NUREG–1532

Draft Technical Evaluation Report for the Proposed Revised Reclamation Plan for the Atlas Corporation Moab Mill

Source Material License No. SUA 917
Docket No. 40–3453
Atlas Corporation

U.S. Nuclear Regulatory Commission

Office of Nuclear Material Safety and Safeguards

January 1996

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ABSTRACT

This Draft Technical Evaluation Report (DTER) summarizes the U.S. Nuclear Regulatory Commission staff's review of Atlas Corporation's proposed reclamation plan for its uranium mill tailings pile near Moab, Utah. The proposed reclamation would allow Atlas to (1) reclaim the tailings pile for permanent disposal and long-term custodial care by a government agency in its current location on the Moab site, (2) prepare the site for closure, and (3) relinquish responsibility of the site after having its NRC license terminated. The NRC staff review has identified open issues in geology, seismology, geotechnical engineering, erosion protection, water resources protection and radon attenuation. The NRC will not approve the proposed reclamation plan until Atlas adequately resolves these open issues.

ATLAS MOAB MILL TER

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1.0 INTRODUCTION

1.1 Background

Source Material License SUA-917 for the Moab Mill is held by the Atlas Corporation (Atlas). The mill has not operated since 1984. A decommissioning[1] plan for the mill was approved by Amendment No. 3 dated November 28, 1988. Decommissioning of the mill began in 1988, and interim cover placement over the tailings disposal area began in 1989. The reclamation[2] plan that was prepared in 1981 and approved by NRC in 1982 was based on projected disposal capacity requirements and was designed for an ultimate crest elevation of 4076 feet. The maximum crest elevation constructed before mill operations ceased was 4058 feet, resulting in the necessity to redesign the tailings impoundment and thus revise the reclamation plan. In July 1993, NRC noticed in the Federal Register the intent to approve Atlas' revised reclamation plan and made available for public comment an environmental assessment of the effects of the proposed action. As is usual in cases where a licensee proposes revisions to an approved reclamation plan, both the NRC technical evaluation and environmental assessment only addressed the revised elements of the plan and the environmental effects of changes to the plan approved in 1982. Extensive adverse public comments were received in response to the Federal Register notice. As a result, NRC decided to reevaluate the entire reclamation plan and to prepare an Environmental Impact Statement (EIS) addressing reclamation.

This draft Technical Evaluation Report (TER) documents the NRC staff review of Atlas' proposed reclamation plan and staff conclusions with respect to the appropriate regulations. The regulations governing reclamation of uranium mill tailings appear primarily in 10 CFR Part 40. Technical criteria appear in Appendix A to Part 40.

A draft TER is usually prepared when there is sufficient information to document the staff's review of a proposed reclamation plan and its conclusions with respect to the appropriate regulations. This draft TER contains open issues that must be resolved by Atlas before NRC can approve the proposed reclamation plan. In most licensing reviews, the draft TER is provided to the licensee, in lieu of an additional round of questions and requests for information, as a means to expedite the review process. While the draft TER is a publicly available document, it is not normally available for public comment in most licensing cases. However, due to the extensive public interest and comment on the 1993 TER, NRC decided to make this draft TER available for public comment.

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[1]Decommissioning refers to the dismantling and disposal of the mill buildings and structures.

[2]Reclamation refers to the stabilization and closure of the tailings impoundment.

1.2 Site Description

1.2.1 Location and Description

The Atlas' Moab Mill site is located in Grand County, Utah. The site is located on the northwest shore of the Colorado River, 5 km (3 miles) northwest of Moab (Figure 1-1). The site can be accessed from U.S. Highway 191 north of Moab. The Atlas mill site encompasses 162 hectares (400 acres) on the outside bend of the Colorado River, at the southern terminus of the Moab Canyon. The site is surrounded on the north and west sides by high sandstone cliffs. To the north and east is Moab Wash, to the east and south is the flood plain of the Colorado River, and across the river is Moab Marsh. The city of Moab is southwest of the marsh. The elevation at the mill is approximately 1130 meters (3700 feet) above mean sea level (MSL).

The mill grounds slope generally towards the Colorado River and Moab Wash. The substratum upon which the mill was constructed is composed mainly of alluvial materials brought down the Moab Canyon and Colorado River. Adjacent to the mill site on the north and west are U.S. Highway 191 and Utah Highway 279, respectively. The Rio Grande Railroad traverses a small section of Atlas property, just west of Highway 279, prior to entering a tunnel that emerges many kilometers down river.

