Remedial Action Plan and Site Design for Stabilization of the Inactive Uranium Mill Tailings Site At Grand Junction, Colorado

Remedial Action Selection Report

Final

September 1991

Appendix B of the
Cooperative Agreement
No. DE-FC04-81AL16257

UM/GRJ-A9.A.1 (Final)

UMTRA-DOE/AL-050505

REMEDIAL ACTION PLAN AND SITE DESIGN FOR STABILIZATION OF THE INACTIVE URANIUM MILL TAILINGS SITE AT GRAND JUNCTION, COLORADO

REMEDIAL ACTION SELECTION REPORT

FINAL

SEPTEMBER 1991

APPENDIX B OF THE
COOPERATIVE AGREEMENT
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1.0 INTRODUCTION

The inactive uranium mill tailings site in Grand Junction, Colorado, was designated as one of 24 abandoned uranium processing sites to be remediated by the U.S. Department of Energy (DOE) under the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA). The UMTRCA requires that the U.S. Nuclear Regulatory Commission (NRC) concur with the DOE's selection of remedial action and conclusion that the remedial action complies with the standards promulgated by the U.S. Environmental Protection Agency (EPA). The Remedial Action Plan (RAP), which includes this Remedial Action Selection Report (RAS), has been developed to serve a two-fold purpose. First, it describes the series of activities that are proposed by the DOE to accomplish long-term stabilization and control of radioactive materials at the inactive uranium processing site. Second, upon concurrence and execution by the DOE, the State of Colorado, and the NRC, this document becomes Appendix B of the Cooperative Agreement between the DOE and the State of Colorado.

1.1 EPA STANDARDS

As required by the UMTRCA, remedial action at the Grand Junction site must comply with regulations established by the EPA in 40 CFR Part 192, Subparts A-C. These regulations may be summarized as follows:

- The disposal site shall be designed to control the tailings and other residual radioactive materials for 1000 years to the extent reasonably achievable and, in any case, for at least 200 years (40 CFR 192.02(b)).
- The disposal site design shall prevent the radon-222 flux from residual radioactive materials to the atmosphere from exceeding 20 picocuries per square meter per second (pCi/m^2s) or from increasing the annual average concentration of radon-222 in air at any location outside the disposal cell by more than 0.5 picocuries per liter (pCi/l) (40 CFR 192.02(b)).
- The remedial action shall be conducted to ensure that the radium-226 concentration in land averaged over any area of 100 square meters shall not exceed the background level by more than: five picocuries per gram (pCi/g), averaged over the first 15 centimeters of soil below the surface, and 15 pCi/g, averaged over 15-cm-thick layers of soil more than 15 cm below the surface (40 CFR 192.12(a)).

On September 3, 1985, the U.S. Tenth Circuit Court of Appeals remanded the portion of the EPA standards that related to groundwater (40 CFR 192.2(a)(2)-(3)) and stipulated that the EPA promulgate new groundwater standards. The EPA proposed these standards in the form of revisions to Subparts A-C of 40 CFR 192 in September 1987. The proposed standards consist of two parts: a first part governing the control of any future groundwater contamination that may occur from the disposal cell after remedial action, and a second part that applies to the cleanup of contamination that occurred before the remedial action. Under the UMTRCA, the DOE must comply with the proposed standards until final standards are promulgated. When final standards are promulgated, the DOE will evaluate groundwater protection requirements and undertake such action as necessary to ensure that the final standards are met.

1.2 SITE AND PROPOSED ACTION

Location

The Grand Junction site is in Grand Junction, Colorado, in an industrial area adjacent to the north side of the Colorado River (Figures 1.1 and 1.2). The site is in Sections 23 and 24, Township 1 South, Range 1 West, Sixth Principal Meridian, or north latitude 39°-03'-30", west longitude 108°-34'-00".

History

The Climax Uranium Company processed uranium and vanadium ore at the Grand Junction mill site from June 1951, to March 1970. The mill produced 2.2 million tons of tailings, of which approximately 300,000 tons were removed from the site and used as construction material or earth fill. The locations to which these materials were moved are referred to as "vicinity properties."

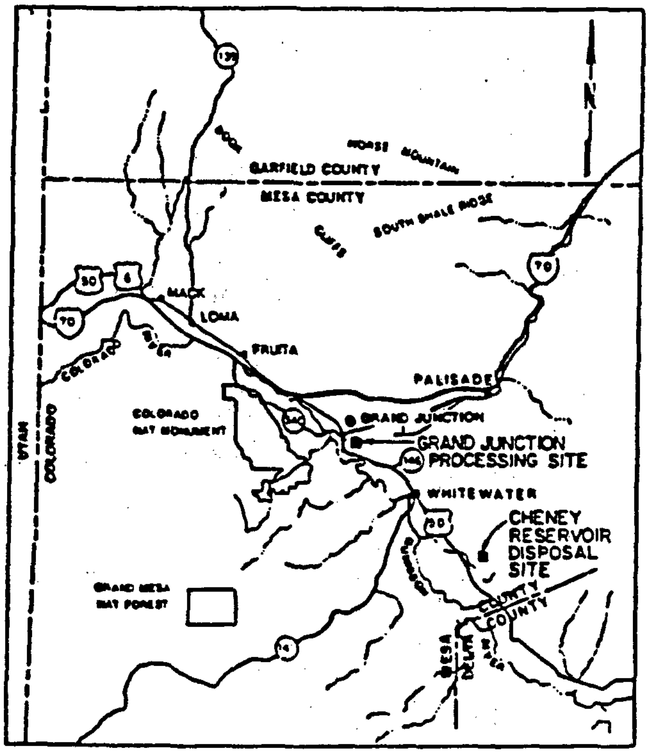
The mill processed 2.3 million tons of ore, averaging 0.28 percent uranium and 1.41 percent vanadium. The ore was crushed, ground, and treated to extract the product. The U.S. Atomic Energy Commission purchased the uranium and vanadium produced through 1966. The uranium and vanadium produced after 1966 were sold commercially.

Shortly after the mill was shut down, efforts were made to stabilize the pile. Much of the concrete and brick from demolished mill buildings was placed as riprap along the riverbank. The remainder was placed on the effluent ponds along with a portion of the mill tailings. The tailings pile was covered with six inches of soil, vegetated, and irrigated for awhile; however, little vegetation remains. The entire tailings area is fenced to control access.

Between 1970 and 1976, the land was divided and sold as follows: the tailings area to the Sand Extraction Company; the mill site to Bess Investments; the effluent pond area to the State of Colorado; the ore storage area to Colorado West Improvements, Inc.; and a tract north of the effluent ponds to L. D. Sievers.

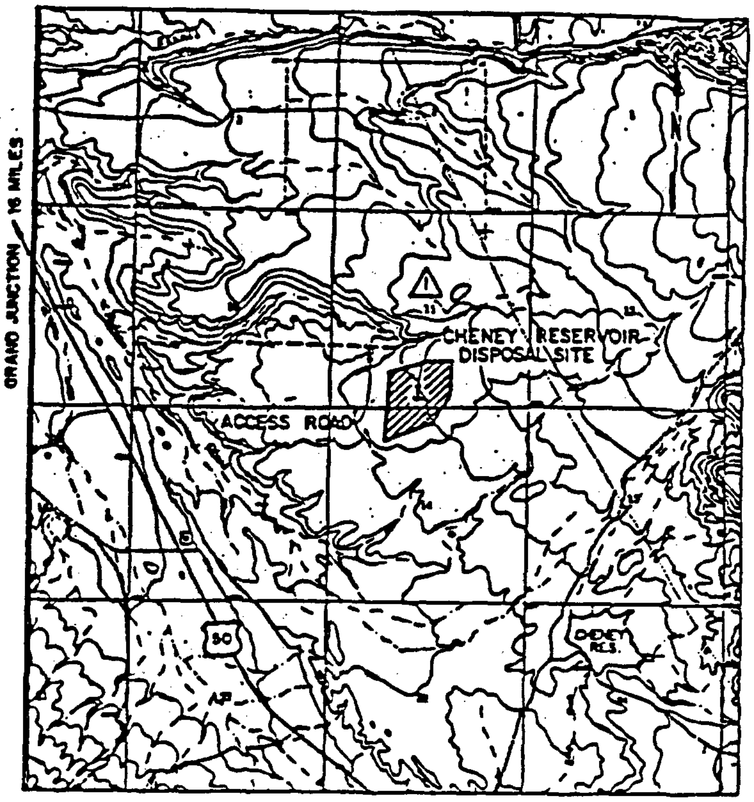
Contaminated materials

The Grand Junction processing site totals 114 acres and contains the tailings pile, mill site, and effluent ponds. The State of Colorado uses the effluent ponds area to store material obtained from vicinity properties. Table 1.1 presents the contaminated material volumes, including the Surplus Facilities Management Program (SFMP) material from the Grand Junction Projects Office Compound.



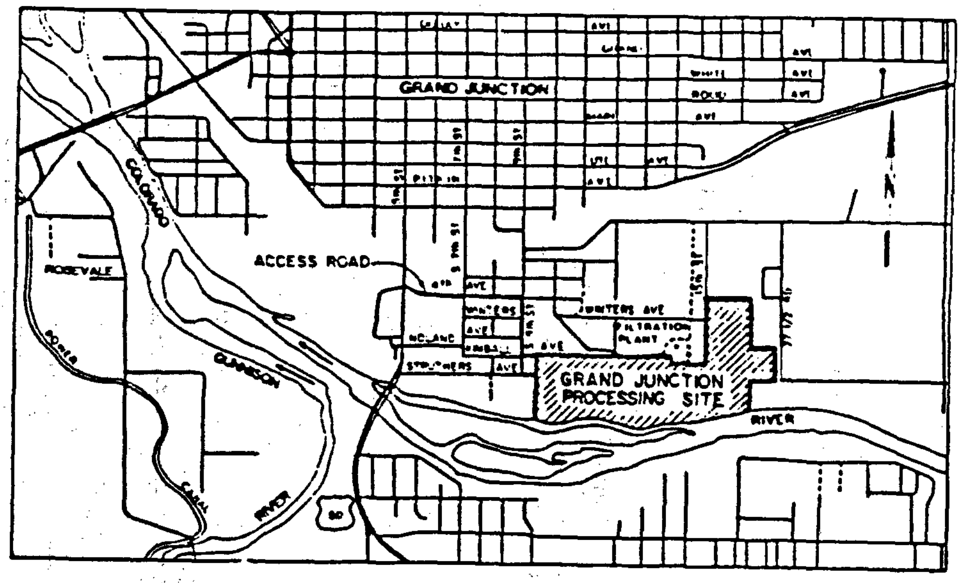
LOCATION MAP

5 0 5 10 15
SCALE MILES



CHENEY RESERVOIR DISPOSAL SITE AND VICINITY

1/2 0 1/2 1
SCALE MILE



GRAND JUNCTION PROCESSING SITE AND VICINITY

1000 0 1000 2000 3000
SCALE FEET

FIGURE 1.1
GRAND JUNCTION LOCATION MAPS

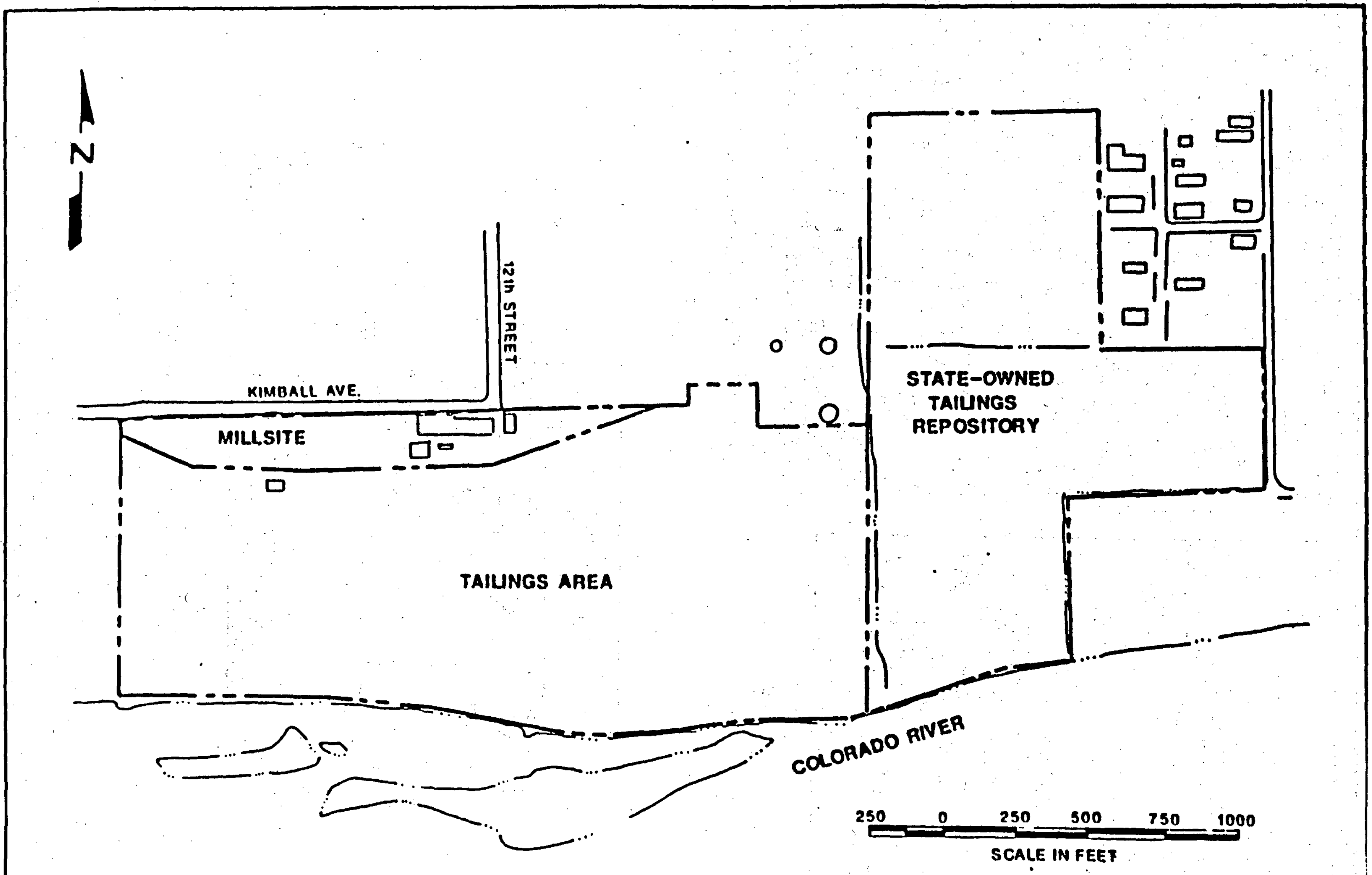


FIGURE 1.2
GRAND JUNCTION SITE MAP

Table 1.1 Contaminated material volume at the Grand Junction site

Description	Volume[a] (cubic yards)
On-pile materials	
Main pile	2,831,000
Mill yard, west and south area	51,000
Total	2,882,000
Off-pile materials	
Pond 1	31,000
Pond 2	28,000
Pond 3 (VP)	2,219,300
SFMP material	100,000
Total	2,378,300
Grand Total	5,260,300

[a]From Calculation 05-670-02-03 (Attachment 1).

