity properties	
	Grand Junction	Mesa County	Grand Junction	Mesa County	Grand Junction	Mesa County	Grand Junction	Mesa County	Grand Junction	Mesa County	Grand Junction	Mesa County
1985	--	--	--	--	--	--	--	--	--	--	--	--
1986	--	--	--	--	--	--	--	--	--	--	124	196
1987	50	67	47	67	45	64	47	67	47	67	645	935
1988	127	200	133	226	130	221	140	238	142	242	660	957
1989	295	501	332	559	329	555	355	596	362	608	550	767
1990	35	56	65	103	64	102	69	109	69	110	45	71
1991	12	16	17	23	17	22	19	24	19	24	34	42
1992	8	9	11	12	11	11	10	12	12	13	26	33
1993	7	7	9	9	9	9	9	9	10	10	25	30
1994	6	6	8	8	8	8	9	9	8	8	23	26
1995	6	6	8	8	8	8	8	8	8	8	21	21

^aFrom Planning and Assessment System, 1985.

Table K.2.2 Employment impacts of remedial action on Mesa County and Grand Junction
by alternative and vicinity properties cleanup^a

Year	Stabilization on site		Cheney truck		Cheney train and truck		Two Road truck		Two Road train and truck		Vicinity properties	
	Grand Junction	Mesa County	Grand Junction	Mesa County	Grand Junction	Mesa County	Grand Junction	Mesa County	Grand Junction	Mesa County	Grand Junction	Mesa County
1985	--	--	--	--	--	--	--	--	--	--	--	--
1986	--	--	--	--	--	--	--	--	--	--	357	440
1987	160	203	119	149	128	164	202	256	138	176	1,174	1,436
1988	278	356	229	291	244	315	253	327	269	346	386	424
1989	189	255	218	284	210	282	231	303	231	309	28	58
1990	5	35	20	60	22	59	19	64	20	64	--	9
1991	-14	4	-16	8	-14	8	-20	8	-18	8	-5	3
1992	-17	1	-21	1	-18	1	-25	1	-23	1	-6	1
1993	-17	--	-21	--	-18	--	-25	--	-24	--	-6	1
1994	-17	--	-22	--	-19	--	-25	--	-24	--	-6	1
1995	-17	--	-22	--	-19	--	-25	--	-24	--	-5	1

^aFrom Planning and Assessment System, 1985.

million would be paid in wages and salaries under the stabilization on site alternative). These secondary effects are captured by the PAS model.

The total employment impact (including direct, indirect, and induced jobs) of the stabilization on site alternative on Mesa County would be 203 jobs in 1987, reach a peak of 356 jobs in 1988, and fall to 255 jobs in 1989. The employment impact would decline to 35 jobs in 1990 and reduce to zero by 1993. The employment generated during the peak period would reduce the countywide unemployment rate by 0.9 percent.

Of the total number of employed holding jobs created directly, created indirectly, or which would be induced by the stabilization on site alternative in 1987, 160 would reside in the Grand Junction area (defined as the city of Grand Junction and adjacent developable areas and estimated by the PAS model as having a 1985 population of 48,286). The number of employed in the Grand Junction area whose jobs would be project-related would increase to 278 in 1988, decline to 189 in 1989, and fall to five by 1990. Between 1991 and 1995, the number of unemployed residing in the Grand Junction area would be slightly higher than it would be without the project due to a small number of project related immigrants remaining in the Grand Junction area after the remedial action was complete; they would either be searching for other work while unemployed or displacing others who would have otherwise held jobs taken by immigrants. However, the number of immigrants remaining would be small in relation to the total number of employed, and there would not be a noticeable effect on the Grand Junction area unemployment rate.

In 1987, approximately 64 percent of the total employment generated by the project would be in the construction sector. Approximately 10 percent of the employment generated would be in wholesale and retail trade, six percent in services, and four percent in the government sector. As the project continued to completion, the effects of the circulation of project wages, salaries, and nonlabor expenditures would increase the number of indirect and induced jobs. Thus, by 1989, the proportion of the employment generated by the project held by the construction sector would fall to 53 percent, while the proportions held by trade, services, and government would increase to 13, nine, and six percent, respectively. Once the remedial action was complete, direct project employment would fall to zero and only indirect and induced employment impacts would remain. Trade (30 percent), services (20 percent), and government (15 percent) would hold the largest shares of this remaining employment; the share held by the construction sector would fall to six percent.

The immigrant project workers and immigrants searching for work related to the remedial action would create population increases. In 1987, the project related population im-

fact would be an estimated 67 persons. This population increase would consist primarily of immigrant project supervisors, field staff, and their families.

The unemployment rate in Mesa County is projected to decline between 1985 and 1990 with or without remedial action. The employment created by the stabilization on site alternative would reduce the local labor supply and unemployment rate to levels which would encourage others outside Mesa County to immigrate. A countywide population impact of 200 people in 1988 and a peak of 501 people by 1989 would be the result. The peak impact would represent a 0.6 percent increase in the county population. Once the remedial action was completed, the loss of the direct project employment combined with the induced contractive effects on employment in related establishments would result in outmigration, reducing the population impact to six persons by 1995.

The estimated population impact on the Grand Junction area in 1987 is 50 persons. The impact would reach a peak of 295 persons in 1989, or 0.6 percent of the Grand Junction area population. Once the remedial action was completed, the population impact would fall, declining to an impact of six persons by 1995.

K.2.1.3 Cheney truck alternative

Relocation of the tailings to Cheney Reservoir via the Cheney truck alternative would involve an average of 128 project workers over the proposed 34-month construction period starting in 1987. Approximately 103 of these workers would be expected to come from the local Mesa County work force, while the remainder, primarily supervisory and field staff workers, would be obtained outside the county. During the peak construction period, a total of 146 project workers would be employed.

An estimated \$10.3 million in wages and salaries would be paid to the project work force. The circulation throughout the Mesa County economy of the portion of this total spent locally, combined with the circulation of dollars spent locally for nonlabor items, would create secondary employment effects. The total employment impact (including direct, indirect, and induced jobs) of the Cheney truck alternative on Mesa County would be 149 jobs in 1987, increase to 291 jobs in 1988, and decline to 284 jobs in 1989. The employment impact would fall to 60 jobs by 1990 and finally reduce to zero by 1993. The total employment generated during the peak period would reduce the countywide unemployment rate by 0.7 percent.

Of the total number of employed holding jobs created directly, created indirectly, or which would be induced by the Cheney truck alternative in 1987, 119 would reside in the Grand Junction area. This number of project related employed

residing in the Grand Junction area would increase to 229 in 1988, decline to 218 in 1989, and fall to 20 by 1990. Between 1991 and 1995, the number of unemployed residing in the Grand Junction area would be slightly higher than it would be without the project due to the small number of project related immigrants remaining in Grand Junction after the remedial action was complete. However, the number of immigrants remaining would be small in relation to the total number of employed, and there would be no noticeable effect on the Grand Junction unemployment rate.

In 1987, approximately 61 percent of the total employment generated by the Cheney truck alternative would be in the construction sector. Other sectors holding relatively large shares of the employment generated would include trade (10 percent), services (six percent), and government (five percent). As the project continued to completion, the effects of the circulation of project wages, salaries, and nonlabor expenditures would increase the number of indirect and induced jobs. Thus, by 1989, the proportions of the project generated employment held by the construction and transportation/communications/public utilities sectors, which hold substantial shares of direct project employment, would decline (to 56 and six percent, respectively), while the proportions held by trade, services, and government would increase (to 12, eight, and six percent, respectively). Once the remedial action was complete, direct project employment would fall to zero and the proportion of the project generated indirect and induced employment held by the construction and transportation/communications/public utilities sectors would fall to 26 percent and five percent, respectively; the shares held by the trade, services, and government sectors would increase to 21, 15, and 11 percent, respectively.

The countywide population impact caused by immigrant project workers and immigrants searching for remedial action related work would be an estimated 67 persons in 1987. These would primarily consist of immigrant project supervisors, field staff, and their families. The impact is expected to increase to a peak of 560 persons in 1989 as the falling unemployment rate encourages further immigration. This peak would represent a 0.6 percent increase in the county population. Once the remedial action was completed, the loss of the direct project employment combined with the induced contractive effects on employment in related establishments would result in outmigration, reducing the population impact to eight persons by 1995.

The estimated population impact on the Grand Junction area in 1987 is 47 persons. The impact would reach a peak of 332 persons in 1989, or 0.7 percent of the Grand Junction area population. Once the remedial action was completed, the population impact would fall, declining to an impact of eight persons by 1995.

K.2.1.4 Cheney train and truck alternative

Relocation of the tailings to Cheney Reservoir via the Cheney train and truck alternative would involve an average of 112 project workers over the proposed 34-month construction period starting in 1987. Approximately 89 of these workers would be expected to come from the local Mesa County work force, while the remainder, primarily supervisory and field staff workers, would be obtained outside the county. During the peak construction period, a total of 127 project workers would be employed.

An estimated \$8.7 million in wages and salaries would be paid to the project work force. The circulation throughout the Mesa County economy of the portion of this total spent locally, combined with the circulation of dollars spent locally for nonlabor items, would create secondary employment effects. The total employment impact (including direct, indirect, and induced jobs) of the Cheney train and truck alternative on Mesa County would be 164 jobs in 1987, increase to 315 jobs in 1988, and decline to 282 jobs in 1989. The employment impact would fall to 59 jobs by 1990 and finally reduce to zero by 1993. The total employment generated during the peak period would reduce the countywide unemployment rate by 0.8 percent.

Of the total number of employed holding jobs created directly, created indirectly, or which would be induced by the Cheney train and truck alternative in 1987, 128 would reside in the Grand Junction area. This number of project related employed residing in the Grand Junction area would increase to 244 in 1988, decline to 210 in 1989, and fall to 22 by 1990. Between 1991 and 1995, the number of unemployed residing in the Grand Junction area would be slightly higher than it would be without the project due to the small number of project related immigrants remaining in Grand Junction after the remedial action was complete. However, the number of immigrants remaining would be small in relation to the total number of employed, and there would be no noticeable effect on the Grand Junction unemployment rate.

In 1987, approximately 52 percent of the total employment generated by the Cheney train and truck alternative would be in the construction sector. Other sectors holding relatively large shares of the employment generated would include transportation/communications/public utilities (13 percent), trade (10 percent), and manufacturing and services (both with 10 percent). As the project continued to completion, the effects of the circulation of project wages, salaries, and nonlabor expenditures would increase the number of indirect and induced jobs. Thus, by 1989, the proportions of project generated employment held by the construction, transportation/communications/public utilities and manufacturing sectors, which hold substantial shares of direct project employment, would decline (to 51, nine, and five percent, respectively), while the pro-

portion held by trade and services would increase (to 12 and eight percent, respectively). Once the remedial action was complete, direct project employment would fall to zero and the proportion of the project generated indirect and induced employment held by the construction and transportation/communications/public utilities sectors would fall to 25 percent and seven percent, respectively; the shares held by the trade and services sectors would increase to 22 and 15 percent, respectively, while the share held by the manufacturing sector would remain at five percent.

The countywide population impact caused by immigrant project workers and immigrants searching for remedial action related work would be an estimated 64 persons in 1987. These would primarily consist of immigrant project supervisors, field staff, and their families. The impact is expected to increase to a peak of 555 persons in 1989 as the falling unemployment rate encourages further immigration. This peak would represent a 0.6 percent increase in the county population. Once the remedial action was completed, the loss of the direct project employment combined with the induced contractive effects on employment in related establishments would result in outmigration, reducing the population impact to eight persons by 1995.

The estimated population impact on the Grand Junction area in 1987 is 45 persons. The impact would reach a peak of 329 persons in 1989, or 0.7 percent of the Grand Junction area population. Once the remedial action was completed, the population impact would fall, declining to an impact of eight persons by 1995.

K.2.1.5 Two Road truck alternative

Relocation of the tailings to the Two Road site via the truck alternative would involve an average of 127 project workers over the proposed 34-month construction period starting in 1987. Approximately 103 of these workers would be expected to come from the local Mesa County work force, while the remainder, primarily supervisory and field staff workers, would be obtained outside the county. During the peak construction period, a total of 147 project workers would be employed.

An estimated \$10.3 million in wages and salaries would be paid to the project work force. The circulation throughout the Mesa County economy of the portion of this total spent locally, combined with the circulation of dollars spent locally for nonlabor items, would create secondary employment effects. The total employment impact (including direct, indirect, and induced jobs) of the Two Road truck alternative on Mesa County would be 256 jobs in 1987, increase to 327 jobs in 1988, and decline to 303 jobs in 1989. The employment impact would fall to 64 jobs by 1990 and finally reduce to zero by 1993. The total employment generated during the peak period would reduce the countywide unemployment rate by 0.8 percent.

Of the total number of employed holding jobs created directly, created indirectly, or which were induced by the Two Road truck alternative in 1987, 202 would reside in the Grand Junction area. This number of project related employed residing in the Grand Junction area would increase to 253 in 1988, decline to 231 in 1989, and fall to 19 by 1990. Between 1991 and 1995, the number of unemployed residing in the Grand Junction area would be slightly higher than it would be without the project due to the small number of project related immigrants remaining in Grand Junction after the remedial action was complete. However, the number of immigrants remaining would be small in relation to the total number of employed, and there would be no noticeable effect on the Grand Junction unemployment rate.