1.2.2 Description of Mill Facility

The processing facility and tailings pond combined, cover approximately 81 hectares (200 acres) of an available 162 hectares (400 acres) owned by Atlas. The mill was authorized to extract uranium oxide (yellowcake) by both the acid and alkaline leach processes and was licensed for production at 850 metric tons (MT, 1,870,000 pounds) of yellowcake annually. During the life of the mill, only one tailings pond was used.

The plant site, before decommissioning, was composed of a main processing plant, a 53-hectare tailings pond, storage yards, ore receiving facilities, various process-related structures, and an office complex. These structures and facilities are enclosed by a four-strand barbed wire fence which prevents random access. All structures, including the office complex, are being razed during decommissioning of the facility.

1.2.3 Description and Characteristics of Tailings

The majority of the ore for the Atlas Mill came from the Big Indian Uranium District approximately 130 km (80 miles) to the southeast. The ore was primarily a sandstone with minor amounts of carbonate. Ore was trucked to the mill, ground to a sufficiently fine consistency to allow maximum efficient chemical reactions to occur. It was then processed through either the acid-leach circuit or the alkaline-leach circuit, both of which were used in this mill. Analysis of the mineral content of the ore would determine which circuit the ore would be processed through. After milling, the combined waste slurry from both circuits was pumped to the tailings impoundment.

The approximate wet weight of the tailings contained within the tailings impoundment is determined to be 9.5 million MT (10.5 million tons), with a