Remedial action

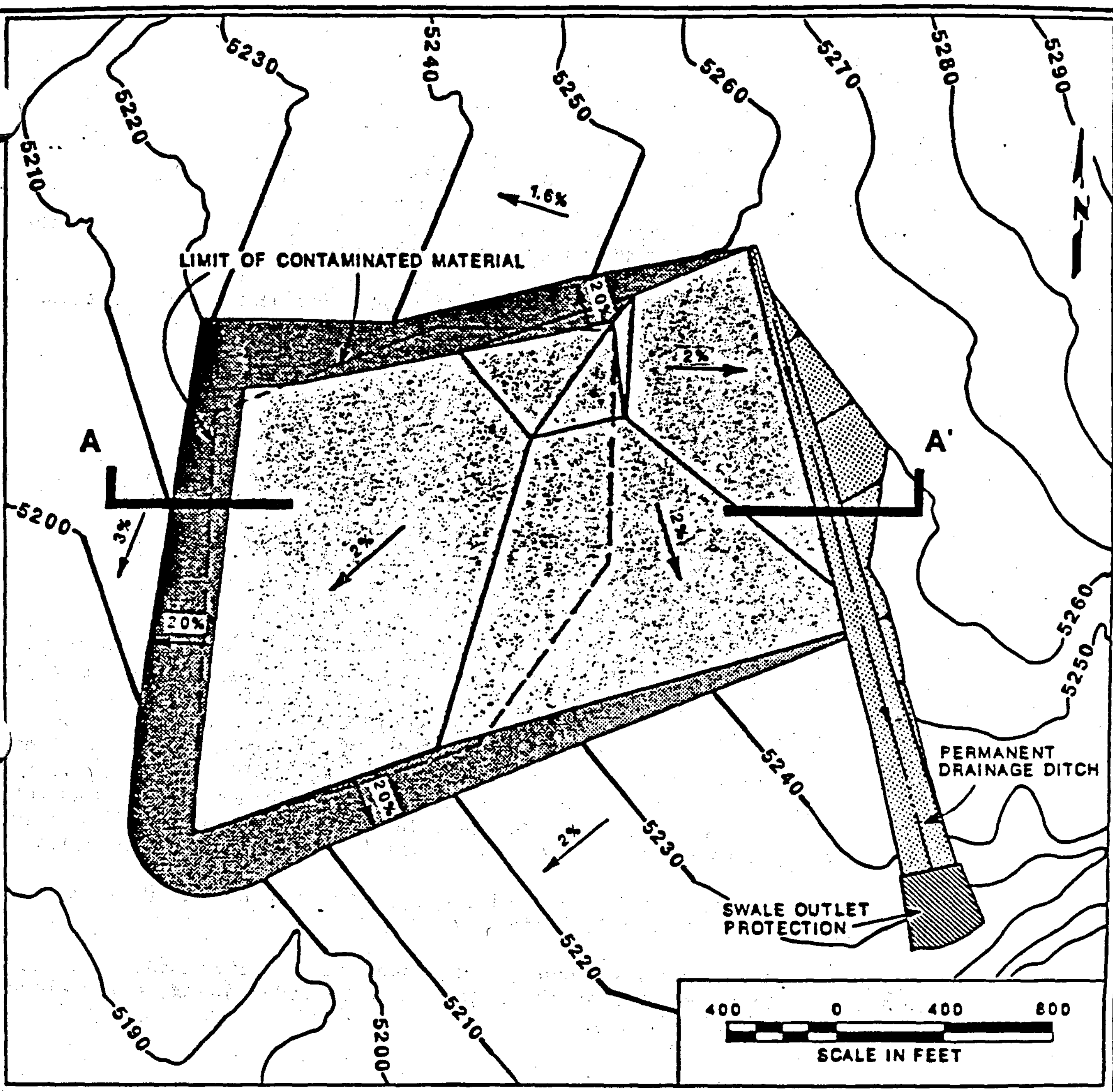
The remedial action consists of the removal, and subsequent relocation, of all contaminated materials to the Cheney disposal site, 18 miles southeast of the processing site in Sections 11 and 12, Township 3 South, Range 2 East, Sixth Principal Meridian, or north latitude 38°-54'-30", west longitude 108°-20'-00" (Figures 1.1 and 1.3). Containerized rail cars will transport contaminated materials from the processing site to the Cotter transfer site at Whitewater. From there, the contaminated materials will be transported to the disposal site in off-road haul trucks on a dedicated haul road.

Disposal will consist of constructing a 60-acre engineered cell partially below grade. (Detailed drawings of the disposal cell facility are shown in Attachment 1, Drawings GRJ-DS-10-0124 through GRJ-DS-10-0223.) The excavation will extend approximately 40 feet below existing grade, through the alluvium and into the Mancos Shale. [] The excavation will be surrounded, above and below grade, by clean fill dikes which will consist of compacted Mancos Shale derived from the excavation. The dikes will form a liner-type barrier between contaminated material and adjacent natural materials. The contaminated material will be placed in horizontal lifts and compacted. Above-grade clean fill dikes will form surfaces possessing two percent topslopes and twenty percent sideslopes in order to comply with long-term stability requirements established by EPA regulation 40 CFR 192. Two percent sideslopes will be constructed on the north and east sides of the disposal cell extending outward until existing grade is met. No contaminated material will be placed beneath these extensions. In no instance will contaminated materials be placed above saturated paleogullies known to exist in the alluvium overlying the Mancos Shale.

The topslope of the cell that is immediately underlain by contaminated materials will consist of a five-and-one-half []-foot-thick, multiple-layered [] cover that includes a 24-inch-thick radon/infiltration barrier. This cover will serve to control erosion, reduce the amount of infiltration, protect the radon barrier from freezing/thawing disturbance, and reduce radon emanation to acceptable levels. A portion of the contaminated materials will be placed under the sideslope area. The cover for these sideslope areas will consist of a 3.5-foot-thick radon barrier protected from erosion by one foot of rock and six inches of bedding.

The rock in the cover will protect the cell from erosion due to precipitation runoff. The steeper clean fill dikes and the dike extensions will be protected with suitably sized rock erosion protection. This erosion protection will be tied to the cobbly soils (the alluvium) at the site. Upland drainage will be diverted around the cell by a shallow swale formed between the dike extensions and the natural topography. Any natural resistant armoring of the existing ground surface that is disturbed or destroyed during construction will be repaired or replaced.

After the contaminated materials are removed, the processing site will be restored with uncontaminated fill from the disposal site excavation, and then revegetated or mulched. These activities will be coordinated with the local riverfront planning commission.



NOTE: SEE FIGURE 5.1 FOR CROSS SECTION.

FIGURE 1.3
CHENEY DISPOSAL SITE PLAN

1.3 SCOPE AND CONTENT

This RAS has been structured to provide a brief but comprehensive description of the remedial action. An extensive amount of data and supporting information have been generated that cannot all be incorporated into this single document. Pertinent information and data are included with reference given to the supporting documents. The RAP consists of this RAS and the following attached reports, which describe various aspects of the remedial action in more detail:

- Attachment 1, Contract Documents and Engineering Calculations (five volumes).
- Attachment 2, Geology Report.
- Attachment 3, Groundwater Hydrology Report.
- Attachment 4, Water Resources Protection Strategy.
- Attachment 5, Summary of Field and Lab Data.

1.4 RAS ORGANIZATION

The following (Sections 2.0 through 6.0) have been organized by technical disciplines. The approach adopted in the RAS is similar to that adopted by the NRC for site Technical Evaluation Reports (TERs), and this RAS is formatted in accordance with the requirements of the NRC's Standard Format and Content (SF&C) guide (NRC, 1989) for remedial action selection reports for Uranium Mill Tailings Remedial Action (UMTRA) Project sites. The RAS has been compiled to facilitate the NRC in the preparation of TERs; the RAS does not contain design details. Details are available in supporting documents, reports, drawings, specifications, and calculations.

Table 1.2 summarizes the relationship between design details and criteria and supporting calculations and reports.

Where cited in this report, references to computer codes are not detailed; rather, details of these codes may be found in the calculation sets of Attachments 1 and 3.

1.5 COLLATERAL DOCUMENTS

The Environmental Impact Statement (EIS) for the Grand Junction site (DOE, 1986) describes existing conditions at the site, the proposed remedial action, the alternatives to the proposed action, and the environmental impacts of the proposed action, and includes details not reported in the RAP.

An additional supporting document is the Technical Approach Document (TAD) (DOE, 1989a). The TAD describes technical approaches and procedures used on the UMTRA Project. It includes discussions of major

Table 1.2 Relationship between design details or criteria and supporting calculations and reports

Design details or criteria	Technical reference	Title	Remark
Tailings and contaminated materials volumes	RAP Attachment 1 05-626-01-03	Tailings Excavation; Tailings Pile Limits and Quantities	Total volume shown on Table 1.1 of RAS.
	RAP Attachment 1 05-626-02-04	Tailings Excavation; Off-Pile Excavation Limits and Quantities	
Processing site restoration	RAP Attachment 1 05-633-01-01	Site Grading; Restoration Quantity for Grand Junction Processing Site	Positive drainage restored.
Disposal cell layout	RAP Attachment 3	Groundwater Hydrology Report	Locating the "dry" site [].
Seismicity	RAP Attachment 2	Geology Report	
Geomorphology	RAP Attachment 2	Geology Report	
	RAP Attachment 1 05-504-07-00	Permanent Site Drainage; Off-Pile Drainage Swale	
	[]	[]	
Surface water	RAP Attachment 1 05-655-01-00	Surface Water Runoff Accumulation and Discharge	Cell designed to withstand PMF event.
	RAP Attachment 1 05-628-01-00	Site Drainage; Hydrology Parameters	
Erosion protection	RAP Attachment 1 05-504-01-02	Erosion Protection; Top and Sideslopes of Tailings Embankment	
	RAP Attachment 1 05-504-02-00	Erosion Protection; Time of Concentration, Cheney Disposal Site Embankment	

Table 1.2 Relationship between design details or criteria and supporting calculations and reports (Continued)

Design details or criteria	Technical reference	Title	Remark
	RAP Attachment 1 05-505-02-02	Rock Quality for the Erosion Protection; Cheney Disposal Site	Rock durability meets minimum NRC criteria.
	RAP Attachment 1 05-504-05-02	Riprap Toe Protection	Designed to protect disposal cell from possible headward migration of gullies.
[]			
	RAP Attachment 1 05-505-03-02	Availability and Suitability of Materials	Rock sized to withstand PMF event.
Radon barrier	RAP Attachment 1 05-670-01-05	Radon Barrier Design; Thickness	Two feet thick on top, 3.5 feet thick on sideslopes.
	RAP Attachment 1 05-670-02-03	Radon Barrier Design; Average Ra-226 Concentrations	Minimum lower 18 inches protected from frost.
	RAP Attachment 1 05-670-11-00	Radon Barrier; Ra-226 Concentrations in DOE Compound	
	RAP Attachment 1 05-505-03-02	Availability and Suitability of Materials	
Geotechnical	RAP Attachment 1 05-670-05-03	Embankment Design; Material Properties	
	RAP Attachment 1 05-670-06-02	Embankment Design; Settlement and Cover Cracking	
	RAP Attachment 1 05-670-07-05	Embankment Design; Slope Stability	Minimum acceptable safety factors are achieved.
	RAP Attachment 1 05-670-09-02	Embankment Design; Depth of Frost Penetration	Maximum frost penetration calculated to be 3.5 feet.
	RAP Attachment 1 05-670-08-01	Embankment Design; Drain Layer/Bedding Layer	

Table 1.2 Relationship between design details or criteria and supporting calculations and reports (Concluded)

Design details or criteria	Technical reference	Title	Remark
Groundwater	RAP Attachment 3	Groundwater Hydrology Report	Supplemental standards.
	RAP Attachment 4	Water Resources Protection Strategy	
	RAP Attachment 1	Disposal Cell, Cover Infiltration	
	05-670-12-00	Paleochannel Remediation	
[]			

technical areas; design considerations; surface water hydrology and erosion control; geotechnical aspects of pile design; radiological issues (the design of the radon barrier, in particular); and protection of groundwater resources.

Copies of these documents, as well as supporting data and calculations, are on file in the UMTRA Project Office in Albuquerque, New Mexico.

2.0 GEOLOGIC STABILITY

The objective of this section is to present the data and analyses that show that the DOE has adequately characterized the Cheney disposal site with regard to the impacts of geologic conditions on the long-term performance objectives of the remedial action as defined by 40 CFR 192.02.

The EPA standards listed in 40 CFR 192 do not include generic or site-specific requirements for the characterization of the geological conditions at UMTRA Project sites. Rather, 40 CFR 192 requires the stabilization and control of the tailings to be effective for 1000 years to the extent reasonably achievable and, in any case, for at least 200 years. In order for this long-term stability to be achieved, certain geologic performance objectives have to be met. For example, as noted in the NRC Standard Review Plan (SRP) (NRC, 1985), information is required about the basic regional and site geology and stratigraphy. This information is required as a basis for the geotechnical and groundwater aspects of the disposal cell performance evaluation as described in Sections 3.0 and 5.0. An evaluation of the potential for geomorphic hazards is required, and the DOE should show that potential geomorphic change will not affect the site or the disposal cell's integrity for its design life. The geological characterization of the site should provide estimates of earthquake-induced ground accelerations that could occur at the site, as well as the potential for other types of tectonic hazards that could affect disposal cell performance. In addition, geological site characterization must demonstrate that future resource development will not adversely affect the disposal cell stability. Additional criteria that form the basis of the work described in this document and the evaluation of the adequacy of the site and regional geology are contained in the DOE TAD (DOE, 1989a).

2.1 SCOPE OF WORK

Detailed investigations of geologic, geomorphic, and seismic conditions at the site were conducted. The geologic investigations were carried out in accordance with the procedures and approaches described in the TAD in order to gather the data specified in the NRC SRP and the SF&C Guide. These investigations included, but were not limited to: 1) the compilation and analysis of previously published and unpublished geological literature and data; 2) the review and analysis of historical and instrumental seismic data; 3) geological field mapping and observations; 4) refraction seismic surveys; 5) the review of site-specific subsurface geologic and geotechnical data, including borehole logs and samples from boreholes, test pits, and analysis of stereo-pair aerial photographs; and 6) studies of previous work. Details of the data gathering and interpretation procedures are provided in the documents referenced in this section.

Special attention was given to the geologic potential for ground rupture and exposure of seepage downdip because they were identified as the most significant features likely to impact the long-term stability of the disposal cell.

2.2 REGIONAL GEOLOGY

A description of the regional geology is required in order to provide a background of the detailed site geology. As noted in the NRC SRP, the regional geology must be defined in sufficient detail to provide a clear perspective and orientation to site-specific subsurface information.

The DOE has characterized the regional geologic conditions in Attachment 2 of the RAP. Most of this information was derived from published studies referenced in the report. The site region is defined as the area within a 65-kilometer (km) (40-mile) radius of the disposal site on the basis of relevant seismic attenuation distance.

2.2.1 Regional physiography

The Cheney disposal site region is in the Canyon Lands subprovince of the Colorado Plateau. The Canyon Lands are characterized by deeply incised drainages, isolated mesas, and gently dipping strata. Elevations in the site region range from 5180 to 11,000 feet above mean sea level (MSL).

As required in the NRC SF&C Guide, the following are the main physiographic features of the region.

- o Type of geomorphic surface that surrounds the site: The surface topography results from the development of a pediment on an older terrace of the Gunnison River.
- o General relief and topography of the region: The site is on a gently sloping terrace that has been dissected by younger terrace systems. The topography is controlled by the Mancos Shale, which underlies most of the region.
- o Regional drainage system: The Gunnison River is in a deep valley that is incised into gently dipping Cretaceous and Jurassic sandstone and mudstone strata. The river merges downstream into the broad floodplain valley where it converges with the Colorado River.
- o Major regional geomorphic processes: Major processes are the retreat of steep escarpments of the Book Cliffs and Grand Mesa that are underlain by the Mancos Shale; and the aggradation-degradation cycles of the major drainage systems.