In 1987, approximately 61 percent of the total employment generated by the Two Road truck alternative would be in the construction sector. Other sectors holding relatively large shares of the employment generated would include trade (10 percent), transportation/communications/public utilities (eight percent), services (six percent), and government (five percent). As the project continued to completion, the effects of the circulation of project wages, salaries, and nonlabor expenditures would increase the number of indirect and induced jobs. Thus, by 1989, the proportions of project generated employment held by the construction and transportation/communications/public utilities sectors, would decline (to 54 and seven percent, respectively), while the proportions held by trade, services, and government would increase (to 13, eight, and six percent, respectively). Once the remedial action was complete, direct project employment would fall to zero and the proportion of the project generated indirect and induced employment held by the construction and transportation/communications/public utilities sectors would fall to 25 percent and six percent, respectively; the shares held by the trade, services, and government sectors would increase to 22, 16, and 11 percent, respectively.

The countywide population impact caused by immigrant project workers and immigrants searching for remedial action related work would be an estimated 67 persons in 1987. These would primarily consist of immigrant project supervisors, field staff, and their families. The impact is expected to increase to a peak of 596 persons in 1989 as the falling unemployment rate encourages further immigration. This peak would represent a 0.7 percent increase in the county population. Once the remedial action was completed, the loss of the direct project employment combined with the induced contractive effects on employment in related establishments would result in outmigration, reducing the population impact to eight persons by 1995.

The estimated population impact on the Grand Junction area in 1987 is 47 persons. The impact would reach a peak of 355 persons in 1989, or 0.7 percent of the Grand Junction area

population. Once the remedial action was completed, the population impact would fall, declining to an impact of eight persons by 1995.

K.2.1.6 Two Road train and truck alternative

Relocation of the tailings to the Two Road site via the train and truck alternative would involve an average of 118 project workers over the proposed 34-month construction period starting in 1987. Approximately 94 of these workers would be expected to come from the local Mesa County work force, while the remainder, primarily supervisory and field staff workers, would be obtained outside the county. During the peak construction period, a total of 136 project workers would be employed.

An estimated \$9.4 million in wages and salaries would be paid to the project work force. The circulation throughout the Mesa County economy of the portion of this total spent locally, combined with the circulation of dollars spent locally for nonlabor items, would create secondary employment effects. The total employment impact (including direct, indirect, and induced jobs) of the Two Road train and truck alternative on Mesa County would be 176 jobs in 1987, increase to 346 jobs in 1988, and decline to 309 jobs in 1989. The employment impact would fall to 64 jobs by 1990 and finally reduce to zero by 1993. The total employment generated during the peak period would reduce the countywide unemployment rate by 0.8 percent.

Of the total number of employed holding jobs created directly, created indirectly, or which were induced by the Two Road train and truck alternative in 1987, 138 would reside in the Grand Junction area. This number of project related employed residing in the Grand Junction area would increase to 269 in 1988, decline to 231 in 1989, and fall to 20 by 1990. Between 1991 and 1995, the number of unemployed residing in the Grand Junction area would be slightly higher than it would be without the project due to the small number of project related immigrants remaining in Grand Junction after the remedial action was complete. However, the number of immigrants remaining would be small in relation to the total number of employed, and there would be no noticeable effect on the Grand Junction unemployment rate.

In 1987, approximately 51 percent of the total employment generated by the Two Road train and truck alternative would be in the construction sector. Other sectors holding relatively large shares of the employment generated would include transportation/communications/public utilities (14 percent), trade (10 percent), and services and manufacturing (both at six percent). As the project continued to completion, the effects of the circulation of project wages, salaries, and nonlabor expenditures would increase the number of indirect and induced

jobs. Thus, by 1989, the proportions of project generated employment held by the construction and transportation/communications/public utilities sectors would decline (to 50 and nine percent, respectively); while the proportions held by trade and services would increase (to 12 and eight percent, respectively), the share held by manufacturing would decline to five percent. Once the remedial action was complete, direct project employment would fall to zero and the proportion of the project generated indirect and direct employment held by the construction and transportation/communications/public utilities sectors would fall to 23 percent and six percent, respectively; the shares held by the trade and services would increase to 22 and 16 percent, respectively. Manufacturing would continue to hold a five percent share.

The countywide population impact caused by immigrant project workers and immigrants searching for remedial action related work would be an estimated 67 persons in 1987. These would primarily consist of immigrant project supervisors, field staff, and their families. The impact is expected to increase to a peak of 608 persons in 1989 as the falling unemployment rate encourages further immigration. This peak would represent a 0.7 percent increase in the county population. Once the remedial action was completed, the loss of the direct project employment combined with the induced contractive effects on employment in related establishments would result in outmigration, reducing the population impact to eight persons by 1995.

The estimated population impact on the Grand Junction area in 1987 is 47 persons. The impact would reach a peak of 362 persons in 1989, or 0.7 percent of the Grand Junction area population. Once the remedial action was completed, the population impact would fall, declining to an impact of eight persons by 1995.

K.2.1.7 Vicinity properties

The vicinity properties cleanup would involve an average of 513 project workers over the proposed 27-month construction period starting in 1986. Approximately 443 of these workers would be expected to come from the local Mesa County work force, while the remainder, primarily supervisory and field staff workers, would be obtained outside the county. During the peak construction period, a total of 815 project workers would be employed.

An estimated \$28.8 million in wages and salaries would be paid to the project work force. The circulation throughout the Mesa County economy of the portion of this total spent locally, combined with the circulation of dollars spent locally for nonlabor items, would create secondary employment effects. The total employment impact of the vicinity properties cleanup on Mesa County would be 440 jobs in 1986, increase to 1436

jobs in 1987, and decline to 424 jobs in 1988. The employment impact would fall to 58 jobs by 1989 and become negligible by 1992. The employment generated during the peak period would reduce the countywide unemployment rate by 3.5 percent.

Of the total number of employed holding jobs created directly, created indirectly, or which were induced by the vicinity properties cleanup in 1986, 357 would reside in the Grand Junction area. This number of project related employed residing in the Grand Junction area would increase to 1174 in 1987, decline to 386 in 1988, and fall to 28 by 1989. Between 1991 and 1995, the number of unemployed residing in the Grand Junction area would be slightly higher than it would be without the project due to the small number of project related immigrants remaining in Grand Junction after the remedial action was complete. However, the number of immigrants remaining would be small in relation to the total number of employed, and there would be no noticeable effect on the Grand Junction unemployment rate.

In 1987, approximately 60 percent of the total employment generated by the vicinity properties cleanup would be in the construction sector. Other sectors holding substantial shares of the employment generated would include trade (13 percent) and services (six percent). As the project continued to completion, the sectoral distribution of project generated employment would remain roughly constant. Once the remedial action was completed, direct project employment would fall to zero and the proportion of the project generated indirect and direct employment held by the construction sector would fall to five percent, while the shares held by the trade, services, and government sectors would increase to 28, 19, and 14 percent, respectively.

The countywide population impact caused by immigrant project workers and immigrants searching for remedial action related work would be an estimated 196 persons in 1986. These would primarily consist of immigrant project supervisors, field staff, and their families. The impact is expected to increase to a peak of 957 persons in 1988 as the falling unemployment rate encourages further immigration. This peak would represent a 1.1 percent increase in the county population. Once the remedial action was completed, the loss of the direct project employment combined with the induced contractive effects on employment in related establishments would result in outmigration, reducing the population impact to 21 persons by 1995.

The estimated population impact on the Grand Junction area in 1986 is 124 persons. The impact would reach a peak of 660 persons in 1988, or 1.3 percent of the Grand Junction area population. Once the remedial action was completed, the population impact would fall, declining to an impact of 21 persons by 1995.

K.2.2 IMPACTS ON HOUSING, SOCIAL STRUCTURE, AND COMMUNITY SERVICES

K.2.2.1 No action alternative

The Grand Junction site is located in an industrial area which is interspersed with houses to the west. The industrial nature of the area, the abundance of buildable land in the Grand Junction area, and the fact that the Grand Junction site is located in a 100-year floodplain are reasons to conclude that the no action alternative will have no impact on local housing. In general, because no project work force would be employed, no impacts on the local social structure or community services would be expected. However, community recreational services would be affected since the Grand Junction site could not be developed into part of the Colorado River Park System as set forth in the Parks and Recreation Plan of the City of Grand Junction.

K.2.2.2 Stabilization on site alternative

The stabilization on site alternative would bring maximum population increases to Mesa County and the Grand Junction area of 501 and 295 people, respectively. The 1980 Mesa County and Grand Junction housing stocks were 32,573 and 12,706 total housing units, respectively. Considering the size of the housing stocks relative to the expected population increases, combined with the recent Mesa County and Grand Junction population declines, it is expected that an adequate supply of housing would be available for project related immigrants.

Since approximately 80 percent of the project work force would come from local areas, no impacts on the social structure in Mesa County or Grand Junction would be expected.

A maximum of 105 school age (five to 18 years old) children would be expected to immigrate to Mesa County with their parents as a result of the remedial action. The majority of these children would be enrolled in the Mesa County Valley School District. Enrollment in this district reached a peak in 1983 of 16,460 students. The number enrolled fell by 879 students to 15,581 in 1984 as the local population declined. Thus, adequate facilities exist to accommodate the immigrant population.

Project population related water consumption would be expected to reach a peak in 1989 of 125,250 gallons per day in Mesa County using a 250 gallon per day per capita consumption factor. Direct project use would include 65.3 million gallons of non-potable water for compaction, dust control, and vehicle wash; it would also include 1.1 million gallons for drinking, showers, and laundry. Given the size of available water supplies, no problems would be expected regarding the required quantities of water.

The project population related sewer demand in Mesa County would be expected to reach a peak of 50,100 gallons per day in 1989, using a 100 gallon per day per capita sewage generation factor. The recently completed Grand Junction waste water treatment plant is currently operating well below capacity. Thus, regarding sewage treatment capacity, no problem would be expected.

An estimated 1,768,000 kilowatt-hours of electricity would be used directly for project related activity. Additional demands would be placed on electricity supplies, natural gas supplies, telephone services, police, fire, and other community services. However, since community facilities and services have been built to accommodate a larger population than currently exists in Grand Junction and Mesa County, no adverse impacts would be expected.

K.2.2.3 Cheney truck alternative

The Cheney truck alternative would bring maximum population increases to Mesa County and the Grand Junction area of 559 and 332 people, respectively. Considering the size of the Mesa County and Grand Junction housing stocks, combined with the recent population declines, an adequate supply of housing would be expected to be available for project related immigrants.

Since approximately 80 percent of the project work force would come from local areas, no impacts on the social structure in Mesa County or Grand Junction would be expected.

A maximum of 117 school age (five to 18 years old) children would be expected to immigrate to Mesa County with their parents as a result of the remedial action. The majority of these children would be enrolled in the Mesa County Valley School District. Adequate facilities would exist to accommodate the immigrant population.

Project population related water consumption would be expected to reach a peak in 1989 of 139,750 gallons per day in Mesa County, using a 250 gallon per day per capita consumption factor. Direct project use would include 70.7 million gallons of non-potable water for compaction, dust control, and vehicle wash; it would also include 1.8 million gallons for drinking, showers, and laundry. No problems would be expected regarding the required quantities of water.

The project population related sewer demand in Mesa County would be expected to reach a peak of 55,900 gallons per day in 1989 using a 100 gallon per day per capita sewage generation factor. No problems would be expected regarding sewage treatment capacity.

An estimated 1,323,000 kilowatt-hours of electricity would be used directly for project related activity. Additional demands would be placed on electricity supplies, natural gas supplies, telephone services, police, fire, and other community services. However, since community facilities and services have been built to accommodate a larger population than currently exists in Grand Junction and Mesa County, no adverse impacts would be expected.

K.2.2.4 Cheney train and truck alternative

The Cheney train and truck alternative would bring maximum population increases to Mesa County and the Grand Junction area of 555 and 329 people, respectively. Considering the size of the Mesa County and Grand Junction housing stocks, combined with the recent population declines, an adequate supply of housing would be expected to be available for project related immigrants.

Since approximately 80 percent of the project work force would come from local areas, no impacts on the social structure in Mesa County or Grand Junction would be expected.

A maximum of 115 school age (five to 18 years old) children would be expected to immigrate to Mesa County with their parents as a result of the remedial action. The majority of these children would be enrolled in the Mesa County Valley School District. Adequate facilities would exist to accommodate the immigrant population.

Project population related water consumption would be expected to reach a peak in 1989 of 138,750 gallons per day in Mesa County, using a 250 gallon per day per capita consumption factor. Direct project use would include 69.9 million gallons of non-potable water for compaction, dust control, and vehicle wash; it would also include 1.7 million gallons for drinking, showers, and laundry. No problems would be expected regarding the required quantities of water.