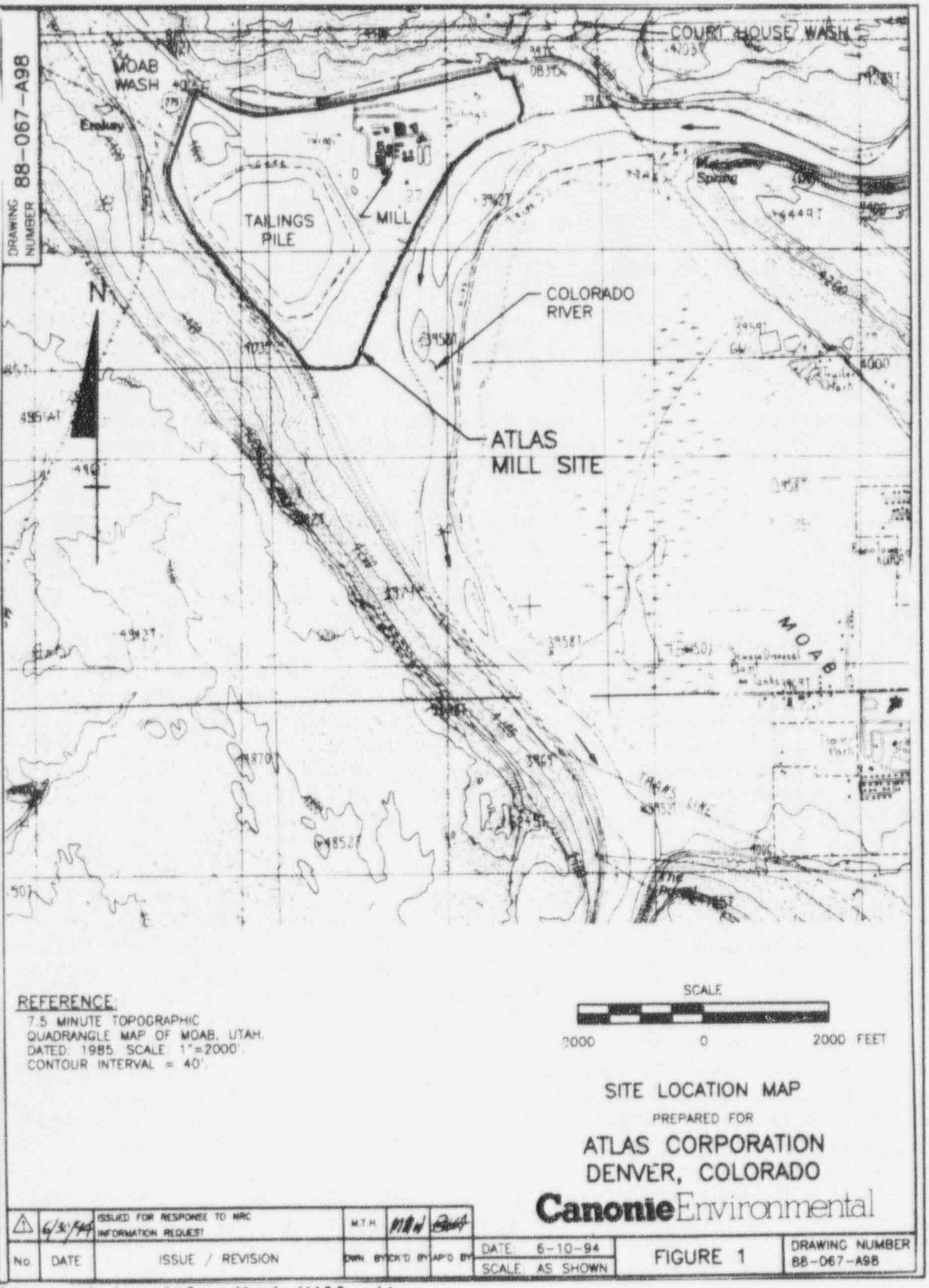

Figure 1-1: Atlas Moab Mill site

volume of 5.7 million cubic meters (7.5 million cubic yards). The tailings basin is composed of fine tailings (slimes), coarse tailings (sand), and ore which was placed there at the end of operation of the mill as part of the interim cover. A composite analysis of the tailings by Atlas, determined that the average radium activity of the slimes was 1275 picocuries per gram (pCi/g) and that of the sands was 241 pCi/g. The activity of the ore in the tailings impoundment was determined to be 213 pCi/g radium.

1.3 Site History and Proposed Action

The Uranium Reduction Company (URC) built and began operations at the Moab Mill in October 1956. Atlas acquired URC in 1962 and operated the mill until 1984 when it was placed in stand-by status. Atlas holds NRC Source Material License SUA-917 for the Moab Mill which was changed to a possession only status on December 18, 1992.

A decommissioning plan for the mill was approved on November 28, 1988. Decommissioning of the mill began in 1988, and interim cover placement over the tailings disposal area began in 1989.

The proposed action is approval of a reclamation plan for onsite disposal of the tailings. A reclamation plan was prepared by Atlas in 1981 and approved by NRC in 1982. This plan was based on the projected life of facility disposal capacity requirements; the disposal pile was designed for an ultimate crest elevation of 4076 feet. The maximum crest elevation constructed before the mill ceased operation was 4058 feet, resulting in the necessity to revise the reclamation plan. In accordance with 10 CFR 40, Appendix A, Atlas, by letter dated August 2, 1988, submitted a revised reclamation plan for NRC review and approval. NRC staff review of the proposed plan resulted in requests for additional information, reevaluation, and redesign. As a result, Atlas submitted a revised reclamation plan (Canonie, 1992). NRC staff review of this document resulted in a request for additional information dated March 5, 1993. Revisions to the 1992 reclamation plan were submitted by letters dated April 14, and April 23, 1993. On July 20, 1993, NRC noticed in the Federal Register its intent to approve the reclamation plan and made available for public comment an environmental assessment of the effects of the proposed action which only addressed the environmental effects of changes to the plan approved in 1982. Extensive adverse public comments were received. Major concerns and questions related to seismic and fault evaluations, the potential effects of the Colorado River and local tributaries on the stability of the disposal cell, and the need for an updated, complete environmental assessment of the entire reclamation plan, including alternative disposal locations. The comments received prompted NRC to withdraw, by Federal Register notice dated October 8, 1993, its previously noticed intent to approve the revised reclamation plan. By Federal Register notice dated March 30, 1994, NRC announced its intent to prepare an EIS.

The NRC staff review that resulted in the decision to approve the revised reclamation plan (and noticed on July 20, 1993, in the Federal Register), focused only on revisions to the previously approved reclamation plan. Due to the extensive public comments, NRC decided to reevaluate the revised reclamation plan in its entirety. This lead to additional requests for information by the staff and to submittals by Atlas, in response, in

January 1994, June 1994, and March 1995. As a result, the reclamation plan reviewed by the NRC staff consists of the following documents:

1. Base Reclamation Plan of June 1992 (Canonie, 1992),
2. April 1993 Response (Canonie, 1993),
3. January 1994 Response (Canonie, 1994a),
4. June 1994 Response (Canonie, 1994b), and
5. March 1995 Response (Canonie, 1995).