Further details of the regional physiographic setting and the basis for the above brief description are contained in Attachment 2, Section 2.1, which describes the geomorphic landforms, the relief and topography of the region, the drainage systems, and the types and rates of the major geomorphic processes.

2.2.2 Stratigraphic setting

Bedrock in the site region consists of a thick sequence of marine and continental sedimentary rocks representing the Precambrian, Paleozoic, Mesozoic, and Tertiary Systems. In the southwestern portion of the region, the Uncompahgre Plateau has Middle Triassic-aged rocks resting directly on peneplained Precambrian igneous and metamorphic rocks. The northeastern portion has thick Tertiary deposits in the Piceance Basin; in the site area, the Mancos Shale of Cretaceous age is the youngest rock exposed. Quaternary deposits consist of alluvial pediments and river deposits along the river valleys.

Further details of the technical approach to and the results of the characterization of the regional and site stratigraphy are in Attachment 2, Sections 1.0, 2.2, 3.1, and 3.2. Figures 2.3, 3.1, and 3.2 of Attachment 2 show the lithologic characteristics at the disposal site and within the site region for rocks of the Colorado Plateau and the unconsolidated deposits within the drainages. Table 2.2 of Attachment 2 provides a description of the stratigraphic units. Attachment 2 shows further details of the age, name, thickness, lithology, induration, relations to adjacent units, and geographic distribution.

2.2.3 Structural setting

The Colorado Plateau is a stable, intercontinental subplate with a greater thickness than the adjoining provinces. Its margins exhibit crustal structures similar to the more disturbed provinces bordering it. The principal structural elements in the site region of the Colorado Plateau consist of the Uncompahgre Uplift and the Piceance Basin. Since Late Tertiary, the Plateau has been experiencing gradual uplift.

Attachment 2 contains greater details and descriptions of the site structural setting (Section 2.3); regional structural elements (Figures 2.4, 2.5, and 3.2); and bedrock structure of the disposal site foundation (Section 3.2 and Figures 2.5, 3.2, and 3.4).

2.2.4 Seismotectonics

The DOE has characterized the potential for tectonic activity in the local and regional structures that may contribute to earthquake generation and affect the suitability of the site and design as follows.

The Uncompahgre Uplift has experienced recurrent activity on deep-seated faults established during Precambrian time. Faults on the northeastern flank of the uplift, identified as potentially active, lie at distances of nine to 36 km (six to 22 miles) from the site. However, only one of these faults can be shown by direct geologic evidence to have moved during the Quaternary age.

The nearest earthquake to the site was Intensity III, occurred in 1915, and had its epicenter approximately seven km (4.5 miles) from the site. Only two macroseismic events (magnitude 4.0 or greater) occurred within the interior portion of the Colorado Plateau. These were earthquakes with magnitudes of 4.0 and 4.4 associated with the Paradox Basin and the Uncompahgre Uplift, respectively. The largest of seven events that occurred in the border zone between the Colorado Plateau and the Western Mountain Province was a magnitude 5.5 event near Montrose, Colorado.

The earthquake data file for a radius of 200 km (124 miles) from the site was reviewed for the seismic analysis. Because of the attenuation-distance relationship, earthquakes beyond the 65-km site region are not considered relevant to the design of seismic stability when a floating earthquake of magnitude 6.2 or greater is considered as a minimum design. Attachment 2, Plates 2.1 and 4.2, show the location of epicenters and faults within the 65-km site radius. The maximum earthquakes for the site and adjacent seismotectonic province are presented in Attachment 2, Tables 4.1 and 4.3, and are discussed in Attachment 2, Sections 2.4 and 4.2.

The seismic record is discussed in detail in Attachment 2, Section 2.4. The section also describes seismic activity that may be related to known or suspected fault systems (Attachment 2, Section 4.2), and details the expected accelerations resulting from the largest regional earthquakes.

The information discussed here forms the basis of the parameters used in the design of the pile to be stable against earthquake-induced instability (see Sections 2.4.2 and 3.0).

2.2.5 Resource development

To ensure that future resource development will not jeopardize the remedial action, the occurrence of recoverable earth resources in the disposal site area must be characterized. Resources of concern are those which, if exploited, could result in inadvertent intrusion into the disposal site.

Economic resources in the 65-km site region consist essentially of uranium and vanadium ores, oil shale, oil and gas deposits, and coal. It is expected that the only economic deposits within the site area, approximately 1 km (0.62 mile) site radius, would be oil and gas. However, the regional structure is not favorable for these resources.

Further details of the economic resources of the site and region are presented in Attachment 2, Section 2.5.

2.3 SITE GEOLOGY

Bedrock geologic conditions at the site are characterized primarily to provide the basic information required for geotechnical stability evaluations (Section 3.0) and for groundwater performance assessments of the site (Section 5.0). Surficial geologic conditions are characterized to establish the geomorphic history and processes at the site, and therefore to determine that long-term stability standards will be met.

The procedures used to characterize site geology (Attachment 2, Section 1.2) and the details of that site characterization are contained in Attachment 2, Section 3.0. Figures 2.5 and 3.1 through 3.6 of Attachment 2 are presented to characterize the site geology and geomorphology by the use of topographic base maps, cross sections, and sketch drawings. The following sections give a brief description of the salient site geologic features.

2.3.1 Bedrock geology

The rocks underlying the site consist of shale and claystone of the Mancos Shale Formation. (Further details of the bedrock at the site are described in Attachment 2, Section 3.0.) As described in Attachment 2, the bedrock surface has been stabilized by the overburden alluvial pediment surface. It is not subject to erosional or seismic instability that could affect the stability of the disposal cell. The low-permeability bedrock will form the foundation of the cell. Special attention was given to describing the fracture systems in the bedrock and the erosional surface that formed the paleochannel system.

2.3.2 Surficial geology

Surficial unconsolidated deposits are described in Attachment 2, Section 3.1. These deposits consist of 17 to 29 feet of unconsolidated alluvial and colluvial deposits with one to two feet of soil.

The DOE has provided detailed descriptions of Quaternary deposits in the site area and the depositional environment as applicable to these deposits. These deposits will be excavated from below the cell. The paleochannel systems on the bedrock surface were avoided in locating the cell footprint.

2.3.3 Geomorphology

Site geomorphology is characterized in order to confirm the stability of the current landscape and to provide reasonable assurance that the stability will be maintained for the performance period required by EPA standards. The DOE has characterized the regional and site geomorphology by reference to published literature, topographic maps, site inspections, and the procedures described in the TAD. Details of the regional geomorphology are provided in Attachment 2, Section 2.1. Site-specific geomorphology is detailed in Attachment 2, Section 3.3, and shown in Attachment 2, Figures 3.5 and 3.6.

The site geomorphology is controlled by the erosion-resistant desert pavement surface that has developed on the terrace slope and the bouldery deposits contained in the unconsolidated alluvium. The primary potential geomorphic hazard is the head cutting of re-entrant gullies at the edges of the escarpment and in the adjacent Creek "C" drainage. Natural armoring by the basalt rock clasts has resulted in slow rates of erosion and stability for the site. The DOE has examined the geomorphic processes that could affect site stability, and has described the geomorphic processes that could determine the site's landforms and the future geomorphic processes in Attachment 2, Section 3.3. This characterization is considered sufficient to undertake an assessment of the geomorphic stability of the site.

2.4 GEOLOGIC STABILITY

This section describes the local geologic and seismic conditions that could affect the geotechnical stability of the disposal cell and the long-term stability of the landscape environment. The analysis also considers the characteristics of unconsolidated deposits and geomorphic processes at the site that may affect the long-term stability. In general, this section shows that the site lithology, stratigraphy, and structural conditions are such that the bedrock is a suitable foundation for the disposal cell. Sufficient data are provided to assess the potential interaction of tailings leachate on the groundwater and demonstrate compliance with EPA standards. This section demonstrates that geomorphic processes will not impact the long-term stability of the disposal cell. Potential geologic events, including seismic shaking, liquefaction, and on-site rupture, are ruled out as disturbing forces on the disposal cell, either because they will not occur or because the geotechnical design of the cell is formulated to resist such forces.

2.4.1 Geomorphic stability

The DOE provides evidence of the long-term stability of the site in Attachment 2, Section 3.3. Erosion resistance provided by the gentle slope and the natural armoring of the gravel- to boulder-sized rocks on the pediment surface provide geomorphic stability for the site. The relative age of the geomorphic surfaces has been established. The long-term geomorphic processes that could influence the tailings stabilization have been identified and quantified by the DOE. Specific projections relating to recommendations and engineering designs for site stability are presented in Attachment 2 regarding potential for flooding, scarp retreat, and headward advance of gullies.

On the basis of these evaluations, the DOE concludes that the site is geomorphically stable and will continue to be so for the performance period of the remedial action.

2.4.2 Seismotectonic stability

The DOE has determined that the disposal site and disposal cell design will provide long-term stability during seismic events. This has been done by defining anticipated ground motion at the site. Having catalogued the seismic activity, identified the significant geologic structures, and delineated the tectonic provinces, the DOE analyzed the seismic sources that may affect the stability of the site and the disposal cell. This analysis and technical approach are described in Attachment 2, Section 4.2. Each of the potentially active faults and the remote seismotectonic sources is shown in Attachment 2, Tables 4.3 and 4.4. The calculated maximum earthquake (ME) as well as the estimated ME of previous studies for the region are shown in Attachment 2, Table 4.1.

The following is a brief summary of the main points: The floating earthquake for the region is assigned a magnitude of 6.2 and is assumed to occur at a distance of 15 km (9.3 miles) from the site. The resultant peak horizontal acceleration (PHA) for this event is shown to be greater than that resulting from adjacent province sources, but less than the PHA for the nearest potentially capable fault.

The design earthquake for this site was determined to be an m_b = 6.8 event occurring at a distance of nine km (5.6 miles) from the site based on the conservative assumption that the largest critical tectonic fault is capable. Although this fault does not exhibit Quaternary activity, the Uncompahgre Uplift structure has been shown to be tectonically active. The PHA of bedrock at the site is estimated to be 0.42g.

Specific seismic parameters were used in conjunction with appropriate soil strength parameters, pile geometry, and groundwater information in order to assess slope stability and liquefaction potential. The results are presented in Section 3.0.

Seismic design parameters were derived using procedures set forth in the TAD (DOE, 1989a). The acceleration attenuation relationship of Campbell (1981) was used to derive the on-site PHA.

Design criteria

- Long-term slope stability seismic coefficient: K = 0.28 (two-thirds of PHA).
- Short-term slope stability seismic coefficient: K = 0.21 (one-half of PHA).
- Liquefaction analysis: ground surface horizontal acceleration a_{max} = 0.42g.

2.5 GEOLOGIC SUITABILITY

On the basis of the site characterization described in this section and supporting documents, the details of the final remedial action plan, and the provisions for stability included in the design of the disposal cell, the DOE concludes that there is reasonable assurance that the regional and site geologic conditions have been characterized adequately to meet 40 CFR 192. Conditions potentially affecting long-term stability have been identified and either avoided by design layout or mitigated by the details of the remedial action design, as follows:

- The cell location will intercept upslope drainage and prevent excessive flow concentration at the perimeter of the cell. The desert pavement surface will be preserved at the site as much as possible and restored around the perimeter of the cell.
- The seismic potential for the site has a design criterion of 0.42 g. Because of the stability of the bedrock underlying the cell foundation, the potential for failure of the foundation is considered as negligible.

3.0 GEOTECHNICAL STABILITY

3.1 INTRODUCTION

This section and associated reference documents describe the geotechnical engineering aspects of the proposed remedial action. The following aspects of the remedial action are described: the geotechnical information and design details related to the disposal site, the disposal cell and cover, and the properties of soil materials. Materials described include the foundation and excavation materials, the tailings, and other contaminated vicinity properties materials. Related geologic aspects such as geology, geomorphology, geomorphic and seismic characterization are presented in Section 2.0 of this report.

3.2 SITE AND MATERIAL CHARACTERIZATION

3.2.1 Geotechnical investigations

This section describes the scope and results of the geotechnical investigations performed to define the occurrence and properties of the subsurface materials both at and in the vicinity of the proposed disposal cell, the borrow materials, and the tailings and contaminated materials to be incorporated into the disposal cell. Data obtained from these investigations were used in Attachments 1 and 5. Information was obtained from test pits, boreholes, coreholes, downhole neutron probe water content determinations, and surface geophysical electromagnetic (EM) conductivity survey lines. See Plate 3.1 (Attachment 3) for the location of borings and test pits, and Figure 3.1 (Attachment 5) for the location of EM conductivity lines.

Information was obtained from an extensive hydrogeologic investigation performed from March 1989 to November 1989. Logs of all test pits and borings advanced at the Cheney disposal site are presented in Attachment 5. All of the investigations were continuously observed or logged by a field engineer or geologist.

The drilling program at the Cheney disposal site was initiated in November 1982, when the first six boreholes (501 through 506) were completed. Individual borehole logs provide precise information about the drilling methods. Generally, hollow-stem augers were advanced until refusal on gravels, cobbles, or bedrock. Samples were collected from select intervals as indicated on the borehole logs. Standard penetration tests were performed at five-foot intervals, and in situ permeability tests were performed at select locations within the borings. Two boreholes were completed to bedrock in March 1985. These boreholes terminated at 38 feet; geotechnical and groundwater data were obtained from them. Continuous standard penetration tests were performed at one-foot intervals and disturbed split-spoon drive samples were retained for laboratory analysis.

As a part of the additional site characterization performed in 1989, an ODEX continuous sampling system was used to advance the boreholes through the upper gravelly and cobbly mudflow unit. The sampling system allows a borehole to be advanced through gravels and boulders without refusal to the underlying bedrock unit while obtaining disturbed samples for classification and moisture content determinations. Moisture contents were determined per foot in the laboratory on select borehole samples and were used to calibrate a downhole neutron probe, thus providing indirect moisture content determinations.

The first four test pits were completed in December 1984. In every case, the backhoe refused on boulders or very hard soil and the pit was stopped. Bulk soil samples were collected from the pits. In February 1986, nine additional test pits were excavated using a larger backhoe. The primary purpose of this program was to evaluate the ease of separating material of different sizes and estimating material quantities of on-site radon cover and erosion protection material. Test pit excavation with large, track-mounted backhoes was also part of the additional investigation in 1989. An attempt was made to advance each of these pits to the Mancos Formation interface; however, occasionally the backhoe refused on a highly cemented sand and gravel layer. These investigations supplemented the borehole data and were used in conjunction with results from the EM conductivity survey to define the Mancos Formation interface. A bedrock contour map generated from this combined data is presented in Attachment 2, Figure 3.3.

Stand pipes and/or monitor wells were installed in the majority of the boreholes and many of the test pits (see individual logs for details). A complete discussion of the groundwater conditions at the disposal site is found in Attachment 3, Groundwater Hydrology Report.

3.2.2 Testing program

The materials at the Cheney disposal site were classified according to the Unified Soil Classification System (USCS). Select samples were subjected to Atterberg Limits testing, and particle size distribution tests to determine the classification according to the USCS (see Calculation 05-670-05-03, Attachment 1). In addition, the following tests were performed: specific gravity, moisture density relationships, saturated hydraulic conductivity, unsaturated hydraulic conductivity and capillary relationships, consolidation tests, shear strength testing, and erosion barrier durability. The results of the individual tests are contained in Attachment 1. Results from tests performed on samples obtained during the additional investigation in 1989 are presented in Attachment 5.