The project population related sewer demand in Mesa County would be expected to reach a peak of 55,500 gallons per day in 1989, using a 100 gallon per day per capita sewage generation factor. No problem would be expected regarding sewage treatment capacity.

An estimated 1,323,000 kilowatt-hours of electricity would be used directly for project related activity. Additional demands would be placed on electricity supplies, natural gas supplies, telephone services, police, fire, and other community services. However, since community facilities and services have been built to accommodate a larger population than currently exists in Grand Junction and Mesa County, no adverse impacts would be expected.

K.2.2.5 Two Road truck alternative

The Two Road truck alternative would bring maximum population increases to Mesa County and the Grand Junction area of 596 and 355 people, respectively. Considering the size of the Mesa County and Grand Junction housing stocks, combined with the recent population declines, an adequate supply of housing would be expected to be available for project related immigrants.

Since approximately 80 percent of the project work force would come from local areas, no impacts on the social structure in Mesa County or Grand Junction would be expected.

A maximum of 124 school age (five to 18 years old) children would be expected to immigrate to Mesa County with their parents as a result of the remedial action. The majority of these children would be enrolled in the Mesa County Valley School District. Adequate facilities would exist to accommodate the immigrant population.

Project population related water consumption would be expected to reach a peak in 1989 of 149,000 gallons per day in Mesa County, using a 250 gallon per day per capita consumption factor. Direct project use would include 67.3 million gallons of non-potable water for compaction, dust control, and vehicle wash; it would also include 1.9 million gallons for drinking, showers, and laundry. No problems would be expected regarding the required quantities of water.

The project population related sewer demand in Mesa County would be expected to reach a peak of 59,600 gallons per day in 1989, using a 100 gallon per day per capita sewage generation factor. No problems would be expected regarding sewage treatment capacity.

An estimated 1,365,000 kilowatt-hours of electricity would be used directly for project related activity. Additional demands would be placed on electricity supplies, natural gas supplies, telephone services, police, fire, and other community services. However, since community facilities and services have been built to accommodate a larger population than currently exists in Grand Junction and Mesa County, no adverse impacts would be expected.

K.2.2.6 Two Road train and truck alternative

The Two Road train and truck alternative would bring maximum population increases to Mesa County and the Grand Junction area of 608 and 362 people, respectively. Considering the size of the Mesa County and Grand Junction housing stocks, combined with the recent population declines an adequate supply of housing would be expected to be available for project related immigrants.

Since approximately 80 percent of the project work force would come from local areas, no impacts on the social structure in Mesa County or Grand Junction would be expected.

A maximum of 127 school age (five to 18 years old) children would be expected to immigrate to Mesa County with their parents as a result of the remedial action. The majority of these children would be enrolled in the Mesa County Valley School District. Adequate facilities would exist to accommodate the immigrant population.

Project population related water consumption would be expected to reach a peak in 1989 of 152,000 gallons per day in Mesa County, using a 250 gallon per day per capita consumption factor. Direct project use would include 70.4 million gallons of non-potable water for compaction, dust control, and vehicle wash; it would also include 1.7 million gallons for drinking, showers, and laundry. No problems would be expected regarding the required quantities of water.

The project population related sewer demand in Mesa County would be expected to reach a peak of 60,800 gallons per day in 1989, using a 100 gallon per day per capita sewage generation factor. No problems would be expected regarding sewage treatment capacity.

An estimated 1,365,000 kilowatt-hours of electricity would be used directly for project related activity. Additional demands would be placed on electricity supplies, natural gas supplies, telephone services, police, fire, and other community services. However, since community facilities and services have been built to accommodate a larger population than currently exists in Grand Junction and Mesa County, no adverse impacts would be expected.

K.2.2.7 Vicinity properties

The vicinity properties cleanup would bring maximum population increases to Mesa County and the Grand Junction area of 957 and 660 people, respectively. Considering the size of the Mesa County and Grand Junction housing stocks, combined with the recent population declines, an adequate supply of housing would be expected to be available for project related immigrants.

Since approximately 85 percent of the project work force would come from local areas, no impacts on the social structure in Mesa County or Grand Junction would be expected.

A maximum of 167 school age (five to 18 years old) children would be expected to immigrate to Mesa County with their parents as a result of the remedial action. The majority of these children would be enrolled in the Mesa County Valley School District. Adequate facilities would exist to accommodate the immigrant population.

Project population related water consumption would be expected to reach a peak in 1988 of 239,250 gallons per day in Mesa County, using a 250 gallon per day per capita consumption factor. Direct project use would include 12 million gallons of water for compaction, dust control, vehicle wash, drinking, showers, and laundry. No problems would be expected regarding the required quantities of water.

The project population related sewer demand in Mesa County would be expected to reach a peak of 95,700 gallons per day in 1988 using a 100 gallon per day per capita sewage generation factor. No problems would be expected regarding sewage treatment capacity.

An estimated 6930 kilowatt-hours of electricity would be used directly for project related activity. Additional demands would be placed on electricity supplies, natural gas supplies, telephone services, police, fire, and other community services. However, since community facilities and services have been built to accommodate a larger population than currently exists in Grand Junction and Mesa County, no adverse impacts would be expected.

K.2.3 IMPACTS ON ECONOMIC STRUCTURE

The Planning and Assessment System (PAS) model, which is maintained by the State of Colorado-Division of Local Government, was used to develop personal income and labor income impacts described in the following section. The model captures the direct, indirect, and induced income effects resulting from project wage and salary payments and nonlabor expenditures. The terms "personal income impact" and "labor income impact" will be used to describe the difference between the baseline projections, which exclude project impacts, and the projected scenario which includes project impacts. The personal income and labor income impacts are presented on Tables K.2.3 and K.2.4, respectively.

K.2.3.1 No action alternative

The no action alternative would not affect economic structures in Mesa County or Grand Junction. The Grand Junction site would continue to be undeveloped. However, the Grand Junction area has an abundant supply of industrial land capable of accommodating industrial growth in the area.

K.2.3.2 Stabilization on site alternative

In 1987, the personal income impact of the stabilization on site alternative on Mesa County would be \$5.4 million, increasing county income by 0.6 percent. The personal income impact would reach a peak of \$9.2 million in 1988, or an increase of 0.9 percent over the projected Mesa County personal income level without the project. The impact would fall to

Table K.2.3 Personal income impacts of remedial action on Mesa County
by alternative and vicinity properties cleanup^a
(thousands of dollars)

Year	Stabilization on site ^b		Cheney truck ^b		Cheney train and truck ^b		Two Road truck ^b		Two Road train and truck ^b		Vicinity properties ^b	
	Amount	Percent change	Amount	Percent change	Amount	Percent change	Amount	Percent change	Amount	Percent change	Amount	Percent change
1985	--		--		--		--		--		--	
1986	--		--		--		--		--		10,497	1.1
1987	5,405	0.6	3,943	0.4	4,229	0.4	6,834	0.7	4,542	0.5	34,637	3.6
1988	9,210	0.9	7,528	0.8	7,968	0.8	8,369	0.9	8,752	0.9	10,523	1.1
1989	6,465	0.7	7,300	0.7	7,084	0.7	7,801	0.8	7,790	0.8	1,308	0.2
1990	790	0.1	1,429	0.1	1,404	0.1	1,513	0.2	1,509	0.2	374	c
1991	138	c	218	c	214	c	231	c	231	c	140	c
1992	37	c	53	c	53	c	56	c	57	c	105	c
1993	23	c	29	c	28	c	31	c	31	c	100	c
1994	21	c	25	c	25	c	27	c	27	c	117	c
1995	20	c	25	c	24	c	26	c	27	c	129	c

^aFrom Planning and Assessment System, 1985.

^bPercentage change from baseline scenario.

^cLess than 0.1 percent.

Table K.2.4 Labor income impacts of remedial action on Mesa County
by alternative and vicinity properties cleanup^a
(thousands of dollars)

Year	Stabilization on site ^b		Cheney truck ^b		Cheney train and truck ^b		Two Road truck ^b		Two Road train and truck ^b		Vicinity properties ^b	
	Amount	Percent change	Amount	Percent change	Amount	Percent change	Amount	Percent change	Amount	Percent change	Amount	Percent change
1985	--		--		--		--		--		--	
1986	--		--		--		--		--		9,623	1.4
1987	4,995	0.7	3,615	0.5	3,877	0.5	6,265	0.9	4,164	0.6	31,756	4.4
1988	8,444	1.2	6,901	0.9	7,305	1.0	7,673	1.0	8,023	1.1	9,537	1.3
1989	5,927	0.8	6,692	0.9	6,494	0.9	7,151	1.0	7,141	1.0	1,056	0.1
1990	665	0.1	1,243	0.2	1,221	0.2	1,316	0.2	1,311	0.2	201	c
1991	104	c	170	c	167	c	180	c	180	c	59	c
1992	20	c	30	c	30	c	32	c	32	c	32	c
1993	7	c	10	c	10	c	10	c	11	c	28	c
1994	6	c	7	c	7	c	7	c	8	c	31	c
1995	5	c	6	c	6	c	7	c	7	c	34	c

^aFrom Planning and Assessment System, 1985.

^bPercentage change from baseline scenario.

^cLess than 0.1 percent.

\$6.5 million in 1989, \$0.8 million in 1990, and decline to \$20,000 by 1995. The estimated \$10.1 million in direct project wage and salary payments, combined with local nonlabor purchases, would translate into a total increase in Mesa County personal income of \$22.1 million over the 1987 to 1995 period.

In 1987, the labor income impact of the stabilization on site alternative on Mesa County would be \$5.0 million, increasing county labor income by 0.7 percent. The labor income impact would reach a peak of \$8.4 million in 1988, or an increase of 1.2 percent over the projected Mesa County labor income level without the project. The impact would fall to \$5.9 million in 1989, \$0.7 million in 1990, and decline to \$5,000 by 1995. The direct project wage and salary payments, combined with local nonlabor purchases, would translate into a total increase in Mesa County labor income of \$20.2 million over the 1987 to 1995 period.

Local, state, and Federal tax receipts would be affected by the implementation of the stabilization on site alternative. The primary taxes affected would be state and Federal income taxes. Local and state sales taxes would not be affected directly because purchases of supplies, materials, and equipment by contractors for Federal projects are exempt from state and local sales taxes upon application for exemption by contractors. Local property tax receipts would be slightly reduced by the removal of the Grand Junction site from the tax rolls. The Grand Junction site is currently assessed at \$13,450 and faces a mill levy of 79.315 mills (Mesa County Assessor, 1985); thus, Mesa County would lose approximately \$1,070 in property taxes annually.

State income taxes would increase because of taxes on wages and salaries earned by project workers and because of taxes on project-related indirect and induced increases in local labor income. Prior study shows that the average annual state income tax rate for incomes between \$25,000 and \$35,000 is approximately two percent (DOE, 1984b). Applying this rate to the projected \$20.2 million increase in project related labor income, an increase of \$400,000 in state income tax receipts would be expected over the 1987 to 1995 period. Assuming an average Federal income tax rate of 15 percent, Federal income tax receipts would increase by a total of \$3.0 million over the same period. Smaller additional increases in state and Federal income tax receipts would be expected as a result of project related income generated from nonlabor purchases outside Mesa County.

K.2.3.3 Cheney truck alternative

In 1987, disposal of the tailings at Cheney Reservoir via the truck alternative would result in a personal income impact on Mesa County of \$3.9 million, increasing county income by

0.4 percent. The personal income impact would reach a peak of \$7.5 million in 1988, or an increase of 0.8 percent over the projected Mesa County personal income level without the project. The impact would fall to \$7.3 million in 1989, \$1.4 million in 1990, and decline to \$25,000 by 1995. The estimated \$10.3 million in direct project wage and salary payments, combined with local nonlabor purchases, would translate into a total increase in Mesa County personal income of \$20.6 million over the 1987 to 1995 period.

In 1987, the labor income impact of the Cheney truck alternative on Mesa County would be \$3.6 million, increasing county labor income by 0.5 percent. The labor income impact would reach a peak of \$6.9 million in 1988, or an increase of 0.9 percent over the projected Mesa County labor income level without the project. The impact would fall to \$6.7 million in 1989, \$1.2 million in 1990, and decline to \$6,000 by 1995. The direct project wage and salary payments, combined with local nonlabor purchases, would translate into a total increase in Mesa County labor income of \$18.7 million over the 1987 to 1995 period.

Local, state, and Federal tax receipts would be affected by the implementation of the Cheney truck alternative. State and local sales taxes would not be directly affected. The Grand Junction site could be developed; thus, Mesa County would continue to receive property taxes from the owners. The projected \$18.7 million increase in project related labor income would result in an expected increase of \$375,000 in state income tax receipts over the 1987 to 1995 period. Assuming an average Federal income tax rate of 15 percent, Federal income tax receipts would increase by a total of \$2.8 million over the same period. Smaller additional increases in state and Federal income tax receipts would be expected as a result of project related income generated from nonlabor purchases outside Mesa County.