1.4 Review Process and TER Organization

The NRC staff review was performed in accordance with the Final Standard Review Plan (SRP)[3] for the Review and Remedial Action of Inactive Mill Tailings Sites under Title I of the Uranium Mill Tailings Radiation Control Act (UMTRCA), Revision 1 (NRC, 1993) and is a comprehensive assessment of Atlas' proposed reclamation plan as documented by this TER. Appendix A to 10 CFR Part 40 contains the technical requirements for disposition of tailings and waste produced from the extraction or concentration of source material from ores. The TER is organized by the technical disciplines involved in the assessment of the reclamation plan to assure compliance with Appendix A. Each section describes the compliance with the applicable Criteria in Appendix A as it pertains to the specific discipline addressed in that section. Sections 2, 3 and 4 provide the technical basis for the NRC staff's conclusions with respect to long-term stability, Section 5 the plan's compliance with groundwater standards, and Section 6 describes radon control assessment. Section 7 provides a criterion by criterion evaluation of the reclamation plan with respect to Appendix A.

1.5 Open Issues

The NRC staff review of the reclamation plan identified a number of issues that have not been adequately resolved through previous rounds of questions and requests for information. These open issues are given in Table 1-1. Until these open issues are adequately resolved, the staff can not support the issuance of a license amendment approving the proposed reclamation plan.

Table 1-1: Open Issues

Open Issue	Section
1. Whether or not the Moab fault and the West Branch fault are capable faults.	2.4.1.1
2. The nature and consequences of the buried fault or scarp beneath the southern edge of the tailings.	2.4.1.2
3. The nature and rate of future subsidence at the site.	2.4.1.3

[3]Although the SRP is written for the UMTRCA Title I program, the applicable standards for the Title II program are similar. Division of Waste Management guidance directs the staff to use this SRP for Title II reviews to the extent practicable.

4. Whether or not, or in what way, migrating sand dunes might adversely affect the tailings in the future.	2.4.2.1
5. Whether or not a potential landslide hazard exists from Poison Spider Mesa escarpment.	2.4.2.2
6. The licensee has not provided sufficient information to evaluate the seismic design basis for the site.	2.4.3
7. In order to complete the characterization of the tailings and the settlement analysis, the licensee needs to submit additional piezocone information. Prior to approval of the settlement evaluation, the licensee should submit a field exploration plan for the piezocone exploration program.	3.2.2.3
8. The staff cannot conclude that the slopes of the disposal cell are designed to endure the effects of the geologic processes and events, including resistance to earthquake and settlement, to which they may reasonably be subjected during the design life and that the analyses have been made in a manner consistent with Chapter 2 of the SRP (NRC, 1993).	3.3.1
9. The licensee is currently reevaluating the liquefaction potential for the site. The staff's liquefaction analysis review has been suspended until the licensee's reevaluation is complete and the results are made available. Thus, the staff cannot conclude that there is adequate assurance of safety with respect to liquefaction damage.	3.3.3
10. The licensee should provide adequate, detailed construction specifications (or a quality assurance program) for field testing the moisture content of the radon barrier soils when lift placement is interrupted.	3.4.1
11. Portions of the technical specifications have been superseded by later submittals, such as the revised cover design; however, the specifications have not been updated to reflect these revisions. The technical specifications need to be consistent with the reclamation design.	3.4.2
12. The specifications permit the placement of fill in 18-inch-thick lifts; however, such lift thicknesses make uniform compaction difficult to achieve. The licensee should either specify more workable lift thicknesses or describe applicable procedures for verifying that thorough compaction has been achieved.	3.4.2
13. The licensee has not formally submitted revisions to erosion protection features that have been revised; subsequently, inconsistencies with previous submittals exist. Additionally, details of layer thicknesses and gradations have not been provided.	4.5.1