The testing program was consistent with the needs of the proposed remedial action; representative samples of construction materials and samples of geotechnical materials that will affect or be affected by the remedial action were tested. The number of samples tested is considered sufficient to support the necessary geotechnical engineering analyses described in subsequent sections. In particular, the number of samples tested is consistent with the SRP and the TAD (DOE, 1989a). Samples were tested in accordance with standard procedures including the American Society for Testing and Materials (ASTM) or U.S. Army Corps of Engineers (USACE). Quality assurance and quality control were performed in accordance with standard UMTRA Project procedures.

3.2.3 Site stratigraphy

The existing processing site stratigraphy consists of a tailings pile of interlayered and intermixed deposits of sands and slimes. The tailings pile overlies an alluvial sand, gravel, and cobble deposit. Relatively clean beach sands are around the perimeter of the pile; these result from the original depositional sequence. Slime deposits are found along the southern portions of the pile. The vicinity property materials are a heterogeneous fill composed of clayey soils and construction debris.

The existing disposal site stratigraphy consists of an upper unit of alluvium with colluvial deposits and mudflow debris. Soils of this unit range from clays through large boulders. Finer-grained materials consist of clays (CL), silt and clay mixtures (CL-ML), and sandy silts and clays (SM and SC). These materials are intermixed and interlayered with sand and gravel deposits cemented to varying degrees. Larger cobbles and boulders are frequent and randomly mixed throughout the entire thickness of the deposit. Generally, the clays and silts range from low to medium plasticity. The coarse-grained materials are usually rounded to subrounded and contain the full distribution of sizes. Substantial gypsum deposits are present within this unit as a result of evaporation of transient waters in paleochannels throughout this unit.

Thickness of the upper unit varies from 15 to 50 feet and overlies Mancos Shale to depths on the order of 750 feet. The surface of the Mancos Shale was eroded before the debris flow was deposited, creating gullies in the Mancos. A detailed discussion of this system can be found in Attachment 2, Section 3.0.

The upper reaches of the Mancos Shale are weathered to various degrees, contain a general decreasing fracture and discountinunity frequency, and become massive at depth. Many of the fractures are filled with calcium carbonate or contain gypsum crystals.

Radon barrier borrow area

Materials that will be used in construction of the radon barrier will be obtained from the disposal cell excavation. The clay will be screened from overlying mudflow unit materials. If the necessary volume of clay material is not available within the upper unit, Mancos Formation clayshales will be recompacted as a radon barrier.

3.3 GEOTECHNICAL ENGINEERING EVALUATION

3.3.1 General

[] This section and referenced supporting documents present the geotechnical engineering evaluation of the information and analyses that have been undertaken to demonstrate that the proposed remedial action will meet relevant EPA standards for long-term disposal cell stability. Information and analyses that have been performed include slope stability, settlement and cover cracking, and liquefaction analyses. Specific calculation sets which discuss information and present numerical analyses are listed in this document in Section 1.5, Table 1.2. Analyses are performed for design-basis events such as the design earthquake (see Attachment 2); the design flood arising from the Probable Maximum Precipitation (see Attachment 1, Volume I, calculation 05-628-01-00) and extreme meteorological conditions.

The proposed cell design was slightly modified in the summer of 1990 when an increased volume of contaminated material was identified. To accommodate the increased volume, the cell excavation was deepened approximately five extra feet. Stability, settlement and liquefaction calculations were updated to account for this modification. There were no significant changes to the originally proposed design.

3.3.2 Slope stability

The slope stability analyses are presented in Attachment 1, Calculation 05-670-07-05. These analyses show that for both static and dynamic conditions, the slopes of the disposal cell, the cell foundation, and other slopes resulting from construction procedures will not fail or otherwise adversely affect the remedial action. The most critical slope section was analyzed for both short-term (end-of-construction) and long-term conditions. The following is a brief description of the work done to support these conclusions.

Adopted design properties

Calculation 05-670-05-03 of Attachment 1, Volume IV, lists the geotechnical design parameters used in the stability analyses. This calculation describes in detail the properties of the soils and rocks that comprise the slopes, and the field and laboratory data used to establish design parameters. The geotechnical properties of the compacted contaminated materials (tailings and vicinity property materials) which will be placed in the disposal cell were tested at densities and moisture contents which are consistent with the placement specifications []. Assignment of geotechnical parameters for the slope stability analysis followed conventional geotechnical engineering practice, and was done in accordance with the provision of the SRP and the TAD.

Method of analysis

Calculation 05-670-07-05 of Attachment 1 describes the stability analyses performed. Circular slope stability methods were employed including the Fellenus or Ordinary Method, the Bishop Simplified Method, the Morgenstern-Price Method, and the Janbu Simplified Method, which are incorporated in the computer code PC-Slope (Fredlund, 1985). Each of these methods is performed during execution of the program and the output provides the minimum factor of safety for each method. Therefore, comparisons between the different methods can be performed. The results from the Morgenstern-Price Method were used because this method represents the most realistic analysis of actual field conditions. Results from the other methods are presented for comparative purposes in the referenced calculation. Additionally, a computer infinite slope stability analysis was also performed using the INSLOPE.BAS (Gray, 1985) computer code.

Seismic conditions were analyzed using a pseudo-static method. Motion is transmitted from the maximum ground acceleration of 0.42g from the bedrock up through the soil deposit. Seed and Idriss (1982) have developed curves relating the effects of soil deposits that alter ground accelerations. Alluvial soils and materials within the disposal cell are considered stiff soil deposits. Effects of these deposits on the predicted bedrock acceleration indicate an attenuation of the site acceleration from 0.42g to 0.38g at the surface. The horizontal coefficient for both the long-term and short-term conditions were determined by calculating two-thirds of the ground acceleration, resulting in values of 0.25g and 0.19g, respectively. The values used to calculate the horizontal earthquake coefficient are discussed in Section 2.0 and were derived in accordance with procedures of the TAD (DOE, 1989a). The use of the pseudo-static method is acceptable in view of the conservatism in selection of the soil parameters and the flat slopes used in design.

Results of analysis

- The minimum factors of safety against failure of the slopes of the disposal cell are summarized in Table 3.1. These factors of safety are equal to or exceed the acceptable values established in the SRP and the TAD. All cuts and grubbed slopes will be restored to prevent long-term instability. Accordingly, the DOE concludes that the slopes will be stable in accordance with the requirements of the EPA standard (40 CFR 192.02(a)) for long-term stability.

3.3.3 Settlement

Calculation 05-670-06-02, Volume IV, of Attachment 1 describes the analyses of the settlement of the disposal cell as a result of volume changes of its contents and the subsurface materials. Total and differential settlements, both immediate and secondary, will not cause instability of the disposal cell, its cover, or any other portion of this remedial action. The following is a brief description of the work performed to support these conclusions.

Critical location

The most critical cross section was chosen along an east-west axis through the highest elevation difference between the top of the cell and the toe, perpendicular to the sideslopes as shown in plan view on Sheet 4 and a cross sectional view on Sheet 5 of calculation 05-670-06-02, Volume IV of Attachment 1. Settlements were evaluated for conditions caused by placement of all contaminated materials, the radon barrier, and erosion protection material.

Analysis

Multi-layered analyses, using a one-dimensional consolidation theory, were employed to evaluate primary and secondary consolidations. Total and differential settlements were then assessed and cracking of the radon barrier was evaluated. The maximum horizontal strain calculated was 0.005 percent, which is less than the horizontal strain of 0.108 percent required to crack the type of soil material used in the cover (see Attachment 1, Volume IV, Calculation 05-670-06-02).

3.3.4 Liquefaction potential

Calculation 05-670-07-05 of Volume V, Attachment 1 evaluates the potential for liquefaction of the disposal cell, its contents (the contaminated materials), and the surface materials. The

Table 3.1 Results of slope stability analyses

Case	Loading condition	Short-term conditions (ST)	Long-term conditions (LT)	Minimum required[a] safety factor ST	LT
Critical circular	Static	2.363	3.280	1.3	1.5
Slip surface	Seismic	1.051	1.010	1.0	1.0

[a]Specified by the TAD (DOE, 1989a).

calculation concludes that because the compacted dry density of the materials in the disposal cell will be a minimum of 90 percent of the maximum dry density (ASTM D698)[]. Contaminated materials will be placed in a non-saturated condition and will be in this condition for the majority of the life of the cell. However, the possibility exists for a saturated zone to form within the tailings. Transient drainage may collect in the lower portion of the disposal cell (see Section 3.2 of Attachment 4). Liquefaction is possible while the saturated tailings exist. However, these saturated materials are well below grade and surrounded by clean fill dikes, so a failure due to liquefaction will be of no consequence. The calculation also concludes that the foundation material will not liquefy because it is consolidated shale bedrock. Accordingly, the DOE concludes that the disposal cell and its foundation are not susceptible to liquefaction.

3.3.5 Cover design

A detailed schematic of the cover system is presented in Figure 3.1 showing the top and sideslope covers. Design of the disposal cell cover topslope consists of the following, in descending order from the top:

Topslope

[] o Twelve-inch-thick erosion protection layer.

Description:

- Provides erosion protection to the underlying radon/infiltration barrier. Material consists of type A riprap sized to withstand runoff from the Probable

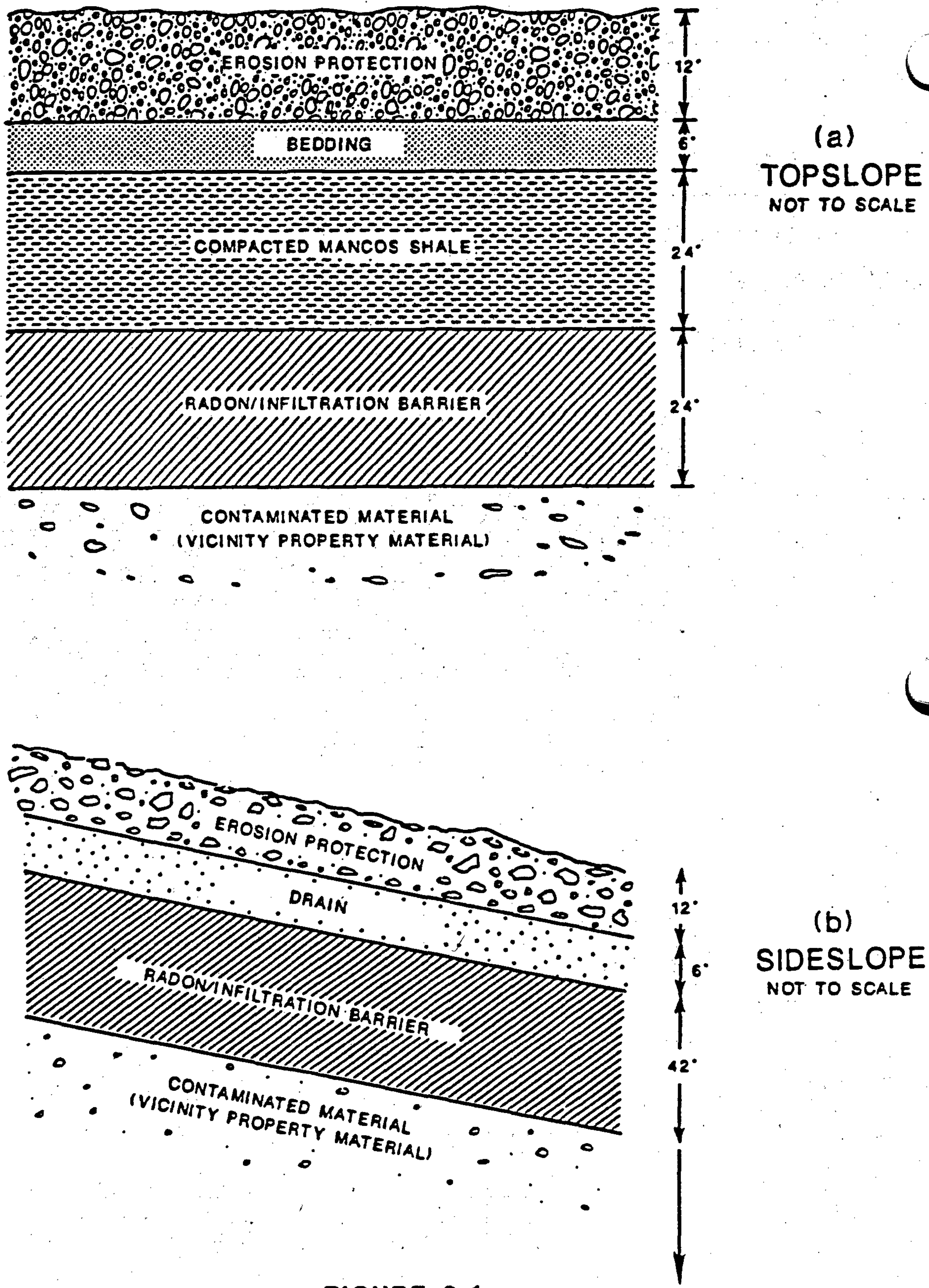


FIGURE 3.1
DETAILS OF THE CHENEY DISPOSAL CELL COVER SYSTEM

Maximum Precipitation (PMP). The PMP is evaluated in Calculation 05-504-02-00 and the riprap is evaluated in Calculation 05-504-01-02, both located in Volume II of Attachment 1 of the RAP.

- Prevents channelization of water by dissipating the flow through interstitial voids.

- Provides the initial cover component for frost protection for the radon/infiltration barrier. The expected depth of frost penetration is calculated in Calculation 05-670-09-02, Volume V of Attachment 1 of the RAP.

- Resists degradation from climatic forces as indicated in Calculation 05-505-02-02 in Volume III of Attachment 1 in the RAP.

o Six-inch-thick bedding layer.

Description

- Prevents overlying riprap from "punching" through to underlying layers. See Calculation 05-670-08-01, Volume V of Attachment 1 of the RAP for gradation limits and other details.

- Provides the second cover component for frost protection for the underlying radon/infiltration barrier. See Calculation 05-670-09-02 in Volume V of Attachment 1 of the RAP.

o Twenty-four-inch-thick compacted Mancos Shale layer.

Description

- Provides the final cover component for frost protection for the radon/infiltration barrier. The expected depth of frost penetration will not extend through this layer as indicated in Calculation 05-670-09-02 in Volume V of Attachment 1 in the RAP.

- Uses excess Mancos Shale excavated from the disposal cell. Due to the required volume necessary for the disposal cell, excess material will exist that can be used beneficially by placement as the final frost protection layer. Quantity Estimate Summary - Phase II Construction, Calculation 05-667-04-02, Volume III of Attachment 1 of the RAP, provides a listing of the quantities of materials estimated for the disposal cell construction.

- As indicated in Calculation 05-670-05-03 in Volume IV of Attachment 1 of the RAP, compacted Mancos Shale possesses a low permeability value. Therefore, this compacted shale layer will also provide the initial barrier to infiltrating water and the final barrier for radon emanation.

o Twenty-four-inch-thick radon/infiltration barrier.

Description

- Consists of compacted clay obtained from the pediment materials excavated during construction of the disposal cell. This component of the cover system will limit and control infiltration of water into underlying contaminated materials by the low permeability of the material. See Calculation 05-670-05-03, Embankment Design - Material Properties, in Volume IV of Attachment 1 of the RAP.