K.2.3.4 Cheney train and truck alternative

In 1987, disposal of the tailings at Cheney Reservoir via the train and truck alternative would result in a personal income impact on Mesa County of \$4.2 million, increasing county income by 0.4 percent. The personal income impact would reach a peak of \$8.0 million in 1988, for an increase of 0.8 percent over the projected Mesa County personal income level without the project. The impact would fall to \$7.1 million in 1989, \$1.4 million in 1990, and decline to \$24,000 by 1995. The estimated \$8.7 million in direct project wage and salary payments, combined with local nonlabor purchases, would translate into a total increase in Mesa County personal income of \$21.0 million over the 1987 to 1995 period.

In 1987, the labor income impact of the Cheney train and truck alternative on Mesa County would be \$3.9 million, in-

creasing county labor income by 0.5 percent. The labor income impact would reach a peak of \$7.3 million in 1988, or an increase of 1.0 percent over the projected Mesa County labor income level without the project. The impact would fall to \$6.5 million in 1989, \$1.2 million in 1990, and decline to \$6,000 by 1995. The direct project wage and salary payments, combined with local nonlabor purchases, would translate into a total increase in Mesa County labor income of \$19.1 million over the 1987 to 1995 period.

Local, state, and Federal tax receipts would be affected by the implementation of the Cheney train and truck alternative. State and local sales taxes would not be directly affected. The Grand Junction site could be developed; thus, Mesa County would continue to receive property taxes from the owners. The projected \$19.1 million increase in project related labor income would result in an expected increase of \$380,000 in state income tax receipts over the 1987 to 1995 period. Assuming an average Federal income tax rate of 15 percent, Federal income tax receipts would increase by a total of \$2.9 million over the same period. Smaller additional increases in state and Federal income tax receipts would be expected as a result of project related income generated from nonlabor purchases outside Mesa County.

K.2.3.5 Two Road truck alternative

In 1987, disposal of the tailings at the Two Road site via the truck alternative would result in a personal income impact on Mesa County of \$6.8 million, increasing county income by 0.7 percent. The personal income impact would reach a peak of \$8.4 million in 1988, or an increase of 0.9 percent over the projected Mesa County personal income level without the project. The impact would fall to \$7.8 million in 1989, \$1.5 million in 1990, and decline to \$26,000 by 1995. The estimated \$10.3 million in direct project wage and salary payments, combined with local nonlabor purchases, would translate into a total increase in Mesa County personal income of \$24.9 million over the 1987 to 1995 period.

In 1987, the labor income impact of the Two Road truck alternative on Mesa County would be \$6.3 million, increasing county labor income by 0.9 percent. The labor income impact would reach a peak of \$7.7 million in 1988, or an increase of 1.0 percent over the projected Mesa County labor income level without the project. The impact would fall to \$7.2 million in 1989, \$1.3 million in 1990, and decline to \$7,000 by 1995. The direct project wage and salary payments, combined with local nonlabor purchases, would translate into a total increase in Mesa County labor income of \$22.6 million over the 1987 to 1995 period.

Local, state, and Federal tax receipts would be affected by the implementation of the Two Road truck alternative.

State and local sales taxes would not be directly affected. The Grand Junction site could be developed; thus, Mesa County would continue to receive property taxes from the owners. The projected \$22.6 million increase in project-related labor income would result in an expected increase of \$450,000 in state income tax receipts over the 1987 to 1995 period. Assuming an average Federal income tax rate of 15 percent, Federal income tax receipts would increase by a total of \$3.4 million over the same period. Smaller additional increases in state and Federal income tax receipts would be expected as a result of project related income generated from nonlabor purchases outside Mesa County.

K.2.3.6 Two Road train and truck alternative

In 1987, disposal of the tailings at the Two Road site via the train and truck alternative would result in a personal income impact on Mesa County of \$4.5 million, increasing county income by 0.5 percent. The personal income impact would reach a peak of \$8.8 million in 1988, or an increase of 0.9 percent over the projected Mesa County personal income level without the project. The impact would fall to \$7.8 million in 1989, \$1.5 million in 1990, and decline to \$27,000 by 1995. The estimated \$9.4 million in direct project wage and salary payments, combined with local nonlabor purchases, would translate into a total increase in Mesa County personal income of \$23.0 million over the 1987 to 1995 period.

In 1987, the labor income impact of the Two Road train and truck alternative on Mesa County would be \$4.2 million, increasing county labor income by 0.6 percent. The labor income impact would reach a peak of \$8.0 million in 1988, or an increase of 1.1 percent over the projected Mesa County labor income level without the project. The impact would fall to \$7.1 million in 1989, \$1.3 million in 1990, and decline to \$7,000 by 1995. The direct project wage and salary payments, combined with local nonlabor purchases, would translate into a total increase in Mesa County labor income of \$20.9 million over the 1987 to 1995 period.

Local, state, and Federal tax receipts would be affected by the implementation of the Two Road train and truck alternative. State and local sales taxes would not be directly affected. The Grand Junction site could be developed; thus, Mesa County would continue to receive property taxes from the owners. The projected \$20.9 million increase in project related labor income would result in an expected increase of \$420,000 in state income tax receipts over the 1987 to 1995 period. Assuming an average Federal income tax rate of 15 percent, Federal income tax receipts would increase by a total of \$3.1 million over the same period. Smaller additional increases in state and Federal income tax receipts would be expected as a result of project related income generated from nonlabor purchases outside Mesa County.

K.2.3.7 Vicinity properties

In 1986, the vicinity properties cleanup would result in a personal income impact on Mesa County of \$10.5 million, increasing county income by 1.1 percent. The personal income impact would reach a peak of \$34.6 million in 1987, or an increase of 3.6 percent over the projected Mesa County personal income level without the project. The impact would fall to \$10.5 million in 1988, \$1.3 million in 1989, and decline to \$129,000 by 1995. The estimated \$28.8 million in direct project wage and salary payments, combined with local nonlabor purchases, would translate into a total increase in Mesa County personal income of \$57.7 million over the 1986 to 1995 period.

In 1986, the labor income impact of the vicinity properties cleanup on Mesa County would be \$9.6 million, increasing county labor income by 1.4 percent. The labor income impact would reach a peak of \$31.8 million in 1987, or an increase of 4.4 percent over the projected Mesa County labor income level without the project. The impact would fall to \$9.5 million in 1988, \$1.1 million in 1989, and decline to \$34,000 by 1995. The direct project wage and salary payments, combined with local nonlabor purchases, would translate into a total increase in Mesa County labor income of \$52.4 million over the 1986 to 1995 period.

Local, state, and Federal tax receipts would be affected by the vicinity properties cleanup. State and local sales taxes would not be directly affected. The projected \$52.4 million increase in project-related labor income would result in an expected increase of \$1,050,000 in state income tax receipts over the 1986 to 1995 period. Assuming an average Federal income tax rate of 15 percent, Federal income tax receipts would increase by a total of \$7.9 million over the same period. Smaller additional increases in state and Federal income tax receipts would be expected as a result of project related income generated from nonlabor purchases outside Mesa County.

K.3 EXISTING LAND USE

K.3.1 REGIONAL SETTING

Grand Junction, the county seat of Mesa County, is the commercial, agricultural, and transportation center of western Colorado. The county has gradually shifted from an economy based on agriculture to one based on construction, manufacturing, and energy development, as well as agriculture. Although most of the land in Mesa County is used as rangeland, the county is a commercial center for the region. Grand Junction contains more than one-third of the county's population.

Table K.3.1 presents the results of a 1982 zoning survey. According to the survey, Mesa County contained a total of 2,133,000 acres. Of the total county acreage, 71.5 percent was owned by the Federal Government, 0.25 percent was owned by the state government, 26.03 percent was privately owned land outside of incorporated cities and towns, and the remaining 2.22 percent represents private and publicly owned land inside incorporated cities and towns, and land in unclassified areas, such as roads, rivers, and canals (City/County Comprehensive Planning Department, 1983).

The 1982 survey placed the majority of the land in Mesa County (96.88 percent) in the agriculture, forestry, and transition zoning classification. The Federally-owned acreage (1,525,933 acres) in this classification was managed by the U.S. Forest Service (545,679 acres), Bureau of Land Management (958,094 acres), National Parks Service (19,406 acres), and Bureau of Reclamation (2754 acres). Mesa County residential acreage included 26,748 acres, or 1.25 percent of total county acreage. County commercially zoned acreage included 4148 acres, or 0.20 percent of total Mesa County acreage. Acreage zoned for industrial use included 4206 acres, or 0.20 percent of total Mesa County acreage (City/County Comprehensive Planning Department, 1983).

In 1978, Mesa County contained a total of 1257 farms. Land in farms (482,856 acres) represented 22.9 percent of the county's total land area. The average farm size was thus 384 acres. Of the 482,856 acres in farms, 100,378 acres were used as cropland, 16,502 acres were woodland, and 365,956 acres were used for other purposes. A total of 103,540 acres were irrigated (City/County Comprehensive Planning Department, 1983).

In 1981, the value of Mesa County crop production totalled \$23.0 million. Major crops include hay, corn grain, corn silage, barley, fruits, and vegetables. The number of irrigated acres increased 23.8 percent between 1974 and 1978. Despite the economic diversification in Mesa County during the past decade, agriculture is expected to continue to be a major component of the Mesa County economic base (City/County Comprehensive Planning Department, 1983).

Within the city of Grand Junction, the 1982 zoning survey showed 43.9 percent of the city's 8373 acres were zoned for residential use, 43.3 percent were zoned for commercial use, and 9.0 percent were zoned for industrial use. Rivers, canals, and roads covered 216 acres, or 2.6

Table K.3.1 Mesa County/City of Grand Junction zoning survey -
December, 1982

Zoning designation	Acres	Percentage
Residential	26,747.8	1.25
Commercial	4,148.2	0.20
Industrial	4,206.1	0.20
Agriculture, forestry, and transition (private)	520,163.7	24.38
Agriculture, forestry, and transition (U.S. Government)	1,525,933.0	71.50
Other (state government)	5,209.7	0.25
Incorporated cities and towns	10,988.0	0.53 ^a
Grand Junction	8,373.0	(100.0) ^a
Residential	3,677.0	(43.9)
Commercial	3,622.0	(43.3)
Industrial	754.0	(9.0)
Rivers, canals, lakes, and roads	216.0	(2.6)
Unzoned	104.0	(1.2)
Mesa County total	2,133,000.0	100.0

^aPercentages in parentheses represent, proportions of the total acreage in the city of Grand Junction zoned as designated.

Ref. City/County Comprehensive Planning Department, 1983.

percent of the city's land. The remaining 1.2 percent of the land in Grand Junction was unzoned (City/County Comprehensive Planning Department, 1983).

K.3.2 GRAND JUNCTION SITE

The Grand Junction tailings site is privately owned and is located in a primarily urbanized area, with residential, commercial, and industrial development nearby. The land within 0.5 mile of the site on the north side of the river is undergoing a transition from residential to commercial and industrial uses. Residences are being replaced with business establishments to the northeast and west of the site itself. The area's proximity to the Denver and Rio Grande Western Railroad makes it desirable for industrial development. Commercial and industrial land use occurs immediately north and northeast of the tailings site (Figure K.3.1). There are some residential areas east, west, and northwest of the site, and there is considerable residential development south of the site, across the Colorado River. The residential area west of the site is an older low-income area, with many old houses interspersed with some commercial establishments. The land east of the site is used for industrial purposes or is vacant. The vacant lands mark the transition between the urban area of the city and the rural residential and agricultural areas east of the city. The railroad is roughly the northern boundary of the area of industrial land use. There is an industrial park near the north side of the site. As this is developed, it is expected to hasten the industrialization of the other land in the vicinity of the site (DOE, 1983).

The site itself is outside the incorporated area of the city of Grand Junction and is therefore not subject to the zoning restrictions of the city. The area is, however, subject to county zoning, and the site and the surrounding area are zoned industrial. Since the site is outside the city limits, it is controlled by Mesa County's Land Use Plan and development policies. The latest addition to the plan and development policies occurred in September, 1982. The part of this document that is most pertinent to the development of the site and its vicinity is Section 9, which includes land use and site planning standards. This section recommends the use of planned unit developments to ensure that all new construction is in conformity with the character of the area. The county encourages developers to draw up their own plan and site planning criteria, which are then subject to gross density limits, performance standards, and a requirement for buffer zones between substantially different types of development (DOE, 1983).

Grand Junction's adopted parks and recreation plan designates the tailings site as part of the proposed Colorado River Park System. However, as previously noted, the site is not currently within the city limits. Thus, there is an apparent conflict between the commercial/industrial zoning and land use designation of the site, as well as the adjacent property, and its designation as part of the Colorado River Park System (City Planning Department, 1979). The site is located in a 100-year floodplain. City regulations require that a Flood Development Permit be obtained before developments in the floodplain may commence and the county discourages development in the floodplain (City Planning Department, 1984).