14. Consequences, with respect to erosion protection, of severe landslides have not been adequately addressed.	4.5.1.3.2
15. The licensee must provide additional data to support its interpretation of groundwater flow directions and gradients in the alluvial aquifer near the southern property boundary of the site.	5.2.4
16. The licensee must provide data showing that monitoring well AMM-1 is not influenced by contaminants from the former ore storage pad.	5.2.5
17. The licensee must clarify whether it plans to take engineering credit for any disposal cell component for meeting compliance with the groundwater protection standards for the site. If engineering credit is taken, costs associated with achieving the necessary cover permeability must be incorporated into the reclamation plan.	5.3
18. The licensee must provide a sampling plan for Ra-226 analysis of the upper 3 to 4 feet of coarse tailings and the technical basis for modeling the coarse tailings on the sideslopes as being homogenous (i.e., a single layer) for Ra-226 concentration.	6.2.2
19. The licensee must provide the gamma survey and sampling procedures for verification of tailings cleanup in the Moab Wash sandy soil borrow area for NRC approval. Also provide revised Reclamation Plan Specifications (Section 1.14 and 5.3.3) and page 40 of the text to indicate that the background soil Ra-226 value is the average value approved by NRC to demonstrate that the radon barrier will comply with Criterion 6 (5).	6.2.3
20. The licensee must include in the testing program for the clay borrow material, analysis and/or gamma surveys determine its Ra-226 value, to demonstrate that the radon barrier will comply with Criterion 6 (5).	6.2.3

1.6 Confirmatory Items

The NRC staff review of the Reclamation Plan identified several instances in which the licensee had agreed to revision of the Reclamation Plan but has not formally provided that revision. These items, which the staff considers to be confirmatory items, are given in Table 1-2. Confirmatory items must be resolved before the staff can support the issuance of a license amendment approving the proposed reclamation plan.

Table 1-2: Confirmatory Items

Confirmatory Item	Section
1. Provide revised Reclamation Plan pages pertaining to the method of composite sampling for ore and tailings to accurately describe the sampling program.	6.2.1
2. Incorporate in the Reclamation Plan, the proposed testing program for "affected" soil to substantiate the radon flux model/calculation parameter values.	6.2.2
3. Incorporate in the Reclamation Plan, the final clay borrow area proposed testing program to substantiate the radon flux model parameter values for the clay material.	6.2.3

2.0 GEOLOGIC STABILITY

2.1 Introduction

This section of the draft TER documents the staff's review of geologic and seismologic information and analyses of Atlas Corporation's revised reclamation plan for its mill tailings site at Moab, Utah. 10 CFR Part 40 requires the tailings disposal area to be closed in accordance with a design which provides reasonable assurance of control of radiological hazards to be effective for 1000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. Also, the tailings may not be located near a capable fault that could cause a maximum credible earthquake larger than that which the tailings could reasonably be expected to withstand [Appendix A, Criterion 4(e)].

NRC staff considers this standard (Appendix A) to mean that certain geologic and seismologic conditions [such as Criteria 4(e) and 6] must be met in order to have reasonable assurance that the long-term performance objectives will be met. Guidance with regard to these conditions is provided in Final Standard Review Plan (FSRP) for UMTRCA Title I sites which are applicable to Atlas and other Title II sites (NRC, 1993).

The staff's review of the geology and seismology is based upon the following sources of information and interpretations: Atlas Corporation's documents; interactions with Atlas Corporation and its consultants, including telephone conference calls, meetings and site visits; interactions (including exchange of documents, phone calls, field trips and office visits) with geologists, seismologists, hydrologists and rangers employed by the Utah Geological Survey (UGS), U.S. Geological Survey (USGS), University of Utah, Utah Division of Radiation Protection, U.S. National Park Service; proprietary reports of the Petroleum Science and Technology Institute, Edinburgh, Scotland; and independent sources, as cited.

2.2 Location

The Atlas site is located at the confluence of Moab Wash and the Colorado River, at the base of an escarpment of about 1100 feet of relief which borders an elongated, northwest-trending, topographic depression called Moab-Spanish Valley. Section 1.2 provides a more detailed description and map location of the site and vicinity in eastern Utah's Paradox Basin.

2.3 Geology

Atlas has presented information about the geology and seismology of its site from such sources as topographic maps and aerial photographs, soil and groundwater samples and literature searches. Subsurface geologic data derived from boreholes and logs of cuttings were presented as recommended in Final Standard Review Plan, Section 1.3.2 (NRC, 1993). However, Atlas has not provided information on the alluvium and bedrock beneath the tailings sufficient to demonstrate a design that ensures that potential future disruptions of the radon and erosion protection barriers will meet NRC requirements (Appendix A, Criterion 6). The staff has independently compiled the following descriptions of the site geologic setting emphasizing those features, conditions, processes and events that represent potential geologic hazards or conditions that could adversely affect site stability during the next 200 to 1000 years.