- Inhibits radon emanation from the contaminated materials. Calculation 05-670-02-03, Radon Barrier - Average Ra-226 Concentrations, in Volume III of Attachment 1 of the RAP provides source concentration while the required thickness of the barrier is found in Calculation 05-670-02-03 in Volume III of Attachment 1 of the RAP.

Sideslopes

The sideslope cover consists of the following, in descending order from the surface:

o Twelve-inch-thick riprap erosion protection layer.

Description

- Provides erosion protection to the underlying radon/infiltration barrier. Riprap material consists of type B and C sized rock to resist high flow velocities down the steeper sideslopes. Sizing requirements are found in Calculation 05-504-01-02, Erosion Protection - Top and Sideslopes of Tailings Embankment, Volume II of Attachment 1 of the RAP.

- Sideslope erosion protection will be tied into the toe apron to provide continuous protection against erosion forces and headward gully migration into the disposal cell. This design is discussed in detail in Calculation 05-504-05-02, Riprap Toe Protection, Volume II of Attachment 1 of the RAP.

- Six-inch-thick sand bedding/drain layer.

  Description

  - Provides a drainage path for water which infiltrates through the erosion protection layer. Material is mostly free of fines (material passing a #200 sieve) to allow for free draining characteristics. See Calculation 05-670-08-01, Embankment Design - Drain Layer/ Bedding Layer, Volume V of Attachment 1 of the RAP.

  - Prevents the erosion protection riprap from "punching" through into the underlying radon/infiltration barrier, thus maintaining the integrity of the cover system.

  - Provides frost protection to the underlying radon/ infiltration barrier. The additional protection provided by this layer can be found in Calculation 05-670-09-02, Embankment Design - Depth of Frost Penetration, Volume V of Attachment 1 of the RAP.

- Forty-two-inch-thick radon/infiltration barrier.

  Description

  - Consists of compacted clays obtained from screening the overburden soils from the disposal cell excavation. This component of the cover system is designed to limit infiltration to contaminated materials. See Calculation 05-670-05-03, Embankment Design - Material Properties, in Volume IV of Attachment 1 of the RAP for permeability values.

  - Inhibits radon emanation from the underlying contaminated materials. The required thickness is provided in Calculation 05-670-01-05, Radon Barrier Design - Thickness, Volume III of Attachment 1 of the RAP.

  - The extra 18-inch thickness compared to the topslope layer is provided to allow frost to penetrate into the upper portion of the barrier without reducing protection from infiltration or radon emanations. See Calculation 05-670-09-02, Embankment Design - Depth of Frost Penetration, Volume V of Attachment 1 of the RAP for details.

Conclusion

The material properties and available quantities for the cover materials have been adequately defined in a manner that conforms with the applicable provisions of the SRP. In addition, the performance of the cover system has been evaluated using the most current techniques. The results indicate that the cover will remain effective for a period of time that is in compliance with the EPA standard in 40 CFR 192.02 for long-term performance.

3.4 CONSTRUCTION DETAILS

3.4.1 Construction methods and features

The remedial action shall be performed and completed in accordance with the details shown in Attachment 1 drawings, which show all relevant features.

Construction specifications are included in Attachment 1. Only those specifications relevant to aspects of the remedial action directly related to meeting EPA standards are included (e.g., road signs, fences, and gates are not mentioned).

3.4.2 Testing and inspection

The Remedial Action Inspection Plan provides details of the methods, procedures, and frequencies by which construction materials and activities are to be tested and inspected to verify compliance with design specifications.

Quality assurance requirements will be in accordance with the Grand Junction Remedial Action Inspection Plan, the UMTRA Project Quality Assurance Plan, and Approved Design Specification Requirements.

3.4.3 Construction sequence

The general construction sequence is outlined in the schedule shown on Figure 3.2.

3.5 GEOTECHNICAL SUITABILITY

On the basis of site characterization described in this section and supporting documents, the details of the remedial action plan, and the provisions for stability included in the design of the disposal cell, the DOE concludes that there is reasonable assurance that the geotechnical and material properties have been suitably analyzed to demonstrate that the disposal cell will meet requirements for stability set forth in 40 CFR 192. The design has been shown to be acceptable for conditions including:

- o Slope stability under conditions of static and earthquake loading for short- and long-term slope performances.
- o Settlements, both total and differential, that could cause cover cracking or flow concentrations during stormwater runoff events.

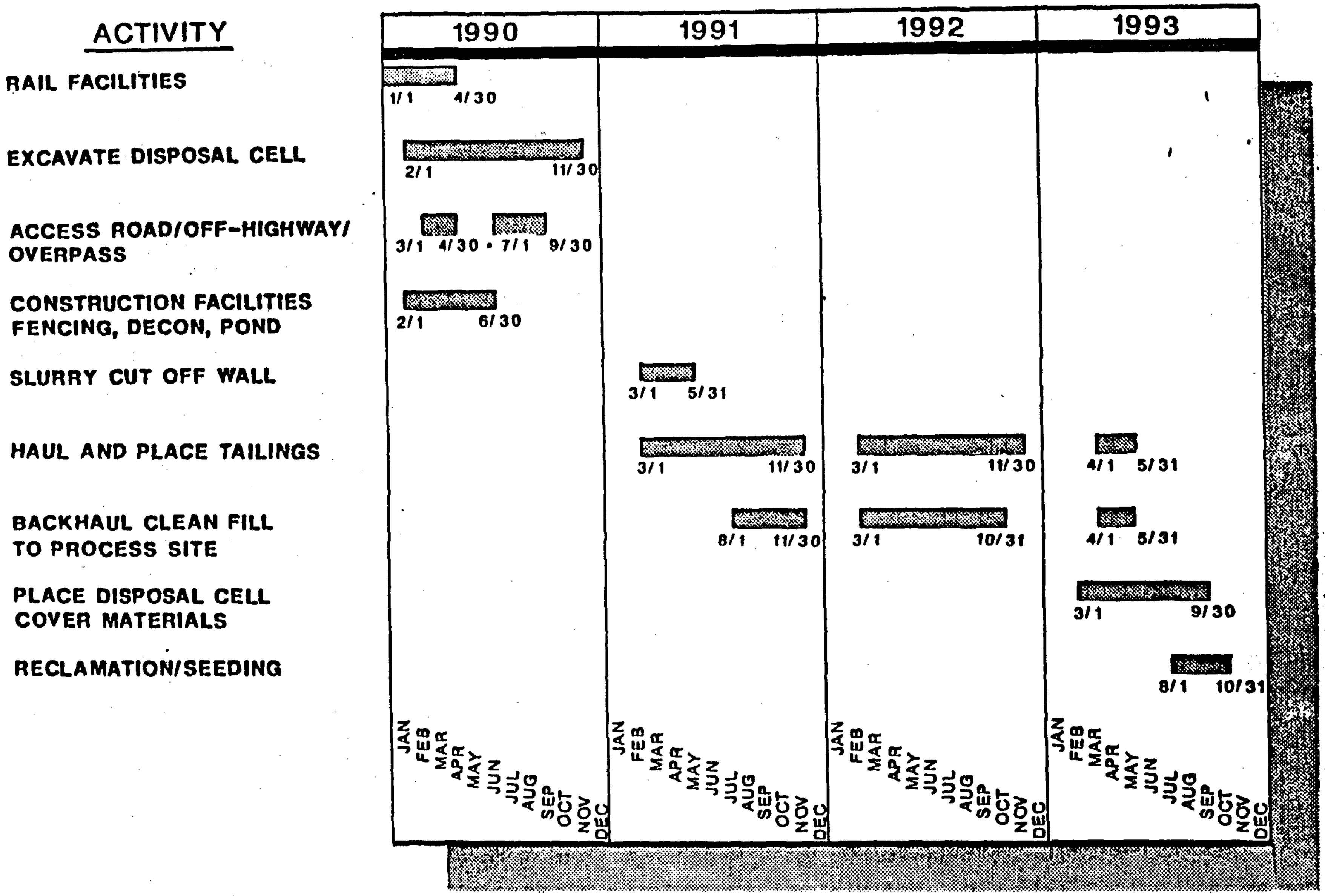


FIGURE 3.2
REMEDIAL ACTION SCHEDULE
CHENEY DISPOSAL CELL

- Liquefaction of soils that could lead to cover cracking or disposal cell instability under seismic conditions.
- Cover components that interact to provide a stable surface capable of protecting the disposal cell for the design life.

4.0 SURFACE WATER HYDROLOGY AND EROSION PROTECTION

4.1 HYDROLOGIC DESCRIPTION AND REMEDIAL ACTION DESIGN

The Cheney disposal site is in a remote, relatively flat area. The site is on a pediment surface that forms a divide between two small ephemeral washes, one about 1400 feet north of the cell location and one around 1000 feet to the south (Figure 4.1). These washes merge with Indian Creek approximately two-thirds of a mile below the site. Indian Creek flows into Kannah Creek four to five miles below the confluence of the ephemeral washes, and Kannah Creek empties into the Gunnison River, two miles below the creek's confluence with Indian Creek.

An area of 240 acres drains toward the Cheney disposal site. Slopes in the watershed average three percent. Elevation is 5260 feet above mean sea level. The maximum flow length is approximately 9500 feet. Sheet wash and rill erosion are the primary erosive forces currently active at the site. Minor gullying is occurring in the small ephemeral washes. A small upland watershed east of the site and a deeply incised surface gully south of the site are the only surface water and geomorphic features of significance. Although these features pose some design constraints, standard UMTRA Project design procedures have been used to provide erosional stability and compliance with the EPA standards.

In compliance with the EPA standards, the existing tailings and contaminated materials will be stabilized into a single disposal cell as described in Section 1.1. The cover system is described in Section 3.3.5. Surface layers of rock will protect the disposal cell from erosion by surface water runoff. The design basis events for protection of the embankment slopes, toe and off-pile drainage swale include the Probable Maximum Precipitation (PMP) and the Probable Maximum Flood (PMF) events.

4.2 FLOODING DETERMINATIONS

In order to determine impacts from flooding, the DOE analyzed peak flows and velocities and <u>determined the necessary</u> erosion protection features. The DOE estimated the PMF <u>and 200-year flood events</u> over the small upland watershed and the various drainage areas. These design events meet the criteria outlined in the SRP.

4.2.1 <u>Probable maximum precipitation (PMP)</u>

Attachment 1, Calculation 05-628-01-00, describes the determination of the site design PMP. A rainfall depth of approximately 7.9 inches in one hour is calculated for the small upland watershed near the disposal site. This rainfall estimate was developed using Hydrometeorological Report No. 49 (NOAA, 1977).

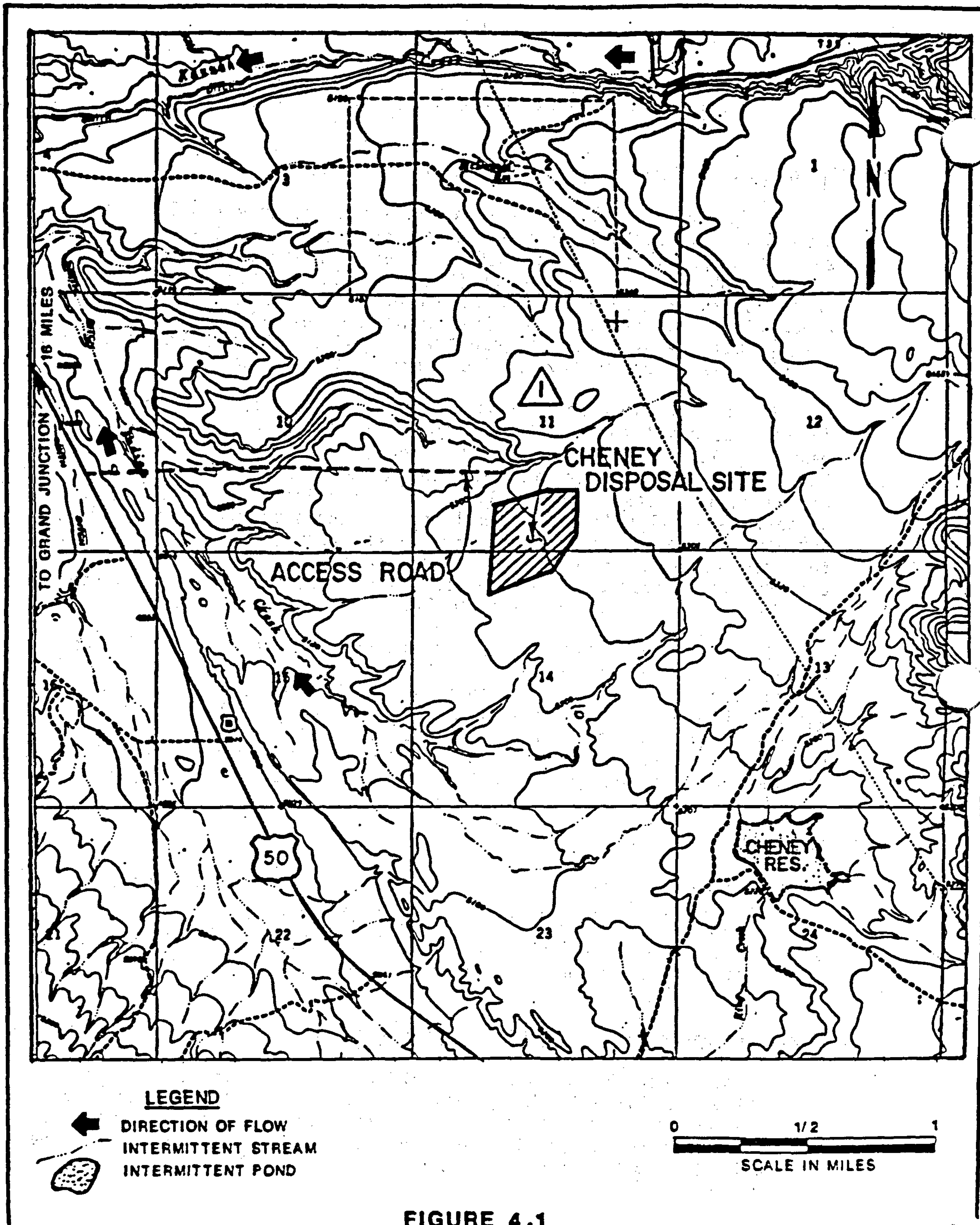


FIGURE 4.1
SURFACE DRAINAGE CHARACTERISTICS OF THE CHENEY DISPOSAL SITE, COLORADO

4.2.2 Infiltration losses

For computing the peak flow rate for the rock erosion protection for the cell sideslopes and toe, the DOE conservatively assumed no infiltration would occur. With this assumption, all precipitation is assumed to run off the cell (see Attachment 1, Calculation 05-504-02-00).

4.2.3 Time of concentration (T_c)

The T_c is the amount of time required for runoff to reach the most remote point in a drainage basin. The peak runoff for a given drainage basin is an inverse function of the T_c for that basin. If the T_c is conservatively computed to be small, the peak discharge will, therefore, be conservatively large.

Various T_c's for the swale east of the disposal cell and for the cell slopes were estimated by the DOE using U.S. Soil Conservation Service (SCS) average velocity charts, the Federal Aviation Adminstration method for airport drainage design, the Izzard Equation, the SCS Time-Lag Method, the Kirpich Method, and the Kinematic Wave Formula. (See Attachment 1, Volume II, Calculation 05-504-02-00, for T_c determinations and discussion of methods.) From these calculations, a conservative T_c value of 4.2 minutes was determined.