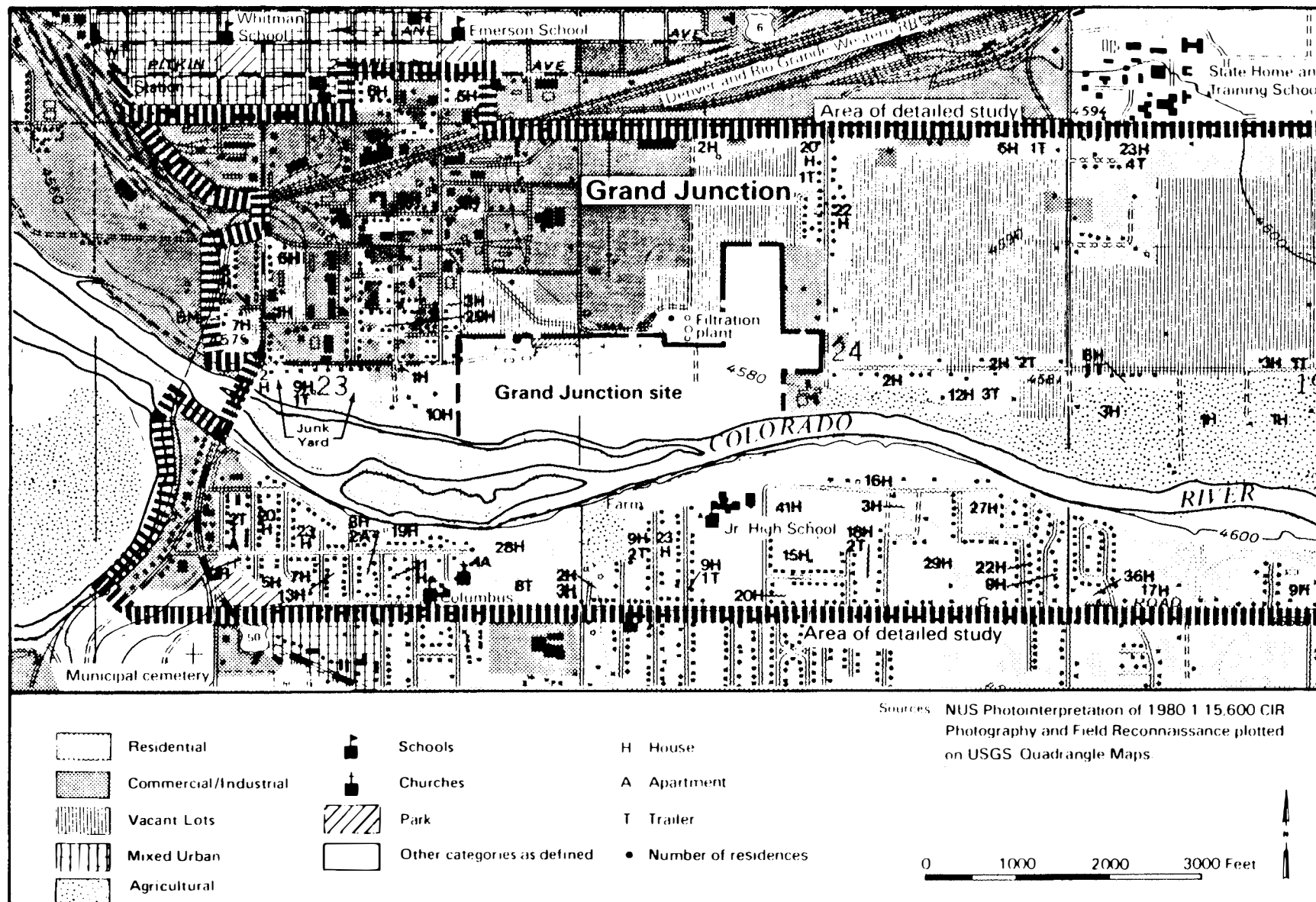


FIGURE K.3.1
LAND USE AT THE GRAND JUNCTION SITE

K.3.3 CHENEY RESERVOIR SITE

The Cheney Reservoir site is located approximately 18 miles southeast of the Grand Junction site off of U.S. Highway 50. The site is Federally owned, and its managed by the Bureau of Land Management (BLM).

The site is located within a BLM grazing allotment designated for cattle. Grazing on the rangeland is the primary use of land within three miles of the site. The site, however, is also under an oil and gas lease. An electric power transmission line bisects the site, and another line occurs east of the site (Logan-Pearce, 1985).

The proposed 1985 Grand Junction Resource Management Plan (a master plan for managing and allocating public land resources over the next 15 to 20 years) shows two "Mandatory Protection Areas," within 1.5 miles of the site, one to the southeast and one to the southwest. These areas are designated for protection due to the existence of resources such as threatened plant/animal species or cultural sites. Under the preferred alternative of the plan, the site's water resources are emphasized (Resources Management Plan, 1985).

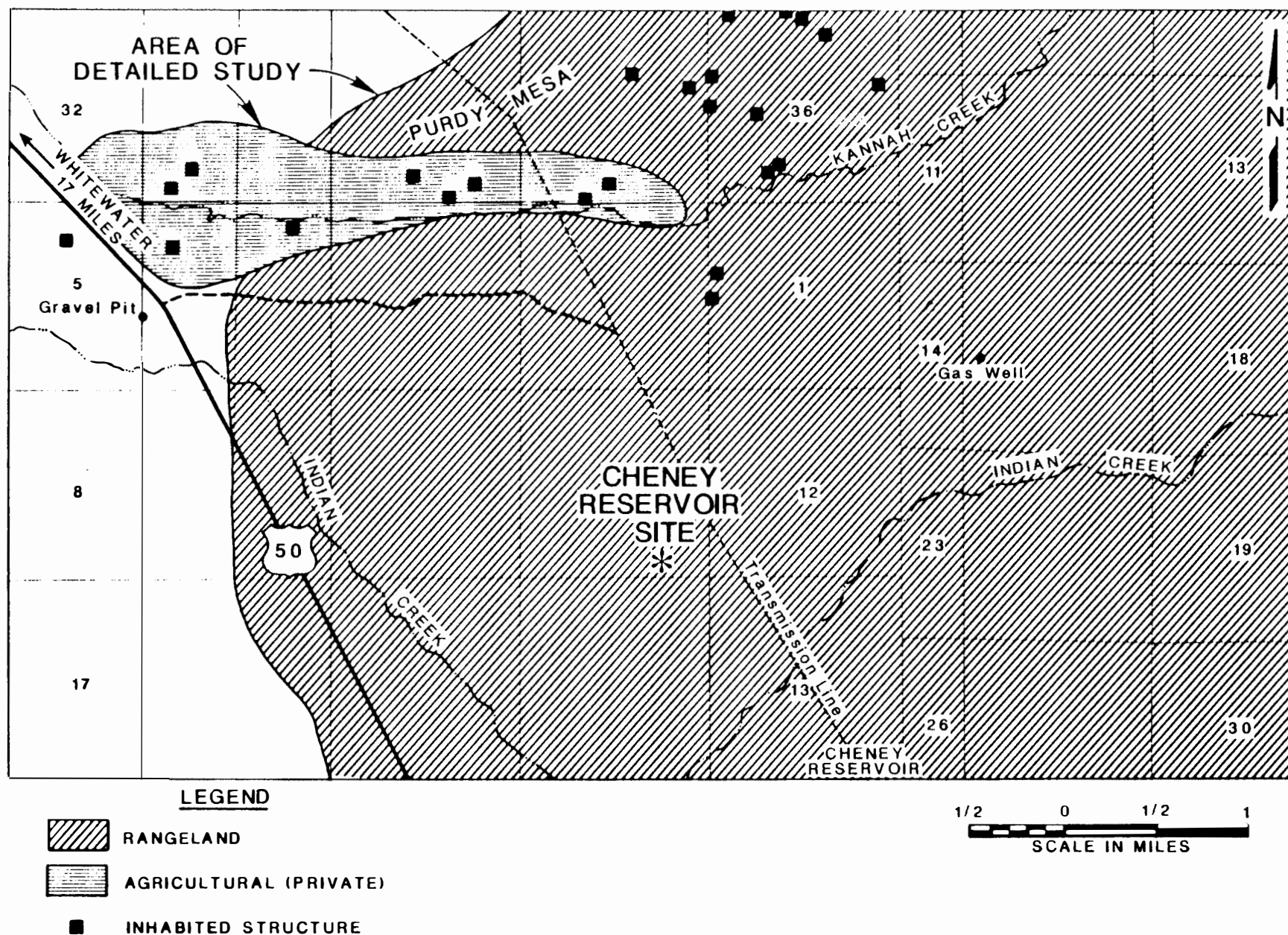
The nearest residences to the site are two mobile homes located approximately 1.5 miles to the northeast (Figure K.3.2). A zone of irrigated agriculture land lies between one and two miles from the site in the valley of Kannah Creek near Smith Ditch. Associated with this zone are farmsteads, ranches, and some trailers. Most of the irrigated land is two and three miles from the site, and there are more farmsteads and ranges in this zone. Between two and three miles northeast of the site there are at least 11 single family homes and two mobile homes (DOE, 1983).

K.3.4 TWO ROAD SITE

The Two Road site is located approximately 33.1 miles (by road) northwest of the Grand Junction site. More specifically, it is located along Two Road, 3.4 miles northwest of the intersection of Two Road and U.S. Highway 6 & 50. The site is Federally owned, and is managed by the Bureau of Land Management (BLM).

The site is within a BLM grazing allotment. The grazing of sheep on the area's sparsely vegetated rangeland is the primary use of land. Deer are the most dominant wild grazing animals; however, their numbers are few in the region containing the site. The land containing the site is also under oil and gas leases; an underground natural gas pipeline (running northwest to southeast) is located approximately 1.5 miles from the site (Logan-Pearce, 1985).

The 1985 Grand Junction Resource Management Plan shows two "Mandatory Protection Areas," one to the east and one to the north, within two miles of the site. Under the preferred alternative of the plan, the site falls into a recreation designation. Examples of possible recreational uses include off-road vehicle pursuits, target shooting, day hiking, and small game hunting (BLM, 1985).



The Two Road site and vicinity are also considered as a potential location for a system of evaporation ponds associated with the recommended plan of the proposed Glenwood-Dotsero project. The project has been proposed as a method of reducing the salt content of the Colorado River. The proposal resulted from the Colorado River Water Quality Improvement Program, which was initiated in 1971 by the Bureau of Reclamation, U.S. Department of Interior. High salinity water is undesirable for irrigation, since it requires greater applications in order to leach mineralization through the soil. It is also corrosive, making it undesirable for industrial use (USD0I, 1983).

According to the recommended plan, the Glenwood-Dotsero project would involve the installation of collection facilities on the Colorado River at Dotsero and Glenwood Springs where clusters of saline springs exist. The saline water would then be transported to the evaporation pond system at the Two Road site. The project would reduce the salt loading into the Colorado River by an estimated 284,000 tons annually. The average annual flow of the Colorado River would be depleted by an estimated 15,560 acre-feet (USD0I, 1983).

The Glenwood-Dotsero project would require approximately 5000 acres in the vicinity of the Two Road site for the evaporation ponds. Recently, the State of Colorado rejected the evaporation ponds design. The final report of the state on the future of the project has not yet been published; however, less expensive salinity control projects exist, and it is unlikely that the Glenwood-Dotsero project will be further considered in the near future (Mezei, 1985).

The nearest residence to the site is a mobile home just east of the intersection of Two Road and U.S. Highway 6 & 50; the location supports a sheep operation, including lambing pens and a small reservoir for watering. A pumping station is located approximately two miles to the southeast of the site. An agricultural area, including residences begins approximately five miles east of the site and extends east and south toward Mack, Fruita, and Grand Junction (Figure K.3.3).

K.3.5 VICINITY PROPERTIES

The types of properties that would be affected by the remedial action include homes, businesses, and open lands in the vicinity of the mill tailings site. Building lots (residential and commercial) may range from small lots of approximately 5000 square feet to several acres in size. However, a typical lot measures approximately 100 x 100 feet (0.25 acre). A private residence or commercial building exists on most identified properties. Approximately 3465 properties in Grand Junction are expected to be candidates for cleanup under the UMTRA Project (Appendix L, Vicinity Properties Report). Because there are several thousand contaminated properties in Grand Junction, and because these properties are not located exclusively in any single section of the community, the land use description for Grand Junction as a whole (Sections 4.9.1 and 4.9.2) can serve as a description of the land use context for the vicinity properties (DOE, 1985).