2.3.1 Physiographic Setting

The site is located in the Moab-Spanish Valley, one of about eight prominent topographic depressions in the Paradox Basin. General technical descriptions, which include maps and cross sections of the Colorado Plateau physiographic province and its subprovince, the Paradox Basin in which the Atlas site lies, may be found in the following references: Cater (1970); Doelling (1985, 1988) and Hunt (1969, 1974).

2.3.1.1 Colorado Plateau Physiographic Province

The Atlas site lies within a geologically distinct sedimentary rock basin - the Paradox Basin - that is part of the Colorado Plateau physiographic province (CPPP). The CPPP is characterized by extensive plateaus bordered by receding escarpments, canyons, altitudes generally exceeding 5000 feet, semi-arid climate (except for variations caused by local altitude), and angular topography due to the combination of gently dipping strata of contrasting resistance to erosion and penetrative near-vertical fracture sets.

Much of the physiography of the CPPP can be related to subsurface geological structures. Examples of physiographic features that are related to subsurface and near-surface structures are salt anticlines and salt depressions like the Moab anticline and Valley, upwarps like the Umcompahgre Plateau, fault valleys like the Lisbon Valley, igneous domal uplifts like the La Sal Mountains, the grabens of Canyonlands National Park (N.P.), and the fins and arches of Arches N.P.

The incised landscape of the CPPP results principally from erosion dominated by stream transport. The depositional effects of transport by gravity (such as talus and landslides) and by wind (such as sand dunes) are also widespread. However, the spectacular canyons and escarpments (such as the Spider Mesa escarpment adjacent to the site) are evidence of stream migration and incision in response to plateau uplift often with obvious structural controls.

The Colorado River and its tributaries dominate the drainage history of the plateau and the Paradox Basin. The geomorphic evolution of the Colorado River is discussed briefly in the Section 2.3.4 on geomorphic setting.

2.3.1.2 Paradox Basin

The Atlas site lies within the thickest stratigraphic section and most structurally deformed zone of a northwest-trending wedge-shaped sequence of sedimentary rocks called the Paradox Basin. Paradox Basin sediments filled an asymmetric structural depression a few miles deep. The sedimentary rock wedge is thinner and less deformed toward the southwest, beyond Monticello, San Juan County, Utah, and in the vicinity of Cortez, Montezuma County, Colorado (Cater, 1970). The thickest part of the basin was subjected to a variety of geologic processes, including cyclical evaporite deposition in the

Pennsylvanian Period, faulting, salt diapirism, folding, igneous intrusion, jointing, uplift, subsidence, erosion, and seismicity.

The topography in the northeastern part of the Paradox Basin, in which Moab is located, is dominated by features associated with northwest-southeast-trending folds, faults and steep-walled valleys elongated parallel to the structures. Prominent valleys are underlain by salt-cored anticlines on block-faulted Precambrian metamorphic basement rock. Salt structures apparently intruded, faulted and upwarped the sedimentary cover rocks by diapirism. Subsequent dissolution and creep of the near-surface salt beds led to the subsidence of the cover rocks. Cover rocks subsided by slipping on normal faults and downwarping, among other processes (Cater, 1970; Doelling, 1985, 1988).

The escarpments which border the elongated valleys formed along fault scarps that have retreated to their present position by erosional processes. The Poison Spider Mesa escarpment adjacent to the Atlas site is such a feature. Moab-Spanish Valley is one of the salt-cored anticlines that breached the surface. However, as the Moab salt-cored anticline plunges to the northwest under the Atlas site, the surface expression of breaching becomes progressively more subdued and is generally absent northwest of the Bartlett Wash area.

2.3.2 Stratigraphic Setting

The thick part of the wedge of the Paradox Basin sedimentary rocks (e.g., the Moab area) has had a long history of deposition and erosion in marine and continental environments periodically punctuated by tectonic, geomorphic and climatic processes and events. The regional stratigraphy is briefly described to provide background to discussions of processes that are deemed likely to continue to operate over the next 1000 years. UGS defers to Molenaar's (1975) lexicon of stratigraphic names for appropriate use in the Paradox Basin. The staff considers the stratigraphic nomenclature and correlations in Doelling, et al. (1995) appropriate for this review. Atlas has not characterized the Quaternary alluvium, the Paleozoic and, if present, the Mesozoic rocks, or the basement rocks beneath the site to the extent necessary to support conclusions of subsurface and bedrock stability, as discussed later in this section. However, the staff has compiled the following descriptions from the literature and from discussions with UGS geologists.