4.2.4 PMP rainfall distribution

The DOE derived rainfall distributions and intensities from Hydrometeorological Report No. 49 (NOAA, 1977). In the determination of peak flood flows in swales and along the pile sideslopes, rainfall intensities for durations as short as 3.7 minutes were used. The peak rainfall intensity was calculated to be approximately 24.5 inches per hour (see Attachment 1, Volume II, Calculation 05-504-02-00 and Volume I, Calculation 05-628-01-00).

4.2.5 Computation of PMF

The swale layout is such that upland surface runoff will be collected and channeled south of the disposal cell into natural drainages. In the PMF analysis, the DOE used the Rational Method to compute the peak flow rates down the watershed into the swale. Triangular cross sections were assumed for the swale. [] The design discharge rate near the swale inlet is 94 cubic feet per second (cfs) and at the outlet is 1680 cfs (see Attachment 1, Calculations 05-504-07-00 and 05-628-01-00).

4.3 WATER SURFACE PROFILES AND CHANNEL VELOCITIES

4.3.1 Off-pile drainage swale

[] The off-pile drainage swale is a trapezoidal channel designed to intercept and divert runoff from the upland area into Creek "C". The 2440-foot swale will run north and south along the east side of the disposal cell, and will be aligned perpendicular to the natural grade west of the swale. The slope of the swale on the embankment side is 20 percent and on the upland side varies from 20 percent to 4 percent. The bottom width of the swale is 20 feet at the most upstream location and gradually widens to 200 feet at the outlet. The total tributary drainage area at the outlet is approximately 135 acres.

The flow depths and velocities along the swale range from 0.7 to 2.2 feet and from 4.5 to 8.2 feet per second, respectively. The invert slope of the swale varies from 1.25 percent at the upstream location to 1.00 percent at the downstream location. (See Attachment 1, Calculation 05-504-07-00.) The U.S. Army Corps of Engineers HEC-2 Water Surface Profiles computer code was utilized to compute the flow depth and velocities (USACE, 1982).

The self-cleaning ability of the swale was verified by assuming that sediment was allowed to accumulate in the channel for 100 years without removal. This sediment was assumed to be produced from erosion of the upland area. The Universal Soil Loss Equation was used to calculate the volume of sediment eroded and transported to the swale. This material was deposited in the swale and reduced the cross-sectional area available to transport water. Analyses using the HEC-2 computer code were performed to determine the flow characteristics for the 10-, 25-, 100-, and 200-year storm events within the reduced swale. The characteristics and complete analysis are provided in Appendix A of Calculation 05-504-07-00.

Reviewing the flow velocities indicates that smaller storm events will transport fine sediments from the swale while larger events will transport coarser sediment, based on tractive shear stress analyses. Based on the analysis, the swale will be self-cleaning and maintenance-free. Also, the swale will still be able to contain the PMF even if the sediment accumulations were permanent.

4.4 EROSION PROTECTION

4.4.1 Off-pile drainage swale

The drainage swale will protect the disposal cell from erosion due to hydraulic forces. The size of the erosion protection for the swale itself is dependent on the topographical slope rather than the quantity of flow under consideration. This is due to the fact that a steeper topographical slope results in a higher tractive shear stress. This higher stress enables larger rock pieces to be entrained in the flow and removed. Thus, the required rock size varies throughout the swale depending on the slopes directing the flow to the particular portion of the swale. The design hydraulic event is the PMP. The hydraulic parameters adopted in Sections 4.2 and 4.3 were used in conjunction with the Safety Factors Method to size the riprap.

[] On the embankment side of the swale, erosion protection has been sized for three different flow conditions under a PMF storm event and they are: 1) PMF flow in the swale itself; 2) overland flow from the two percent embankment topslope; and 3) potential gully-developed flow from the upland watershed. Erosion protection under PMF storm conditions at the swale outlet has also been sized to prevent head cutting from a gully migrating along the swale. On the remaining portions of the swale (including the invert portion and upland sideslope) erosion protection has been sized under a PMF storm event without consideration of gully erosion. However, these portions will be maintained under more frequent flood conditions, such as the 200- and 100-year flood events (see Appendix C of Calculation No. 05-504-07-00). The rationale for not considering gully development is that the swale is at least 400 feet away from the contaminated materials area and is aligned in such a direction that potential gully development along the swale on the upland side will not affect the integrity of the radon barrier, and thus not cause the exposure of contaminated materials.

Applying the hydraulic parameters mentioned previously, the required size of riprap placed on the upland side of the swale is slightly less than five inches (d_{50} minimum). Riprap of this size is classified as Type-B riprap (see Attachment 1, Section 02278, Erosion Protection). In addition, portions of the native slope that are disturbed will be regraded and protected with Type-B riprap.

The required size of riprap to protect the 20 percent embankment side of the swale, with consideration given for a 15 percent oversizing factor (see Section 4.6), is 11 inches (d_{50} minimum). Riprap of this size is classified as Type E riprap. This riprap is sized to prevent a gully from forming in the swale that is carrying approximately 88 percent of the PMF design flow, which relates to a flow concentration factor of about 13 (relative to the design flow rate). The potential scour depth from this concentrated flow is calculated to be two to five feet, depending on the location in the swale. To protect the embankment, this riprap is buried along a 5:1 slope, beginning at the edge of the embankment, to a two- to five-foot depth. Details of this design are presented on Drawing No. GRJ-DS-10-0222 (Attachment 1).

The required size of riprap at the outlet of the swale is 11 inches (d_{50} minimum) and will extend to a depth of five feet. Details of the outlet protection are provided on Drawing No. GRJ-DS-10-0222. Type-C riprap (d_{50} minimum = 6 inches) will be placed for approximately 280 feet past the outlet, with a width of around 200 feet to prevent the swale from being undermined by headward gully development. Boulders with nominal diameters in excess of 24 inches obtained from overburden excavation will be placed along the bank of Creek C in the swale outlet area (about 250 feet long) to ensure the geomorphic stability of the creek and outlet.

The total quantity of runoff entering Creek "C" will not be altered by construction of the drainage swale. However, flow will now enter the tributary at a different location. Natural armoring of the tributary currently limits erosion to an estimated rate of less than 0.3 meter to one meter in 1000 years (see Attachment 2, Section 3.3). Any new erosion caused by the construction of the swale would be of fine material adjacent to the riprap allowing the riprap to reposition itself to form a more resistant armored surface. Any nickpoints or incipient headward erosion that forms would follow the newly constructed swale and would not be directed toward the disposal cell. Lateral migration of Creek "C" could also occur, but at a much slower rate than headward growth (see Attachment 2, Section 4.1).

A summary of the required riprap sizes for erosion protection of the swale is provided in Table 4.1 and a plan view drawing of riprap locations is presented in Drawing No. GRJ-DS-10-0220 Attachment 1.

4.4.2 Topslope and sideslopes

To protect the top and sideslopes of the disposal cell against erosion, the slopes will be covered by an exposed layer of 12-inch-thick riprap with a minimum D_{50} of two inches on the top slope and five to six inches on the sideslopes. Rock layers will be placed on a six-inch-thick sand bedding layer. The standard computer code RPRPSFST (MK-ES, 1987) which is based on Stephenson's Method (Stephenson, 1979) and Safety Factors Method (Stevens et al., 1976) was used to determine required rock sizes for the top and sideslopes. Conservative values for input parameters, including a specific gravity of 2.64, angles of internal friction ranging from 35 to 38 degrees, and a porosity of 0.33, were used. (See Attachment 1, Calculation 05-504-01-02, for a more detailed discussion.) A summary of the required riprap sizes for erosion protection of the disposal cell slopes is provided in Table 4.1.

4.4.3 Toe protection

[] To protect the toe along the north, west, and east sides of the disposal cell, the DOE will place a four-foot-thick riprap

Table 4.1 Rock size requirements and layer thicknesses at the Cheney disposal site

Location and grade	Rock Type	Rock size requirements (inches)	Layer thickness (inches)
2% topslope	A	d_{50} (min) = 2 d_{100} (min) = 4	12
20% sideslopes	B	d_{50} (min) = 5 d_{100} (min) = 9	12
	C	d_{50} (min) = 6 d_{100} (min) = 11	12
Toe			
- Zone 1	D	d_{50} (min) = 16 d_{100} (min) = 20	48
- Zone 2	F	d_{50} (min) = 20 d_{100} (min) = 25	48
- Secondary bedding layer	A	d_{50} (min) = 2 d_{50} (min) = 4	12
Off-pile drainage swale			
- 20% Embankment side	E	d_{50} (min) = 11 d_{100} (min) = 14	24
- Swale invert & upland sideslope	B	d_{50} (min) = 5 d_{100} (min) = 9	10
- 2% Embankment slope	A	d_{50} (min) = 2 d_{100} (min) = 4	6
- Swale outlet toe protection	E	d_{50} (min) = 11 d_{100} (min) = 14	24
- Downstream from swale outlet (4-5%)	C	d_{50} (min) = 6 d_{100} (min) = 11	12
- Bank of Creek "C" in swale outlet area		24	varies

apron. This rock will be placed on extensions of the sideslope erosion protection. Toe areas at the base of the shorter top slope reaches (along the northern and southern sides and near the northwest corner of the disposal cell) are designated as Zone 1 areas and will be protected with 16-inch rock (d_{50} minimum). The toe area at the base of the longest topslope reach (along most of the western side and the southwest corner of the disposal cell) is designated as the Zone 2 area and will be protected with 20-inch rock (d_{50} minimum) (see Attachment 1, MK-ES Drawing No. GRJ-DS-10-0220). Underlying the exposed four-foot-thick rock layer will be a one-foot-thick layer of smaller rock (d_{50} = two inches) followed by six inches of filter and bedding. Using these sizes and this depth of rock will protect the cell against PMP events, scour, potential gully intrusion and long-term soil erosion predicted by the Universal Soil Loss Equation (see Attachment 1, Calculation 05-504-05-02). A summary of the required riprap sizes for erosion protection of the disposal cell toe is provided in Table 4.1.

4.5 ROCK DURABILITY

All of the erosion protection rock will be obtained on the site. A discussion of these materials is found in Attachment 1, Calculation 05-505-03-02. A discussion of testing for rock durability is in Section 3.2.2 of this report.

4.6 EROSION PROTECTION QUALITY CONTROL

See Attachment 1 for details of construction, construction control, quality assurance, and testing and inspection procedures.

4.7 UPSTREAM DAM FAILURE

There are no impoundments upstream from the disposal cell whose failure could potentially affect the site.

4.8 SURFACE WATER HYDROLOGY AND EROSION PROTECTION SUITABILITY

The DOE concludes that the proposed disposal cell at the Cheney disposal site will meet EPA requirements, as stated in 40 CFR 192, with regard to flood design measures and erosion protection. An adequate hydraulic design has been provided to ensure reasonable stability of the contaminated materials at the Cheney disposal site for a period of up to 1000 years.

5.0 WATER RESOURCES PROTECTION

5.1 HYDROGEOLOGIC SITE CHARACTERIZATION

The DOE has characterized the hydrogeologic units, hydraulic and transport properties, geochemical conditions, and water use at the Cheney disposal site. Major points are summarized below. Details of the hydrogeologic site characterization are provided in Attachment 3. Details of the water resources protection strategy are provided in Attachment 4.

5.1.1 Identification of hydrogeologic units

The Cheney disposal site is underlain by five to 40 feet of alluvium consisting of a highly variable mixture of clay, sand, cobbles, and boulders. Beneath the alluvium, 700 to 750 feet of Mancos Shale overlies the Dakota Sandstone. The stratigraphic relationships between these hydrogeologic units and the disposal cell are shown in Figure 5.1. Details of the geology of the Cheney disposal site are provided in Attachment 2.

The Dakota Sandstone is the uppermost aquifer beneath the proposed disposal cell and is approximately 750 feet below the existing ground surface. Groundwater in the Dakota Sandstone is saline (total dissolved solids (TDS) concentrations exceed 10,000 milligrams per liter (mg/l)), and thus has limited use (Class III groundwater; see Section 3.2.5, Attachment 3).

A small quantity of shallow groundwater occurs at the base of the alluvium in thin, isolated paleochannels upgradient from the disposal cell footprint. The closest identified saturated paleochannel is approximately 100 feet from the northwest corner of the disposal cell footprint. Using the observational approach to disposal cell design, the entire cell area has been excavated to confirm the absence of shallow groundwater. During excavation, a previously unidentified saturated paleochannel was exposed in the northwest corner of the cell. As a result, the cell was relocated away from the paleochannel and the paleochannel was restored so that water would resume its original course (see Calculation 05-670-12-00, Volume V of Attachment 1). Isolated groundwater has been documented beneath the disposal cell in the Mancos Shale, but yields to wells completed in the unit are low (less than 150 gallons per day) and the unit is thus not considered to be an aquifer (Class III groundwater; see Section 3.2.4, Attachment 3).

5.1.2 Hydraulic and transport properties

Age dating, hydraulic testing, and chemical analyses indicate that there is very little, if any, hydraulic connection between the Dakota Sandstone and the overlying hydrogeologic units. Carbon-14 analyses of groundwater samples collected from the three

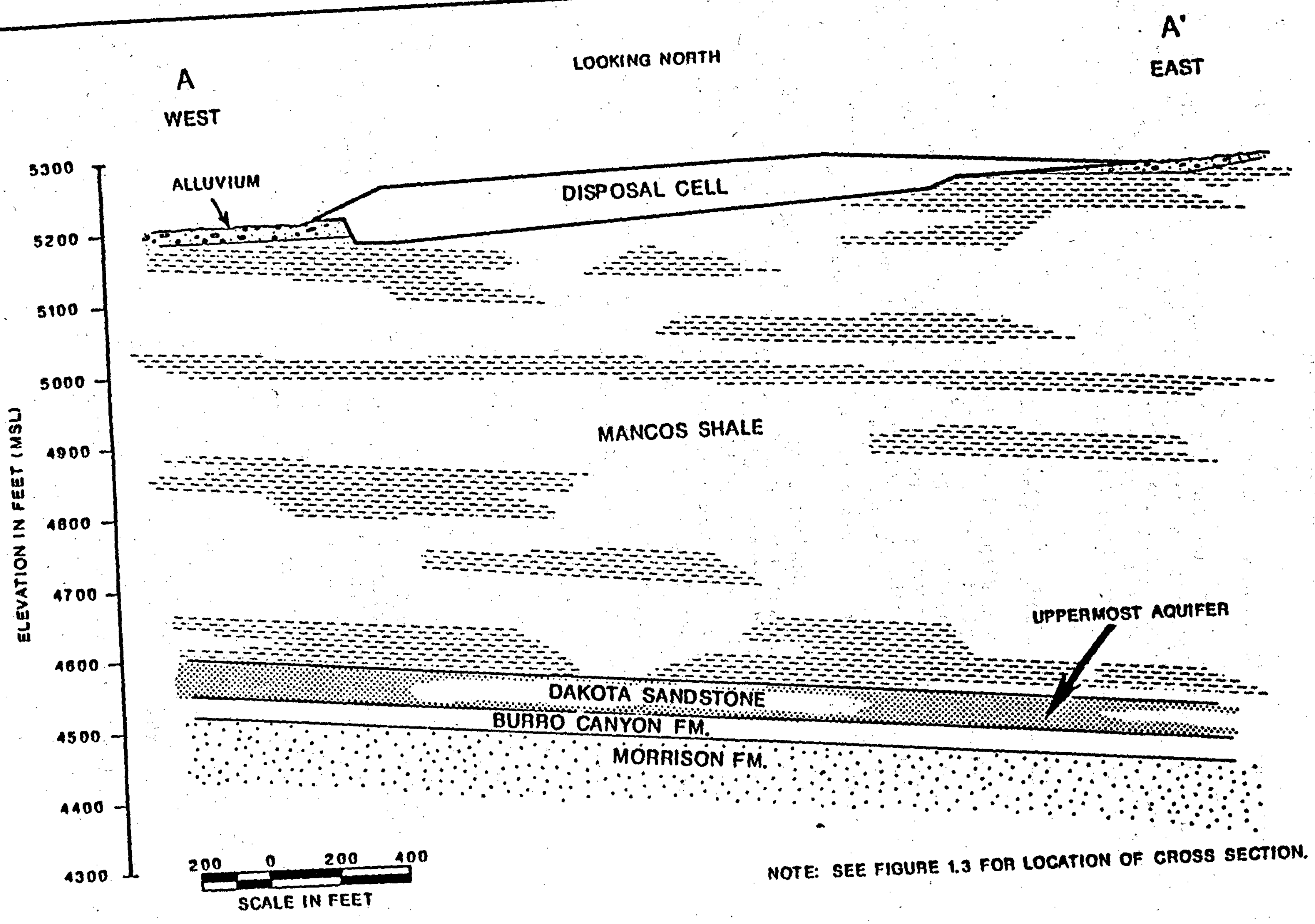


FIGURE 5.1
DIAGRAMMATIC CROSS SECTION OF
THE CHENEY DISPOSAL CELL AND FOUNDATION HYDROGEOLOGY

units show that the alluvial paleochannel waters are relatively young (less than 2000 years), the shallow Mancos Shale waters are old (20,000 to 30,000 years), and the Dakota Sandstone waters are very old (probably more than 42,000 years) (see Table 3.24 and Section 3.2.4 of Attachment 3). If downward movement of water through the Mancos Shale does occur, it must do so extremely slowly, as evidenced by the age of the water in the Dakota Sandstone.