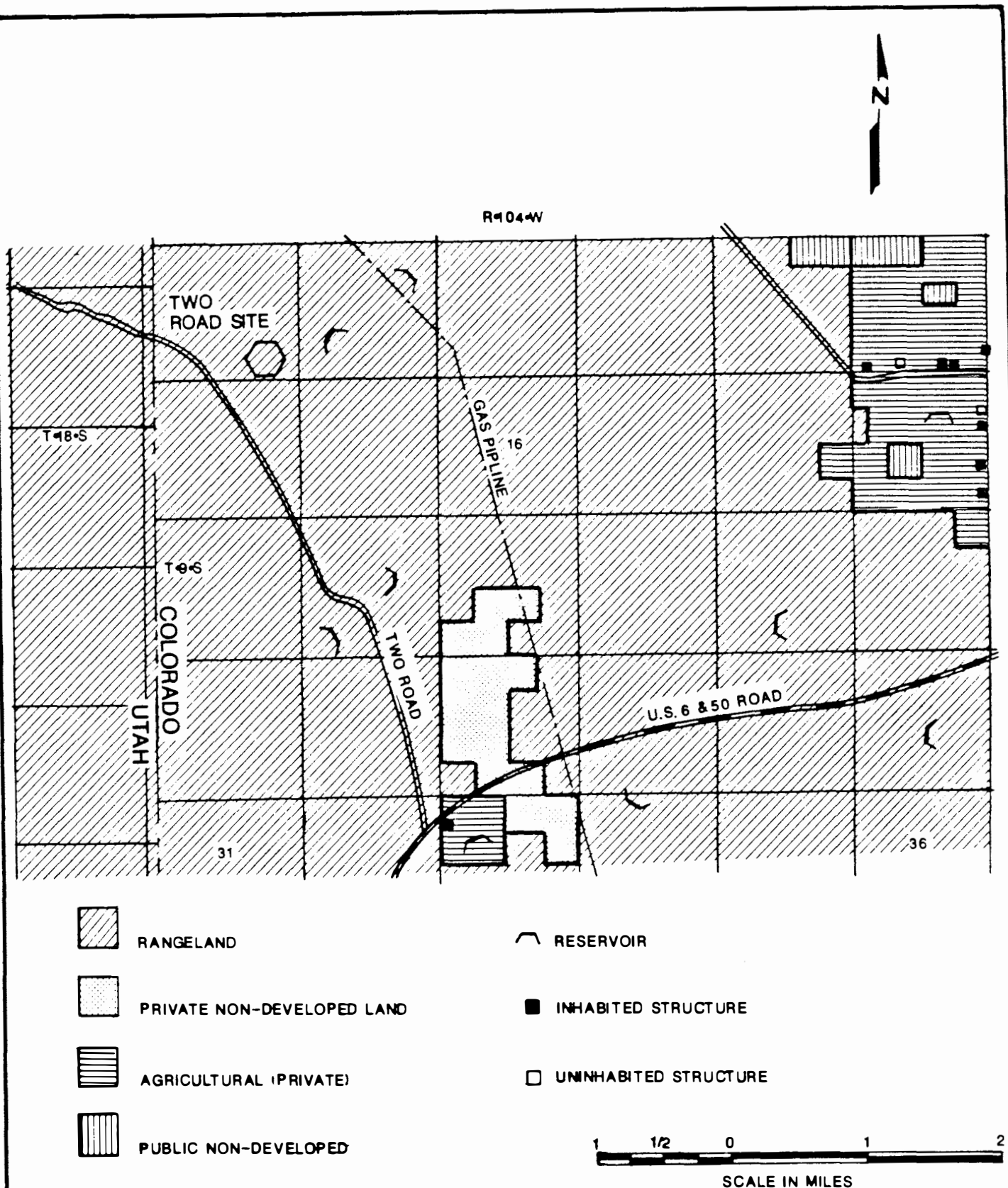


FIGURE K.3.3
LAND USE IN THE VICINITY OF THE TWO ROAD SITE

The existence of the tailings piles and potential contamination of properties has had relatively little impact on land use or values. Within Grand Junction during the 1974 to 1984 period, residential and commercial development increased adjacent to the tailings site; an additional 50 to 60 housing units, a sawmill and lumber yard, several warehouses, and other commercial businesses were established near the tailings site (Metzner, 1984). In a study of land values at, and adjacent to, the South Salt Lake City site, it was found that adjacent land values were unaffected by the tailings pile and were primarily affected by the highest and best use of the parcel (DOE, 1984a). Following decontamination, property values may increase, principally because of improvements during restoration. Most of the potentially contaminated businesses show little impact from the presence of the tailings. U.S. Department of Energy property value assessments do not devalue properties due to tailings contamination (DOE, 1985).

K.3.6 BORROW SITES

The borrow sites considered for the remedial action alternatives include the 32 and C $\frac{1}{2}$ Road site, the Unaweep site, the Fruita site, and local borrow areas at the Cheney Reservoir and Two Road sites.

The 32 and C $\frac{1}{2}$ Road borrow site consists of four privately owned pits located 6.5 miles east of the Grand Junction site and within 0.25 mile of each other. The pits cover a total of approximately 70 acres. The nearest residence to the site is within one mile of any of the four pits. There are orchards in the area which are irrigated occasionally.

The Unaweep borrow site is located 47 miles southwest of the Grand Junction site in Unaweep Canyon. The site is Federally owned and is managed by the U.S. Bureau of Land Management. There are no residences within 0.25 mile of the site. The Unaweep site consists of approximately 25 acres and would be used only under the stabilization on site alternative.

The Fruita borrow site is located 21.9 miles east of the Two Road site in Fruita and would be used only under the Two Road alternative. The site is a privately owned sand and gravel pit and consists of approximately 10 acres. Irrigation ditches run adjacent to the pit. A ready-mix concrete plant is also located adjacent to the pit. The nearest residences are on small irrigated farms located approximately 0.25 mile to the east.

Sections 4.9.3 and 4.9.4 describe the existing land use for the Cheney Reservoir and Two Road sites. Thus, land use information for the local borrow area at the Cheney Reservoir and Two Road sites may be obtained by referring to those sections (DOE, 1985).

K.4 IMPACTS ON LAND USE

K.4.1 NO ACTION

The no action alternative would preclude the 114 acres composing the Grand Junction site from any alternative land use. The Parks and Recreation Plan of the City of Grand Junction, which designates the land area occupied by the site as part of the proposed Colorado River Park System, would be affected. Industrial development, which is the primary land use in the vicinity of the site, would also be affected; however, because there is an abundance of available industrially zoned land in the area, the impact would be slight.

Current land values for large parcels of industrial land in Grand Junction range from approximately \$.25 per square foot to \$1.00 per square foot (Razga, 1984). Applying these values to the 114 acres of the Grand Junction site, the estimated value of the parcel, free of contaminated materials and available for development, would range between \$1.3 million and \$5.0 million. Because the site is within the 100-year floodplain, the value of the parcel may be below even the \$1.3 million estimate. Mesa County discourages development in the floodplain, while the city of Grand Junction, if it issued a Floodplain Development Permit, would require costly special construction to meet floodplain regulations. The parcel without the contaminated material removed is of little market value, since the cost of removing the tailings would have to be incurred before any development would be possible. The no action alternative would have no impact on land values of parcels surrounding the site.

K.4.2 DISPOSAL AT THE GRAND JUNCTION SITE

Stabilization of the tailings pile at the Grand Junction site would preclude 93 acres from any alternative land use. The land occupied by the stabilized tailings pile would not be usable as designated by the city of Grand Junction for part of the proposed Colorado River Park System. It would also be unavailable for industrial use; however, this impact should be slight given the abundance of land available for industrial development in the area.

The 93 acres, free of contaminated materials, would be valued at approximately \$1.0 million if the low price in the range of prices of Grand Junction industrial land per square foot (\$.25/sq ft) were deemed an appropriate price. This value may be high due to the site's location in the 100-year floodplain. Stabilization of the tailings on the site could positively affect the values of land parcels in the proximity of the site; however, given the abundance of buildable land in Grand Junction and because the presence of the unstabilized tailings pile apparently has had little effect on land values, any such positive action would be slight.

A total of 132 acres would be disturbed at the Grand Junction site during the construction period. The total includes the 114 acres of the processing site and an additional 18 acres which would have to be purchased. The 18 acres purchased would become part of the 93 acres making

up the acreage permanently occupied by the stabilized pile. The excavation of borrow materials would disturb approximately 25 acres at the Unaweep Canyon borrow pit and 70 acres at the 32 and C $\frac{1}{2}$ borrow pit. The Unaweep Canyon pit would be in a remote location, while the 32 and C $\frac{1}{2}$ borrow area consists of existing privately owned gravel pits; thus, temporary and permanent impacts at borrow sites would be minimal.

Disposal at the Grand Junction site would have only a negligible impact or no impact on existing or future agricultural resources. Similarly, no existing transportation corridors or recreational sites or resources would be affected. However, as mentioned previously, future recreational resources could be affected.

K.4.3 DISPOSAL AT THE CHENEY RESERVOIR SITE

Disposal of the tailings at the Cheney Reservoir site would permanently remove approximately 80 acres of rangeland from the Bureau of Land Management Kannah Creek allotment. The acreage occupied by the stabilized pile would be unavailable for oil and gas exploration. A stabilized tailing pile at the site, which is surrounded by Federally owned land, would have no impact on area land values. Disposal at the Cheney Reservoir site would make the 114-acre Grand Junction site available for further development.

During the construction period, a total of 480 acres at the Cheney Reservoir site would be disturbed. Of that total, 80 acres would be used for tailings disposal and 400 acres would be used to obtain borrow material. An additional 14 acres of land in the vicinity of the site would be disrupted for an access road. Finally, the 114-acre Grand Junction site would be temporarily disrupted during the relocation to Cheney Reservoir.

The permanent and temporary loss of acreage at the Cheney Reservoir site would affect ranchers who are permitted to run their cattle on the Bureau of Land Management Kannah Creek grazing allotment. However, considering the sparse character of the area's vegetation and the size of range in relation to the acreage permanently lost due to the construction period, the impact of affected cattle operations would be slight. The potential for agricultural development at the Cheney Reservoir site exists because of the land's favorable slope, available water, and proximity to the Kannah Creek farms. Disposal at the Cheney Reservoir site would preclude 80 acres from such development.

Disposal at Cheney Reservoir would not be expected to affect the electric power transmission line which crosses the site or the line that occurs east of the site. No effects on existing or future recreational resources in the area would be expected.

K.4.4 DISPOSAL AT THE TWO ROAD SITE

Disposal of the tailings at the Two Road site would permanently preclude 80 acres from any alternative land use. Thus, the site, which is currently under an oil and gas lease, would not be available for exploration. The 80 acres would be permanently removed from the Bureau of Land Management Bar X grazing allotment, which is stabilized, Federally-owned land. Disposal at the Two Road site would make the 114-acre Grand Junction site available for further development.

During the construction period, 80 acres would be disrupted at the Two Road site, not including access roads. Two Road, U.S. Highway 6 & 50, and approximately two acres of land for other access roads would be disturbed and upgraded as necessary to ensure safe and efficient relocation of the tailings. An additional 10 acres at the Fruita borrow site would be temporarily disturbed. Finally, 114 acres at the Grand Junction site would be disturbed.

The permanent loss of the 80 acres used for the Two Road site would affect ranchers who run their sheep on the Bureau of Land Management Bar X allotment. However, the expansive range and sparse vegetation imply that these effects would be negligible. No effects on existing or future recreational resources in the area would be expected. Feasibility studies for the Glenwood-Dotsero project indicate that alternatives to the Two Road site for evaporation ponds are very expensive due to pumping requirements; if the State of Colorado were to reverse its decision, which disallowed the evaporation pond design, the incompatibility of the Glenwood-Dotsero and uranium mill tailings relocation projects could jeopardize the Glenwood-Dotsero project, assuming that the tailings were relocated to the Two Road site.

K.4.5 VICINITY PROPERTIES

Long-term land use impacts would be negligible if remedial action were taken on the estimated 3465 vicinity properties (866 acres) in Grand Junction. The land uses and zoning of the affected properties would not change following the remedial action. However, approximately 70 acres of open land properties would be available for development following the cleanup work. The affected properties would be disturbed temporarily during the 27 months of the remedial action. No mineral resources, recreational resources, or agricultural resources would be expected to be affected. Following completion of the remedial action, land values of the affected properties conceivably could be slightly enhanced, although there is no evidence that the existing contamination has adversely affected property values.

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APPENDIX L
VICINITY PROPERTY REPORT

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L.1 INTRODUCTION

L.1.1 BACKGROUND

This report provides background information on the Grand Junction vicinity properties, describes the remedial action process, and provides engineering estimates for remedial action. This information was then used to estimate the impacts of remedial action at the vicinity properties. The text of this Environmental Impact Statement (EIS) describes the existing environment and environmental impacts of remedial action at the vicinity properties. Remedial action of the areas adjacent to the tailings pile that have been contaminated by wind and water erosion of the tailings are described in Appendix B, Engineering Designs.

Tailings from the Grand Junction tailings pile have been removed and used as fill and as construction material at locations in the vicinity of Grand Junction. These locations are called "vicinity properties." This activity occurred before the potential health hazards of the tailings were recognized and this removal of the tailings is no longer allowed.

The principal hazard associated with the tailings results from the inhalation of radon-222 and radon daughters. Radon-222 is an inert gas produced from the radioactive decay of the radium-226 contained in the tailings. As a gas, radon-222 can diffuse through the tailings and into the atmosphere. In the atmosphere, radon-222 decays into its solid daughter products which attach to 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 radiation directly to the lungs. If the concentration of radon-222 and its daughter products is high enough and the exposure time long enough cancer may develop. This exposure pathway is especially important in closed structures such as homes because the concentration of radon-222 can build up to higher levels than occur in the ambient atmosphere.

Gamma radiation is also emitted from the tailings. Gamma radiation behaves independently of the atmosphere and travels in a straight line until it impacts with matter. Gamma radiation delivers an external exposure to the whole body which may also cause cancer to develop.