2.3.2.1 Stratigraphy of the Moab Area, Utah

The Moab area was a depocenter during most of the Paleozoic and Mesozoic Eras. The Paleozoic rock sequence is represented by Permian age rocks of the Cutler Formation, Pennsylvanian rocks of the Honaker Trail Formation and Paradox Formation, and Mississippian and older rocks known to occur in the subsurface (Doelling et al., 1995, Description and Correlation of Map and Bedrock Units). A stratigraphic column for Moab 7.5' Quadrangle with unit descriptions was developed by UGS (Doelling et al., 1995). In the Early Pennsylvanian, the basin subsided relative to the tectonic uplifting of the Uncompahgre Mountains. The basin was nearly filled with cyclical deposits of marine evaporite minerals by the end of the Late Pennsylvanian Epoch. Deposits of potash minerals and other evaporite mineral resources occur in these rocks.

Late Pennsylvanian to Late Cretaceous continental (non-marine) deposits are represented in the Moab area. Varying thicknesses of Late Pennsylvanian to latest Triassic (possibly into the Cretaceous) units have been attributed to syndepositional diapirism of the Paradox Formation.

Marine conditions existed in the basin throughout the Late Cretaceous Epoch during which clays, silts, and thin layers of sand now referred to as the Mancos Shale were deposited. The Mancos is exposed by the Moab airport and along Interstate 70 to near Cisco. At the end of the Cretaceous Period, uplift occurred over what is now termed the CPPP and the "Mancos sea" retreated.

There is little rock record for the interval from 67 million to about 5 million years ago in the Paradox Basin. Magma of trachytic and rhyolitic composition intruded the area that is now the La Sal Mountains about 25 million years ago. Regional uplift of the CPPP began about 10 million years ago and could partially explain the dearth of Tertiary sedimentary deposits.[4]

The Paradox Basin salt valleys, such as Moab-Spanish Valley, which formed by collapse of cover rocks above salt-cored anticlines, have conspicuous deposits of sediments and caprock that are predominantly Quaternary in age. These deposits suggest that the Moab Valley has been a local depocenter and site of dissolutioning during the Quaternary.

2.3.2.2 Quaternary Stratigraphy

The Atlas site is underlain by alluvium that apparently is greater than 400 feet thick, as suggested from a drillhole on site. The site is at the confluence of the Colorado River and Moab Wash. Therefore, alluvium from both fluvial systems might be present beneath the site. The local base level is the Colorado River bed and appears to be controlled by the elevation of the bedrock channel at The Portal. Thus, the accumulation of alluvium from either Moab Wash or the Colorado River at the site to depths below the elevation of The Portal suggests that the site and the vicinity of Moab Marsh could have been subjected to local subsidence on the order of hundreds of feet. The general maximum thickness of alluvium in Moab Valley is about 500 feet, shown schematically on UGS cross sections (Doelling et al., 1995).

To date the stratigraphic heterogeneities and geometry of the alluvial wedge beneath the site have not been defined by Atlas for purposes of assessing site response to future geologic events, such as seismicity. A fluvial history of the alluvium beneath the site has not been described sufficiently to be applied to estimate the potential future course of the Colorado River or Moab Wash across the site, to estimate subsidence rate, or to estimate a sedimentation rate for the site. The lack of sufficient information on Quaternary stratigraphy is related to open issues that are discussed in

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[4]Ross, M.L., "Geology of the Tertiary Intrusive Centers of the La Sal Mountains, Utah: Influence of Pre-existing Structural Features on Emplacement and Morphology," U.S. Geol. Surv. Bull., Friedman, J.D. and A.C. Huffman, coord., Laccolith complexes of southeastern Utah: time of emplacement and tectonic setting--workshop proceedings, in press.

Section 2.4.

Fluvial terrace deposits at various levels along the Colorado River and Moab-Spanish Valley represent ancestral higher base levels of the Colorado River and its tributaries. Tilting, angular unconformities and progressively younger ages of Pack Creek terraces toward the Colorado River are evidence of Quaternary subsidence of the Moab salt-cored anticline (Harden et al., 1985). However, as discussed in Section 2.4.1.3, appropriate amounts and rates of subsidence for design purposes, have not been identified. It has been suggested that the marshes across the Colorado River from the site represent a zone of contemporary subsidence (Harden et al., 1985). Atlas plans to investigate latest Quaternary rates of stream incision of Courthouse Wash in order to constrain maximum subsidence rates for Moab Valley northwest of the Colorado River.