The Dakota Sandstone beds crop out near the Gunnison River and recharge, if any, occurs along these outcrops. In addition to being separated from the disposal cell by hundreds of feet of unsaturated Mancos Shale, the confining beds of shale and sandstone overlying the Dakota Sandstone preclude significant vertical recharge from the Mancos Shale. Three monitor wells completed in the Dakota Sandstone encountered confined groundwater, with hydraulic pressures greater than 350 feet above the Dakota Sandstone-Mancos Shale contact (see Section 3.2.3, Attachment 3).

Borehole tests indicated that hydraulic conductivities generally decreased with increasing depth in the alluvium and Mancos Shale. The average hydraulic conductivity of the alluvium was approximately 1.7×10^{-4} centimeters per second (cm/s), while the hydraulic conductivity of the top (weathered) portion of the Mancos Shale was approximately 5.1×10^{-5} cm/s, and the hydraulic conductivity of the main (unweathered) body of the Mancos Shale was approximately 2.7×10^{-6} cm/s (see Section 3.2.4, Attachment 3).

5.1.3 Geochemical conditions

A favorable geochemical environment exists at the Cheney disposal site for attenuation of the hazardous constituents present in the Grand Junction tailings. Experimental data show that alluvial materials are likely to attenuate the concentrations of the hazardous constituents in tailings seepage to below their regulated concentration limits. The geochemical condition of the groundwater in the Mancos Shale, where present below the disposal site, is highly reducing (because of the presence of hydrogen sulfide and methane) and indicates that many of the hazardous constituents (cadmium, lead, molybdenum, selenium, uranium, and zinc) will be removed from the groundwater by chemical precipitation. Geochemical modeling shows that the above constituents are insoluble in the groundwater of the Mancos Shale (see Section 3.2.6, Attachment 3).

5.2 DISPOSAL CELL DESIGN FEATURES FOR WATER RESOURCES PROTECTION

Section 1 discusses the disposal cell design and Section 3.3.5 describes the cover design. Section 2.0 of Attachment 4 discusses the conceptual design considerations and features for water resources protection at the Cheney disposal site in more detail.

5.3 GROUNDWATER PROTECTION STANDARDS FOR DISPOSAL

[] The proposed disposal cell at the Cheney site is designed to control radioactive materials and nonradioactive contaminants in conformance with the proposed EPA groundwater protection standards in 40 CFR 192.02(a)(3). The DOE proposes a narrative supplemental standard for the uppermost aquifer at the Cheney disposal site. The basis for the supplemental standard is the limited use (Class III) designation of groundwater in the uppermost aquifer (Dakota Sandstone) beneath the disposal site. Groundwater in the Dakota Sandstone meets the EPA criteria for a Class III designation because the TDS content is greater than 10,000 mg/l (40 CFR 192.11(e)). Groundwater in the Dakota Sandstone is therefore not considered a water resource.

There are two basic requirements for a supplemental standard (40 CFR 192, Subpart C) as follows:

1. The standard must ensure protection of human health and the environment.

2. The standard must come as close to meeting the otherwise applicable standards as is reasonably achievable under the circumstances.

Protection of human health and the environment at the Cheney disposal site is ensured because the uppermost aquifer (Dakota Sandstone) is hydrogeologically isolated from the surface and the disposal cell by approximately 750 feet of confining shales and sandstones of the Mancos Shale.

Because compliance with the groundwater protection standards at the Cheney disposal site is based on narrative supplemental standards, concentration limits have not been proposed for hazardous constituents. Since the uppermost aquifer is hydrogeologically isolated from any potential seepage of leachate from the disposal cell, no post-closure groundwater monitoring has been proposed, and no point of compliance will be required. To comply with the concept that the supplemental standard must come as close to meeting the otherwise applicable standards as is reasonably achievable under the circumstances, hypothetical concentration limits have been established, based on the EPA maximum concentration limits (MCLs) or the statistical maximum background concentrations, as appropriate. The DOE is reasonably certain that the hypothetical concentration limits could be met at a hypothetical point of compliance in the uppermost aquifer because of the hydrogeologic isolation of the Dakota Sandstone from any potential contaminated seepage from the disposal cell.

5.3.1 Hazardous constituents

Concentrations of hazardous inorganic constituents related to uranium processing activities that exceed laboratory method detection limits in tailings pore waters include those for antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, net gross alpha activity, lead, mercury, molybdenum, nickel, nitrate, radium-226 and -228 activities, selenium, silver, uranium, vanadium, and zinc. Additionally, the following elements contained in hazardous constituent compounds were detected: aluminum, cyanide, fluorine, strontium, and sulfide []. A priority pollutant scan of samples from three monitor wells at the processing site determined that no volatile, semi-volatile, or other organic compounds were present in the groundwater (see Section 3.1.6, Attachment 3).

5.3.2 Proposed concentration limits

[] Because compliance with the groundwater protection standards at the Cheney disposal site is based on a narrative supplemental standard, concentration limits have not been proposed for hazardous constituents. To comply with the concept that the supplemental standard must come as close to meeting the otherwise applicable standards as is reasonably achievable under the circumstances, hypothetical concentration limits have been established, based on the EPA MCLs or the statistical maximum background concentrations. Hypothetical concentration limits are presented in Table 5.1. []

5.3.3 Point of compliance

[] Since the uppermost aquifer is hydrogeologically isolated from any potential seepage of leachate from the disposal cell, no post-closure groundwater monitoring has been proposed, and no point of compliance will be required.

[]

5.4 PERFORMANCE ASSESSMENT

An assessment of the performance of the disposal cell, in conjunction with subpile hydrogeologic conditions, has shown that the underlying Mancos Shale is capable of accepting any tailings pore water that drains from the cell following remedial action. A conservative, two-dimensional, unsaturated/saturated flow analysis of transient drainage of tailings pore water shows that seepage will flow into and be contained within discontinuous fractures which exist in upper portions of the Mancos Shale after the completion of the remedial action (see Section 3.2.1, Attachment 4).

The same analysis shows that saturation will not extend significantly beyond the edge of the disposal cell because of the limited supply of pore water in the tailings. Therefore, this transient condition will not create a surface exposure of tailings fluids, nor will tailings pore water mix with groundwater in any of the alluvial paleochannels upgradient of the cell.

Table 5.1 Hypothetical concentration limits for the uppermost aquifer (Dakota Sandstone) at the Cheney disposal site

Hazardous constituents[a]	Concentration limit Value	Source[b]
Antimony	0.003	BG
Arsenic	0.05	MCL
Barium	45.3	BG
Beryllium	0.005	BG
Cadmium	0.01	MCL
Chromium	0.05	MCL
Cobalt	0.05	BG
Copper	1.0	MCL[c]
Lead	0.05	MCL
Mercury	0.091	BG
Molybdenum	0.21	BG
Net gross alpha (pCi/l)	97.0	BG
Nickel	0.04	BG
Nitrate (as nitrogen)	10.0	MCL
Radium-226 and -228 (pCi/l)	75.0	BG
Selenium	0.01	MCL
Silver	0.05	MCL
Uranium	0.044	MCL
Vanadium	0.03	BG
Zinc	5.0	MCL[c]
Elements contained in hazardous constituent compounds[d]		
Aluminum (aluminum phosphide)	0.1	BG
Cyanide (soluble salts and complexes)	0.01	BG
Fluorine (carbon oxyfluoride)	2.2	BG
Strontium (strontium sulfide)	10.1	BG
Sulfide (carbon disulfide)	10.0	BG

[a]Hazardous constituents identified in the tailings at the Grand Junction processing site. Concentration in mg/l unless otherwise noted; pCi/l = picocuries per liter.
[b]MCL - maximum concentration limit (40 CFR 192.02(a)(3), Table 1). BG = statistical maximum background concentration.
[c]EPA secondary drinking water standard MCL.
[d]Appendix I of 40 CFR 192.02(a)(3)(i).

The unsaturated Mancos Shale beneath the disposal cell also has the capacity to attenuate hazardous constituents geochemically. Geochemical processes that would reduce contamination concentrations include adsorption by the shales and precipitation when reducing conditions are encountered.

The DOE is reasonably certain that MCLs and existing background concentrations, as appropriate, could be met at a hypothetical POC in the uppermost aquifer (Dakota Sandstone) at the Cheney disposal site because the aquifer is hydrogeologically isolated from any tailings seepage.

5.5 CLOSURE PERFORMANCE ASSESSMENT

The DOE has assessed the performance of the proposed disposal cell in conjunction with the hydrogeologic system, and has shown that the disposal cell will minimize and control releases of hazardous constituents to groundwater and surface water, and radon emanations to the atmosphere, to the extent necessary to protect human health and the environment. Natural, stable materials have been proposed for use in construction of the Cheney disposal cell so that long-term performance is ensured. The DOE has also demonstrated that design features necessary for compliance with the EPA groundwater protection standards minimize the need for further maintenance of the disposal site (see Section 3.3, Attachment 4).

5.6 GROUNDWATER MONITORING AND CONCEPTUAL CORRECTIVE ACTION

No groundwater monitoring is proposed for the uppermost aquifer (Dakota Sandstone) at the Cheney disposal site because the contaminated materials will be hydrogeologically isolated from the uppermost aquifer, and groundwater in the Dakota Sandstone is limited use (Class III). Groundwater monitoring is not proposed for isolated groundwater in the alluvial paleochannels peripheral to the disposal cell because the alluvial groundwater is hydraulically upgradient from the cell, and seepage from the cell could not reach the isolated groundwater in the paleochannels.

The Cheney disposal cell has been designed and will be constructed to perform for the mandated design life of 1000 years. The design of the cell has incorporated standard safety factors, and should therefore perform for a period of greater than 1000 years with minimal maintenance. It is not anticipated that the designed disposal cell at the Cheney disposal site will fail, because natural, durable materials will be utilized.

5.7 GROUNDWATER CLEANUP

Demonstration of cleanup and control of existing processing-related groundwater contamination at the Grand Junction processing site will be addressed under a separate DOE project and will be part of a separate

National Environmental Policy Act (NEPA) process. By deferring cleanup of existing groundwater contamination at the Grand Junction processing site, the DOE is not presenting a potential risk to human health or the environment.

[] Water samples were taken from the Colorado River, upstream, adjacent to, and downstream from the processing site during a low stage of the river (January 1991) and analyzed for all potentially hazardous constituents. Results of these analyses indicated that no concentrations of any hazardous constituents of concern exceeded the proposed concentration limits adjacent to or downstream from the processing site. Groundwater contamination from the tailings has persisted beneath the processing site for nearly 30 years at concentrations greater than those currently observed. The area of groundwater potentially affected by existing contamination is based on uranium distribution in alluvial groundwater, and extends approximately 2500 feet downgradient from the tailings site (see Figure 3.10, Attachment 3). A recent survey of domestic wells in the affected area revealed that there are no existing wells in use for any purposes in the potentially contaminated area. By removing the tailings and vicinity property materials, the source of groundwater contamination will be removed and the concentrations of contaminants in the groundwater will decrease. Furthermore, some groundwater cleanup may be accomplished at the processing site as a result of dewatering, which may be required if contaminated materials are excavated from below the water table (see Section 4.0, Attachment 4).

5.8 WATER USE

5.8.1 Processing site

Municipal water for Grand Junction is normally obtained from Grand Mesa surface water or, during dry spells, from the Colorado River. There is no existing or anticipated usage of groundwater from the shallow alluvium or the Dakota Sandstone within the potentially affected hydrogeologic environment near the processing site.

5.8.2 Cheney disposal site

There are no registered wells within two miles of the Cheney disposal site, and no shallow wells within 3.5 miles of the site. Existing and anticipated usage of groundwater in the vicinity of the Cheney disposal site is minimal because of three factors: 1) the current low population density in the area, which results in a low demand for water in the area; 2) the limited availability of shallow groundwater; and 3) quality of the shallow groundwater is too poor for domestic use.

6.0 RADON ATTENUATION AND SITE CLEANUP

6.1 INTRODUCTION

This section summarizes the disposal cell design and relevant parameters selected in evaluating the radon barrier. A discussion of the radiation survey plan is also included with respect to providing reasonable assurance that compliance with EPA standards will be achieved.

6.2 DESIGN

The proposed remedial action at the Grand Junction tailings site is described in Section 1.0. The current estimate of the volume of contaminated materials is 5,260,000 cubic yards (cy) []. The contaminated materials will be relocated to a single disposal cell at the Cheney disposal site. A compacted (100 percent), 24-inch-thick, earthen radon/infiltration barrier will be placed over the topslope of the disposal cell and a 24-inch-thick layer of Mancos Shale will be placed immediately above the radon/infiltration barrier on the top slope for frost protection (see Section 3.3.5 for the cover design). The sideslopes will be covered by a 42-inch-thick radon barrier.

A minimum thickness of 24 inches for the radon/infiltration barrier is required to satisfy criteria for construction, settlement cracking, and infiltration of surface water. Based on modeling, which uses mean values for parameters as described in the following sections, a radon barrier thickness of 12 to 15 inches will be sufficient to reduce radon flux to 20 pCi/m^2s. The erosion protection, frost protection and drain layers were not considered in the calculation of radon barrier thickness required to reduce radon flux to below 20 pCi/m^2s. The covers for the topslope and sideslopes described in Section 3.3.5 will be adequate to meet the EPA standard for radon flux.

[] The placement of contaminated materials within the cell will consider the "as low as reasonably achievable" (ALARA) principle (ICRP, 1973) with respect to reducing radon flux below the EPA standard.

6.3 RADON/INFILTRATION BARRIER PARAMETERS

The radon barrier design parameters and supporting calculations were utilized in conjunction with the RAECOM model (NRC, 1984) to determine the cover thickness necessary to meet the EPA radon flux standard of 20 pCi/m^2s. The radon/infiltration barrier thickness was determined based on procedures specified in the TAD (DOE, 1989a).