There are two programs which involve the cleanup of vicinity properties in the Grand Junction area. The Grand Junction Remedial Action Program (GJRAP) is operated by the State of Colorado and the Uranium Mill Tailings Remedial Action (UMTRA) program operated by the U.S. Department of Energy (DOE).

In passing the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), Public Law 95-604, the U.S. Congress authorized the U.S. Environmental Protection Agency (EPA) to establish standards for remedial action at UMTRA Project sites. These standards are shown in Appendix A, EPA Standards.

Based on initial radiological surveys in the Grand Junction area, a total of 6905 sites (homes, commercial establishments, vacant lots, and public facilities) have been designated as possibly needing remedial action. However, the Department of Energy (DOE) estimates that additional radiological surveys will show that many of these sites do not contain a radiological hazard sufficient to warrant remedial action or that the elevated levels of radiation are caused by sources other than uranium tailings. DOE estimates that only 3648 sites will ultimately require remedial action (DOE, 1984). This is based on historical inclusion rates over the past two years. Since remedial action has been completed at approximately 200 properties, remedial action at 3465 properties is addressed in this EIS.

L.1.2 RELATIONSHIP BETWEEN THE UMTRA PROJECT AND GJRAP

In June, 1972, the U.S. Congress passed Public Law 92-314 which authorized the State of Colorado to perform remedial action at certain Grand Junction vicinity properties. This project is called the Grand Junction Remedial Action Program (GJRAP) and was the first public project developed to support the cleanup of uranium mill tailings. GJRAP is similar to the UMTRA Project vicinity property program.

The GJRAP is administered by the State of Colorado and is financed with 75 percent Federal funds and 25 percent state funds. GJRAP applies only to uranium tailings that affect radiation levels in habitable structures which generally involves tailings beneath and within 10 feet of the structures.

The standards and criteria for GJRAP remedial action were promulgated in December, 1972, by the Atomic Energy Commission (now the Nuclear Regulatory Commission) and are contained in 10 CFR Part 12.

Approximately 650 vicinity properties have been identified as qualifying for remedial action under GJRAP and remedial action has been performed at approximately 500 properties. The remainder of the properties are scheduled for remedial action by 1987. Of the 650 properties presently eligible under GJRAP, approximately 150 properties may also be eligible for the UMTRA Project vicinity property program. These properties are called "dovetail properties." Dovetail properties are those habitable structures with tailings beneath and within 10 feet of the structures which thereby qualify under GJRAP, and which also have tailings further from the structures, exceed UMTRA Project standards, and thereby qualify under the UMTRA Project vicinity property program. Remedial action at these properties is performed at one time with the costs shared between the GJRAP and UMTRA Project programs.

Public Law 92-314 was amended in February, 1978, by Public Law 95-236 to allow owners' application to the program to be extended to June, 1980.

Table L.1.1 provides a comparison of the GJRAP and UMTRA Project programs. Contaminated materials excavated under GJRAP are temporarily stored at the State Repository adjacent to the Grand Junction tailings pile. These contaminated materials will be added to the Grand Junction tailings pile during remedial action on the pile.

Table L.1.1 Comparison of GJRAP and UMTRA Project vicinity property programs

1. GJRAP (PL92-314) was passed in 1972, the first Federal legislation to support cleanup of uranium mill tailings.	UMTRCA (PL95-604) was authorized in 1978 to provide for the stabilization and control of uranium mill tailings at designated inactive mill sites.
2. GJRAP is managed by the State of Colorado.	The UMTRA Project is managed by the U.S. Department of Energy.
3. GJRAP applied only to habitable structures within Mesa County, Colorado.	The UMTRA Project covers 24 mill tailings sites in 10 different states, and their related vicinity properties.
4. GJRAP is limited to remedial action on tailings that affect radiation levels inside structures. Generally, this involves tailings under and within 10 feet of the structure.	The UMTRA Project does not include properties qualifying for remedial action under GJRAP, except under special circumstances.
5. GJRAP excludes remedial action on tailings that do not affect buildings. Vacant lots for example, are not eligible for cleanup under GJRAP.	The UMTRA Project cleans up all eligible vicinity properties including open land.
6. GJRAP will involve the cleanup of about 650 buildings.	The UMTRA Project is responsible for an estimated 3648 vicinity properties in Mesa County, and is not limited to habitable structures.
7. Financing for GJRAP is provided using 75 percent Federal and 25 percent state funds.	Financing for the UMTRA Project is provided using 90 percent Federal and 10 percent state funds.

L.2 DESCRIPTION OF THE GRAND JUNCTION VICINITY PROPERTIES

As discussed in Section L.1.1, an estimated 3465 vicinity properties will require remedial action. As shown below these properties have been divided into four categories:

<u>Category</u>	<u>Estimated number of properties</u>
Residential	2527
Commercial	661
Open Lands	264
Complex	<u>13</u>
Total	3465

Residential vicinity properties are homes and apartments which may have tailings around and beneath the structures. Commercial vicinity properties are businesses, schools, public utilities, or other public structures which may have tailings around or beneath the structures. Open lands are vicinity properties which contain no structures and where tailings have been used as fill material.

Complex vicinity properties are any properties (including homes, businesses, or open lands) where the estimated costs of remedial action exceed \$350,000. These properties are usually buildings which have structural contamination. Structural contamination may include cement or concret which was formed with tailings. Complex vicinity properties may also include vacant lots where large quantities of tailings were used as a source of fill if the remedial action costs would exceed \$350,000.

L.3 REMEDIAL ACTION PROCEDURES

L.3.1 INTRODUCTION

The following discussion of the remedial action procedures was summarized from a paper presented at the 1985 Waste Management Symposium in Tucson, Arizona (Stassi et al., 1985) which is hereby incorporated by reference.

Vicinity properties must be identified, included, engineered, and cleaned up. Once a property is cleaned up, verification that EPA standards have been met must be established. A generic property schedule is provided in Figure L.3.1 to illustrate the steps of the process and the relative time required to accomplish each task. A detailed outline of the remedial action process is contained in the Vicinity Properties Management and Implementation Manual (VPMIM) (DOE, 1984a). This process is summarized below.

L.3.2 PROPERTY ELIGIBILITY

Property identification

As the first step in the cleanup of UMTRA Project vicinity properties, aerial surveys were conducted between 1977 and 1983 by the DOE to identify areas around uranium tailings piles which could possibly be contaminated. Mobile ground surveys were also performed to further define the location and quantity of these vicinity properties. In addition, between 1972 and 1980, on-site surveys were conducted by various agencies on individual properties.

Designations

Vicinity property "designation" is the process by which information from aerial, mobile van, and on-site surveys is used to identify and list candidates for UMTRA Project remedial action. The DOE designates those properties for which uranium mill tailings contamination is suspected.

Property inclusion--definition and purpose

Prior to beginning remedial action activities, each property must be evaluated to determine its eligibility for inclusion in the UMTRA Project. "Included" properties are those properties at which the existence of residual radioactive contamination in excess of EPA standards has been confirmed. The inclusion evaluation usually involves on-site radiological surveys; however, mobile radiation surveys have been used in some cases. The survey information is evaluated and a recommendation is made to the DOE for inclusion or exclusion.

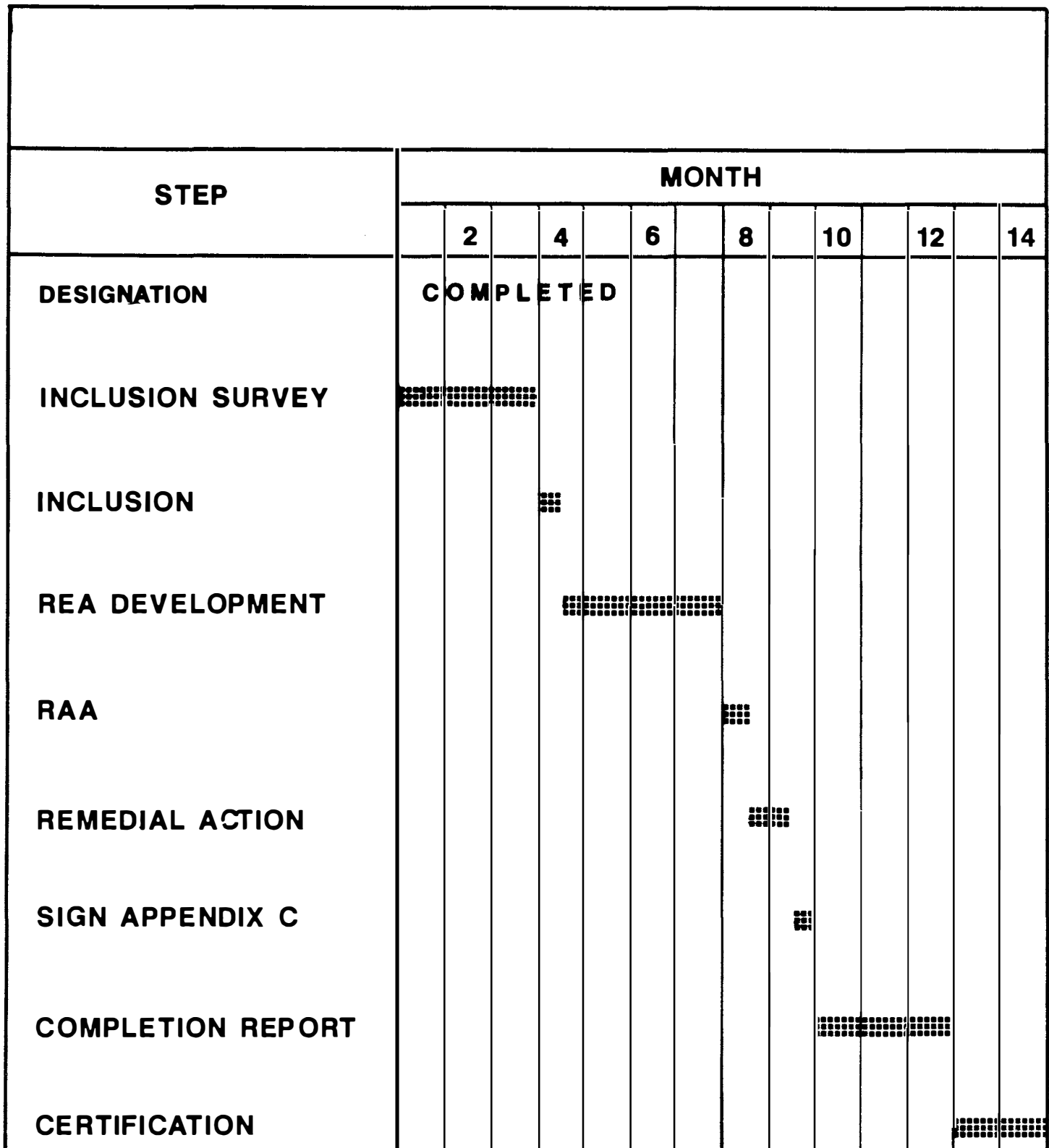


**FIGURE L3.1
GENERIC VICINITY PROPERTY SCHEDULE**

Preliminary radiological data developed by the EPA and others are first referenced to assist in making an inclusion determination. Should additional data be required, additional on-site surveys would be conducted to acquire supplemental measurements. Prior to the initiation of any inclusion survey work, the consent of the property owner must be obtained.

Once consent to survey a property is received from the property owner, a survey is conducted to identify residual radioactive material in excess of the EPA standards. A standard survey procedure is employed consisting of a surface gamma scan indoors and outdoors. Soil sampling and analysis, and working Level (WL) measurements are conducted only if required. The survey procedure is designed to optimize time and to provide for extended measurements only as they are required.

Critical data generated by these surveys could include: maximum radiation exposure levels recorded outside and inside any habitable structures, radon daughter concentrations in the air (indoors only), and soil radium-226 content in suspected contaminated areas. These data are used by DOE for their inclusion/exclusion determination. Once a vicinity property has been officially included by the DOE, engineering designs are prepared for remedial action.

L.3.3 PREPARATION FOR REMEDIAL ACTION

Purpose

Properties which have been included in the UMTRA Project for remedial action are further assessed from a radiological and engineering viewpoint so that preliminary design for a remedial action alternative, or set of alternatives, can be generated. The Radiological and Engineering Assessment (REA) defines the areal extent and depth of any tailings material which exceeds the EPA cleanup standards.

Once a property's REA is approved by DOE, NRC, and the state, the property owner enters into an agreement with the DOE which outlines the remedial action plan for his property. This is called a Remedial Action Agreement (RAA). The REA and RAA processes are discussed below in further detail.

Radiological and Engineering Assessment

The data obtained during the inclusion survey are used as a baseline for the REA survey. The REA radiological assessment defines all tailings deposits on a property. DOE generally performs a complete surface gamma scan of the property. Areas of suspected contamination are outlined on a map and further investigated with grid gamma surveys and drill holes.