Specific design parameters discussed include: 1) long-term moisture content; 2) radon diffusion; 3) radon emanation; 4) bulk dry density; 5) specific gravity; 6) porosity; 7) layer thickness; and 8) average radium-226 (Ra-226) concentrations. Input parameters used for the RAECOM model for Grand Junction materials are presented in Attachment 1, Calculations 05-670-05-03, 05-670-01-05, and 05-670-02-03.

6.3.1 Long-term moisture

The SWRDAT (Baumer, 1985) computer program provided a comparable long-term moisture result for the vicinity property materials. An average long-term moisture content of 18.0 percent by weight was selected for the main tailings area materials based on an assumed four-percent drying after placement. Average long-term gravimetric moisture contents for the evaporation ponds area material (vicinity property material) [] and the radon barrier were determined using: 1) 15-bar capillary moisture tests; 2) the SWRDAT computer program; and/or 3) the Rawls and Brakensiek equation. For the evaporation ponds area materials, the long-term gravimetric moisture was determined by 15-bar capillary moisture tests to be 10.0 percent; this value was used in RAECOM model runs. []

An average long-term moisture content of 14.7 percent by weight was used for the silty clay radon barrier material based on the same results from the 15-bar capillary moisture tests and the SWRDAT computer program.

The Rawls and Brakensiek equation is an empirical equation for estimating long-term moisture content. For the evaporation pond materials and the radon barrier, the long-term moisture contents calculated by the Rawls and Brakensiek equation were lower than the long-term moisture contents measured by 15-bar capillary moisture tests or by the SWRDAT program. According to the TAD (DOE, 1989a), the Rawls and Brakensiek equation is more suited to sandy and silty materials. In particular, it does not account for clay's ability to retain moisture. For the radon barrier, the Rawls and Brakensiek equation resulted in a long-term moisture content of 10.6 percent; however, this value was not used further in radon barrier thickness calculations for the reasons stated above.

6.3.2 Radon diffusion

Average radon diffusion coefficients for the main tailings pile area contaminated materials, the evaporation ponds area contaminated materials, and the silty clay radon barrier materials were determined using four, five, and five samples, respectively. Radon diffusion was measured in the laboratory as a function of moisture saturation. The derived data were plotted and a best-fit curve was obtained using a least squares methodology. An average diffusion coefficient of 0.012 cm^2/s was obtained for the main tailings pile area materials at a moisture content of 50 percent (18 percent by weight). At 95 percent compaction and an average volumetric moisture content of 62 percent (10 percent by weight), a conservatively high diffusion coefficient of 0.01 cm^2/s was assumed for the evaporation ponds area materials (VP materials) because of the material property uncertainties (the calculated value was 0.0073 cm^2/s).

For the silty clay radon barrier materials, the diffusion coefficients were 0.0029 and 0.0037 for 15-bar capillary and SWRDAT computer program determinations, respectively.

6.3.3 Radon emanation

Radon emanation coefficients for contaminated materials were determined from a series of standard laboratory measurements over a range of moistures, Ra-226 concentrations, and types of materials on the site. Emanating fractions for contaminated materials in the main tailings pile area ranged from 0.28 to 0.48. The arithmetic average for 29 samples was 0.36 and the standard error of the mean was 0.008. For the contaminated materials in the evaporation ponds area [], the emanating fraction ranged from 0.25 to 0.43. The average for six samples was 0.35 and the standard error of the mean was 0.029.

Radon emanation was found to be statistically independent of moisture using standard regressional and statistical analyses. However, a slight trend toward lower emanating fractions was noted for materials from the main tailings pile area with Ra-226 concentrations less than 200 pCi/g. This was based on a limited data set. Since the average Ra-226 concentration in these materials is 570 pCi/g, the emanating fraction given above is based on the 29 samples with concentrations greater than 200 pCi/g.

6.3.4 Dry densities and porosities

The dry densities, specific gravities, and porosities were determined using standard tests and procedures, assuming a design compaction of 90 percent for the main tailings pile materials, 100 percent for the evaporation ponds area materials, and 100 percent for radon barrier materials.

For relocated tailings, the average bulk dry density was 1.39 grams per cubic centimeter (g/cm^3) and the porosity was 0.492. For the evaporation ponds area materials, the average bulk dry density was 1.78 g/cm^3 and the porosity was 0.34.

The silty clay radon barrier materials had an average bulk dry density of 1.73 g/cm^3 and a porosity of 0.375.

6.3.5 Layer thickness

Specific layer thicknesses were determined for the contaminated materials within the stabilized embankment. The layers were contaminated materials from the main tailings pile area as layer 1 (40 feet thick), contaminated materials from the evaporation ponds area as layer 2 (10 feet thick), and the radon barrier materials as layer 3. It is anticipated that the as-built [] layers of materials from the evaporation ponds area will be thicker than 10 feet; therefore, use of a 10-foot layer in the RAECOM model is conservative. Information on layer thicknesses can be found in Calculation 05-670-01-05 (Attachment 1).

6.3.6 Radium-226 concentration

Radium-226 concentrations for the tailings pile materials were assessed at 95 borehole locations. Radium-226 analyses were performed by gamma spectroscopy on 423 samples collected from these locations. Subpile materials were included in the sampling activities. For the off-pile areas, including the vicinity property materials, Ra-226 analyses were performed by gamma spectroscopy on 238 samples collected from 154 locations. Since the vicinity property materials are still being excavated and placed at the Grand Junction site, additional characterization of these materials will be performed. The estimated volumes, areas, and average Ra-226 concentrations for contaminated materials are shown in Table 6.1. The overall average Ra-226 concentration for the main tailings pile area contaminated materials is 571 pCi/g, and is 64 pCi/g for the evaporation ponds area materials (which includes vicinity property materials). This off-pile material includes 104,000 cy of contaminated material remediated at the Grand Junction Project Office as part of the SFMP Program (see Calculation 05-670-11-00).

6.3.7 Ambient radon concentration

An ambient radon concentration in air of 0.8 pCi/l was used for the RAECOM model based on air samples collected at background locations.

6.4 EVALUATION OF RADON BARRIER

The radon barrier was evaluated with respect to compliance with the EPA radon flux standard of 20 pCi/m^{2}s using previously discussed parameters as input for the RAECOM model. Several runs of the RAECOM model were performed for the various combinations of cover materials and values for the moisture contents and diffusion coefficients. The RAECOM model runs are summarized in Table 6.2. Radon barrier results using mean values for input parameters were 1.0 feet (run A) and 1.2 feet (run C) when long-term moisture content and diffusion coefficients of the layer of

Table 6.1 Estimated volumes, areas, and average Ra-226 concentrations for contaminated materials at the Grand Junction site

Description	Volume[a] (cy)	Area[b] (acres)	Average Ra-226[a] concentration (pCi/g) (volume weighted)
On-pile materials			
Main pile	2,831,000	54.4	575
Mill yard	25,000	8.1	461
West and south areas	26,000	7.4	297
Total	2,882,000	69.9	571
Off-pile materials			
Pond 1	31,000	11.9	8
Pond 2	28,000	4.2	34
Pond 3 (vicinity property materials)	2,219,300	14.1	60
Grand Junction Project Office (SFMP) material	100,000	--	162
Total	2,378,300	30.2	64
Grand Total	5,260,300	100.1	

[a]From Calculation 05-670-02-03 (Attachment 1).
[b]From Calculations 05-626-01-03 and 05-626-02-04 (Attachment 1).

Table 6.2 Summary of RAECOM model runs

Run	Type of data	Test data or SWRDAT	Radon barrier thickness (ft)
A	Mean	Test data	1.0
B	Mean + SEM[a]	Test data	1.6
C	Mean	SWRDAT	1.2
D	Mean + SEM	SWRDAT	2.0
E	Same as A, except layer 2 = 5 feet	Test data	1.4
F	Same as A, except layer 2 Ra-226 = 150 pCi/g	Test data	1.8
G	Same as A, except layer 2 = 15 feet	Test data	0.9
H	Same as B, except layer 1 Ra-226 = 800 pCi/g	Test data	1.6
I	Same as H, except layer 1 moisture content = 8 percent and diffusion coefficient = 0.02	Test data	1.6

[a]SEM = standard error of the mean.

materials from vicinity properties were determined by 15-bar capillary moisture tests or by the SWRDAT computer program. The RAECOM model run that resulted in the thickest radon barrier of 2.0 feet (run D) was similar to run C, but used the mean plus standard error of the mean (SEM) values for the diffusion coefficient of the radon barrier [], radium-226 (SEM) concentration in tailings and vicinity property materials, long-term moisture content, and radon emanating fraction. Runs E through I were also part of the sensitivity analysis. Mean + SEM Ra-226 concentrations of 600 pCi/g for tailings layer 1 and 81 pCi/g for vicinity property materials layer 2 were determined according to the TAD (DOE, 1989a) and used in RAECOM runs B and D. An alternative method of relative frequency distributions of Ra-226 concentrations was used to represent the variability of the data. The summary on sheet 2c of Calculation 05-670-02-03 (Attachment 1) indicates that approximately 75 percent of the tailings samples were below 800 pCi/g, and 75 percent of the vicinity property materials samples were below 80 pCi/g. RAECOM Run F, which used a vicinity property material layer 2 Ra-226 concentration of 150 pCi/g and mean values for other parameters, resulted in a radon barrier thickness of 1.8 feet. RAECOM run H used a tailings layer 1 Ra-226 concentration of 800 pCi/g and mean + SEM values for other parameters. This RAECOM run resulted in a radon barrier thickness of 1.6 feet. The 24-inch radon barrier design is expected to be more than adequate to reduce the radon flux to below the 20 pCi/m^2s standard.

The final cover design will be based on actual measurements of the as-placed contaminated materials and will incorporate any restrictions on the quantities of the radon barrier materials. The final design will demonstrate compliance with the radon flux standard.

6.5 SITE CLEANUP

Extensive field sampling and radiological surveys have been conducted to determine the extent and degree of contamination at the Grand Junction site. Drawings GRJ-PS-10-0211 and -0212 (Attachment 1) show the distribution of contaminated materials and planned excavation depths.

6.5.1 Radiological site characterization

Details of the site characterization data are presented in Calculation 05-626-01-03 for tailings pile limits and quantities, and Calculation 05-626-02-04 for off-pile excavation limits and quantities (Attachment 1). Measurements of background radioactivity near the Grand Junction site and measurements of existing radiological site conditions are summarized in Table 6.3.

Approximately 5,260,000 cy of contaminated materials (including estimated vicinity property materials and GJPO materials) cover over 100 acres at the Grand Junction site. Excavation depths for the tailings pile range from [] 17.5 to [] 32.5 feet with an average of [] 26.3 feet. This includes approximately [] 1.0 [] foot of excavation beneath the tailings/subsoil interface. []

Areas, volumes, and average Ra-226 concentrations for various contaminated materials are presented in Table 6.1.

6.5.2 Standards for cleanup

The DOE is committed to remove contaminated materials and place them in an engineered disposal cell such that all EPA standards in 40 CFR 192 shall be met. All disturbed areas will be restored for adequate control of surface drainage. Where removal of contaminated materials is not practical or feasible, application of supplemental standards may be considered according to 40 CFR 192.21. In all cases the DOE is committed to keeping potential exposures to the public as low as reasonably achievable (ALARA).

6.5.3 Verification of cleanup

Excavation control monitoring will be conducted during remedial action to ensure that the five pCi/g and 15 pCi/g above background Ra-226 standards are met for surface and subsurface soils, respectively. Excavation control monitoring will prevent both underexcavation and overexcavation.

After completion of excavation in each 100-square-meter (m^2) area, a verification measurement of the residual Ra-226 concentration will be performed. The intent of the verification survey is to provide reasonable assurance that the remedial action has complied with the standards.

Final verification surveys will be performed to document average Ra-226 concentrations on all 100 m^2 areas remediated. [] Nine-plug composite surface soil samples may be collected from a 100 m^2 area and analyzed by gamma spectroscopy to verify compliance with EPA standards, which require that average surface Ra-226 concentrations must be below five pCi/g plus background and average subsurface Ra-226 concentrations must be below 15 pCi/g plus background in each 100-m^2 area. The gamma spectroscopy system shall have an accuracy of plus or minus 30 percent of the standard at the 95 percent confidence level for a sample with a concentration equal to the standard. <u>When soil containing a significant fraction of small rocks is encountered, the Ra-226 concentration determined by gamma spectroscopy will be corrected</u> [] <u>using a site-specific application of the approved "Bulk Radionuclide Determination, Excavation Control, and Site Verification for Cobbly Soils Procedure" (RAC-OP-003).</u>

Table 6.3 Background radioactivity and radiological conditions at the Grand Junction site

Description	Range[a]	Average[a]
Gamma exposure rate		
Background	7-11 microR/hr	11 microR/hr
Above tailings piles	60-830 microR/hr	NA
Radon-222 in air		
Background concentration	0.70-1.0 pCi/l	0.8 pCi/l
Flux above piles	90-1340 pCi/m^2s	550 pCi/m^2s
Soil radioactivity		
Background Ra-226	1.0-3.4 pCi/g	2.0 pCi/g
Uranium-238	0.6-0.9 pCi/g	0.7 pCi/g
Off-pile Ra-226	2-2689 pCi/g	66.5 pCi/g
Tailings and mill yard Ra-226	5-7589 pCi/g	570 pCi/g

[a]microR/hr = microroentgens per hour.

NA - not available.

A nine-point composite gamma measurement technique may be used in place of a verification soil sample [] in areas with windblown contamination or where groundwater has seeped into the excavated area. This hand-held verification technique will be site-specific and must be approved by the DOE UMTRA Project Office. The RTRAK mobile detection unit may be used for verification of contaminated areas that are too large to sample by hand-held detectors.

[]

[] Supplemental standards may be proposed for wetlands located on the floodplain between the tailings pile and the Colorado River. Supplemental standards may be proposed due to the excessive environmental harm associated with excavating contaminated materials in the wetlands area compared to the negligible potential health benefits projected to be gained from remedial action. Excavation of the wetlands is projected to entail destruction of vegetation and would destroy the unique character of the wetlands without commensurate human health protection.

Four percent of all verification samples are sent to an independent lab for verification of Ra-226 concentration and thorium-230 (Th-230) concentration. If [] Th-230 is encountered in significant concentrations after Ra-226 has been removed to the EPA standards, a supplemental standard under criterion (f) of 40 CFR 192.21 will be imposed. For Th-230 contamination, the supplemental standard will be to reduce the Th-230 concentration to a level such that 1) the Ra-226 concentration in 1000 years, including residual and ingrown Ra-226, will not exceed 15 pCi/g in subsurface soil; or 2) the projected concentration of radon decay products in a slab-on-grade house will not exceed 0.02 working levels in 1000 years.

Independent radiological surveillances and health and safety audits will be conducted by the DOE and the Technical Support Contractor during remedial action to ensure that all activities are conducted to meet Federal, state, local, and UMTRA Project standards and guidelines. Quality control and quality assurance requirements and procedures are in place to ensure that adequate cleanup and subsequent verification are properly implemented and documented (DOE, 1990).

6.6 SUMMARY AND CONCLUSIONS

The disposal cell and radon barrier as designed will reduce radon flux to levels below EPA standards stated in 40 CFR 192.02(b). The DOE has committed to clean up the Grand Junction site and associated vicinity properties in accordance with EPA standards, NRC guidelines, and UMTRA Project health and safety requirements.

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