Generally, the DOE performs gamma survey measurements on the interior of a structure only if the inclusion survey has identified elevated readings or potential areas of contamination inside the structure. The areas of indoor contamination are defined by completely gamma scanning the room where contaminants exist. If elevated surface gamma readings are noted at the floor of a structure, holes are drilled through the floor, with permission from the property owner, and through the suspected deposit. A two-inch by two-inch NaI detector is lowered in the drill hole and six-inch incremental readings are taken. The depth of the deposit is estimated based on the readings taken in the hole.

If possible, all holes are drilled to a depth below the tailings deposit. However, drill hole depths can vary based on two conditions: the soil type, and the depth of contamination. For example, if drilling takes place in rocky soil with hand-held augers, the drill hole depth may not be sufficiently deep to penetrate the contamination but may be adequate to determine the depth to clean material.

The locations of drill holes are generally determined by surface gamma readings in an attempt to define the areal extent of the deposit as well as the depth. Holes are usually drilled both within the suspected contamination areas and around the outer perimeter of these areas.

In areas where the down hole logs show no contamination but surface gamma scans still show elevated surface readings, "Delta" readings are taken to confirm that the surface readings are caused by shine from adjacent deposits.

In addition to drilling holes in areas of high gamma anomalies, holes may be drilled in suspected backfill areas. These suspected areas include building foundations, utility lines, and the like. This identifies buried tailings deposits which may otherwise be shielded by concrete foundations or clean fill.

The radiological information is used by DOE to estimate the areal and volumetric extent of contamination. From this determination, DOE identifies design requirements and cost estimates for remedial action. The total package of information is combined with drawings and is presented in an REA.

The REA includes not only a radiological assessment but also an assessment of the engineering conditions and considerations. The engineering assessment generally includes a legal description of the property, identification of utilities and their locations, any potential safety hazards that should be considered during remedial action, and a cost estimate for each considered option.

The cost estimates that are presented in the REA include quantities and unit costs for each work item. Unit costs are usually based on previous contracts for similar work, or on typical costs for that geographic location.

The REA is submitted to DOE, NRC, and the respective state or tribe for comment and approval. The DOE incorporates the comments from each respective organization into a final REA. On noncomplex properties, draft REAs are not required. The final REA is used as the basis for detail design and remedial action. At this stage the DOE interacts with the property owner to obtain his/her agreement on the proposed remedial action plan.

Remedial Action Agreements (RAA)

DOE must obtain an RAA from each property owner whose property requires remedial action. An RAA includes a description of the remedial action plan based on the selected option in the final REA. It also provides the property owner with a guarantee that the property will be restored to its original condition, a release of liability, and, if required, provisions for dislocation and reimbursement cost. An RAA provides the DOE with an approval for remedial action and title to the residual radioactive materials. After the RAA is fully approved, DOE may begin remedial action.

L.3.4 REMEDIAL ACTION

Description

Remedial action is the culmination of the vicinity property process. Although this stage represents, on the average, less than 10 percent of each property's schedule, it represents nearly 75 percent of the cost and is the most visible part of the vicinity property process. After remedial action, the only steps left in the vicinity property process are to certify the property's compliance with EPA standards, to provide formal notification to the property owner, and to notate the property's legal deed.

For purposes of this discussion remedial action involves: contracting, excavation, owner/tenant dislocation, restoration, health and safety, completion reporting, certification, and document transfer/archiving.

Contracting

All remedial action work on vicinity properties is performed by private contractors. The preference is to provide work to local subcontractors so that money can be fed into the local community's economy.

Award of the bid package is given to the qualified lowest bidder. Preference is given to small, disadvantaged, minority, and women-owned businesses. Upon award, the subcontractor submits a schedule so that excavation control and health and safety monitoring can be planned.

Owner/tenant dislocation

Certain conditions established in the RAA must be complied with prior to the start of construction. One such condition is the agreement for dislocation.

Occasionally, owners or tenants must be temporarily dislocated to housing other than their home or business. This is typically required only when extensive structural decontamination is performed; however, it could occur under any conditions which jeopardize the health and safety of the occupants. Based upon the RAA, occupants are dislocated at the DOE's expense. A conservative per diem is allowed and storage of household goods sometimes is permitted.

A less common RAA condition involves reimbursement for losses incurred during remedial action. This condition is allowed under limited circumstances when commercial enterprises are involved. These cases are judged on an individual basis by the DOE and the state.

Excavation and restoration

Once conditions of an RAA are met and the construction crews undergo health and safety training, the excavation of contaminated material can begin. Areas assessed in the REA for contamination are staked. Access control to the area being excavated is established in accordance with health and safety requirements outlined in the VPMIM. These requirements vary, depending primarily upon the volume and concentration of contaminated material being removed. Once access control has been established, the area of contamination is excavated to a minimum depth. Beyond the minimum established depth, the DOE controls excavation with hand-held gamma scintillometers until all material contaminated above EPA standards is removed. If interior (structural) decontamination is required, furnishings are removed and dust curtains may be set up. Floors and foundations above the area to be decontaminated are removed and the tailings excavated. Excavation is controlled in the same manner as for exterior excavation.

In addition to excavation control, the DOE performs occasional radiological surveillances. The surveillance includes duplicate sampling, field measurements, and analyses of soil samples. These surveillances provide DOE with a quality assurance mechanism and control of field activities.

During remedial action, the workplace and local environment are monitored in accordance with the specific monitoring guidelines stipulated in the VPMIM. Along with formal training of the construction crews and access control, health and safety provisions could include posting, personnel and equipment monitoring, protective clothing, dosimetry, and air monitoring.

Once an excavation is complete, the excavated area is monitored and soil samples are usually taken to verify compliance with EPA standards. Clean material is used as backfill and the surface is restored to its original condition, through either placement of landscaping or furnishings. The property owner is then asked to confirm that the property has been restored to his/her satisfaction. Upon confirmation of this fact the property owner signs Appendix C of the RAA--the Owner Acceptance Form. Upon signature of the RAA the DOE develops a Completion Report.

L.3.5 PROPERTY CERTIFICATION

Introduction

Field inspections and analyses are performed after completion of remedial action to determine the effectiveness of the action and to demonstrate that radiation levels at vicinity properties are within the required levels of the relevant EPA standards. Reports are required to document the findings of these inspections and analyses.

This section outlines the guidelines used by the DOE to certify that a vicinity property is in compliance with EPA standards.

Completion Report (CR)

The DOE prepares a CR on each vicinity property which has undergone remedial action. The CR contains two sets of information: an operations summary and a verification summary.

The operations summary documents the administrative portions of remedial action. This includes expenditure data (actual cost versus estimated cost) and volume data (expected excavation volumes versus actual). The remedial action schedule is also presented, with an explanation of any cost or schedule overruns.

The verification summary section documents the effectiveness of the remedial action, in relation to the EPA standards. This section includes the results of pre-remedial action measurements, which include the inclusion survey measurements, supplemented with data obtained during the REA survey. The post-remedial action measurements are also presented in this section. If any contamination is left on the property, through the application of supplemental standards the location, concentration, and volume of contamination are documented in this section of the report.

Certification

The CR is reviewed by DOE and evaluated for completeness, accuracy, and for the property's compliance with the EPA standards.

DOE then certifies the property and issues a letter of certification to the property owner, the NRC, and state or tribe. The letter notifies the owner that his property is in compliance with EPA standards.

The DOE is also required to issue rules and regulations that require notice, in local land records, of the residual radioactive materials which were on the property, and notice of removal of these materials, including the date the remedial action took place. To date, the DOE has not developed these required regulations and, therefore, no property has been officially certified.

L.4 ENGINEERING ESTIMATES AND COSTS

The following estimates provide the basis for the assessment of impacts from remedial action at the vicinity properties.

Total number of properties presently designated as possibly needing remedial action.	6905

Total number of properties estimated to require remedial action (DOE, 1984b).	3648

Approximate number of properties that have already been decontaminated.	200

Total number of properties addressed in this EIS.	3465

Types of properties

Residential.	2478

Commercial.	696

Complex.	13

Open lands.	278

Schedule

Schedule for remedial action of the 3465 vicinity properties.	27 months

Costs

Remedial action.	\$99,360,000

Engineering, construction management, and environmental monitoring.	\$30,810,000

Total	\$130,170,000

Volumes and areas

Estimated volume of contaminated material (average of 105 cubic yards per property).	363,525 cubic yards

Estimated volume of uncontaminated fill required (average of 165 cubic yards per property).	363,525 cubic yards

Estimated surface disturbance at vicinity properties (average of 0.25 acre per property).

866 acres

Amount of contaminated material presently at State Repository.

116,200 cubic yards

Amount of contaminated material that will be transported to the State Repository prior to commencement of remedial action on the tailings pile.

13,975 cubic yards

Distances

Average round trip distance from vicinity property to Grand Junction site.

5 miles

Average round trip distance from vicinity property to borrow site(s).

5 miles

Labor requirements

<u>Skill</u>	<u>Year</u>			
	1987	1988	1989	1990
Truck drivers	87	86	37	0
Heavy equipment operators	102	100	43	0
Carpenters	44	43	19	0
Other skilled laborers (i.e., plumbers)	44	43	19	0
Laborers	305	300	129	0
Construction management, environmental, field supervisors	233	229	99	20
	—	—	—	—
TOTAL	815	801	346	20

Average number of man-months of labor per property

4

Equipment requirements

	<u>Year</u>			
	1987	1988	1989	1990
Front-end loaders	42	41	18	0
10-cy haul trucks	73	72	31	0
Backhoes	42	41	18	0
Graders	2	2	0	0
Water trucks	1	1	1	0

Estimated consumptive volumes

Fuel	1,740,276 gallons
Water	11,986,500 gallons
Other - grass seed, sod, small shrubbery, trees, cement, lumber, cinder block, portable toilets.	

Ref. Compiled from DOE, 1984b.

REFERENCES FOR APPENDIX L

- DOE (U.S. Department of Energy), 1984a. Vicinity Properties Management Implementation Manual, UMTRA-DOE/AL-050601, prepared by the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.
- DOE (U.S. Department of Energy), 1984b. "Vicinity Properties Special Study," Uranium Mill Tailings Remedial Action Program, prepared by the Department of Energy, Albuquerque Operations Office, Albuquerque, New Mexico.
- Stassi et al. (P. Stassi, M. Jackson, and A. Clark), 1985. "Remedial Action at Vicinity Properties," in Proceedings of the Symposium on Waste Management, p. 157, Tucson, Arizona.

APPENDIX M
PERMITS, LICENSES, AND APPROVALS

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PERMITS, LICENSES, AND APPROVALS

This appendix contains a summary of the permits, licenses, and approvals that would be required. Regulatory approvals will be obtained by the Remedial Action Contractor or DOE, whichever is appropriate.

Table M.1.1 Permits, licenses, and approvals for remedial action
(Concluded)

Permit, license, or approval	Granting or approving agency	Statute or regulation	Activity
Mining and reclamation permit	Colorado Department of Natural Resources, Mined Land Reclamation	Mined Land Reclamation Board rules and regulations	Mining of soil and rock construction materials.
State highway access approach permit	Colorado Department of Highways	CRS 1973, 43-2-147; 2 CCR 601-1	Control of access to state highways.
Mesa County conditional use permit	Mesa County Board of Commissioners	Mesa County Land Use Resolution and CRS 1973 30-20-101 <u>et. seq.</u>	Construction of tailings disposal facility.
Miscellaneous Mesa County permits	Mesa County	Mesa County Land Development Code	Building permits, mobile home siting permits, and road access permits.
Mesa County Floodplain use permit	Mesa County Engineering Department	Mesa County Land Development Code	Construction in a floodplain.
City of Grand Junction floodplain permit	Grand Junction Planning Department	City of Grand Junction zoning and development code	Construction in the Colorado River floodplain.

Table M.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 facility after completion of the remedial action.
Section 404 dredge and fill permit	U.S. Army Corps of Engineers	Clean Water Act of 1977	Dredge and fill of wetlands.
Free use permit	Bureau of Land Management	43 CFR Part 3611	Extraction of common minerals (clay, rock, and the like) on BLM administered lands.
Threatened and endangered species consultation	U.S. Fish and Wildlife Service and Colorado Game and Fish	Endangered Species Act of 1973, Section 7.16 USC 1531, <u>et. seq.</u>	Possible presence of threatened or endangered species near disposal sites.
Cultural resource clearance	U.S. Bureau of Land Management and Colorado Historical Society	National Historic Preservation Act	Any action which might impact cultural or historic resources.
Colorado pollutant discharge system permit	Colorado Department of Health, Water Quality Control Division	Colorado Water Quality Control Act	Controlled surface discharge of waste water.
Air pollutant emission notice and permit	Colorado Department of Health, Air Pollution Control Division	Colorado Air Pollution Control Commission regulations 1 and 3	Construction or modification of a new source of pollution.
Water rights application	Colorado District Water Court	CRS 1973, 37-92-300	Water rights.
Permit to construct a well	Colorado Department of Natural Resources, Water Resources Division	Colorado Code for water well construction and pump installation	Drilling and construction of water wells and monitor wells.
Approval of test hole or monitor well plugging	Colorado Department of Natural Resources, Water Resources Division	Colorado Code for water well construction and pump installation	Abandonment and plugging of monitor wells on the tailings pile.