Eolian sand deposits occur as dunes and discontinuous sheets in the Arches N.P. area near the site (Huntoon et al., 1982). They are derived from the numerous sandstones, especially the Jurassic Entrada Sandstone (Doelling et al., 1995, Description of Map Units). In the Moab area, sand is transported from the west and accumulates on the northeast-facing slopes and their base (Doelling, 1988). The slopes of Poison Spider Mesa are a prime zone of accumulation. Such deposits occur near the site and are active.

Landslide deposits, coherent rock masses that slip on shears that develop on oversteepened cliffs or on previously developed faults or joints, have been mapped in Moab Valley, including the cliff adjacent to the site (Huntoon et al., 1982; Doelling et al., 1995). They are often associated with the Morrison Formation (Doelling, 1988).

Talus deposits are accumulations of rock block, and debris falls on and at the base of steep slopes. Talus has been mapped adjacent to the site. Atlas has assessed the effects of rock falls and talus encroachment into the drainage system on the western side of the pile (Section 4.5.1.3.2).

Two volcanic events that might have affected the site have been preserved in Quaternary basins in Arches N.P. A volcano erupted near Bishop, CA, about 740,000 years ago. Ash from the eruption wafted to the area and scattered deposits are preserved. At about 620,000 years ago, ash from an eruption in the Yellowstone area was transported into Arches, and as much as 13 feet of compacted ash have been preserved (Oviatt, 1988).

2.3.3 Structural Setting

Complex geologic structures have been mapped in the site vicinity and beneath the site. The location and activity, if any, of the Moab fault system has been particularly controversial because of the absence of conclusive evidence for its existence beneath the site. Atlas appears to agree with the UGS interpretation (Doelling et al., 1995) that a splay of the Moab fault system underlies the site but appears to disagree with interpretations which suggest that the main Moab fault underlies the site (e.g., Baars and Doelling, 1987; Doelling, 1985, 1988; Huntoon et al., 1982). As discussed in Section 2.4, issues related to the Moab fault and to subsidence have not been adequately resolved. To date Atlas has performed a literature review of the Moab fault system. Atlas has agreed to investigate the Moab fault to gather primary data such as those described in FSRP Sections 1.3.2, 1.3.3 and 1.3.5 (NRC, 1993). Also, Atlas is conducting investigations to assess the potential for local subsidence due to salt dissolutioning or salt flow to occur in the next 1000 years. The staff has reviewed the literature and has developed the following summaries of relevant structural features, conditions, processes, and events which provide a basis for discussions of potential future structural events.

2.3.3.1 Structural Features

The Atlas site area contains evidence of previous seismotectonic, salt tectonic (gravitational tectonic), and igneous activity. On a regional seismotectonic scale, displacement along predominantly northwest-trending faults in the basement rocks created the Paradox sedimentary basin during a Late Paleozoic period of tectonism which thrust the Uncompahgre Plateau, Precambrian basement, 20,000 feet vertically and 30,000 feet horizontally.[4] There is also evidence for Late Mesozoic-Early Tertiary regional tectonism. Regional uplift of the Colorado Plateau commencing in the Miocene and continuing at present is also in evidence (Cater, 1970).

Evidence of normal faulting on northwest- to north northwest-trending pre-existing faults and fractures and strike-slip faulting on northwest- and northeast-trending shallow faults and fractures indicate that the current state of stress in the Colorado Plateau is generally northeast-southwest extension (Wong and Humphrey, 1989). Such conditions suggest that the Moab fault system, faults and fractures parallel to Moab Valley, and basement faults of northwesterly and northeasterly orientation beneath the site area, are favorably oriented for displacement and coseismic activity. However, there is great uncertainty about the likelihood of such events.

Tectonism is generally considered to have initiated the salt-wall diapirism of the Late Paleozoic through Jurassic which led to the formation of salt-cored anticlines with long northwest-trending master faults, such as the Moab fault. Some of the diapirs breached, or nearly breached, cover rocks. Other diapirs, like the Lisbon Valley salt-cored anticline, have a master fault(s) that penetrated cover rocks, e.g., the Lisbon Valley fault, but have not sufficiently deformed the cover rocks and dissolved or flowed laterally to the extent necessary to initiate collapse of the cover rocks (Cater, 1970).

Mid-Tertiary (about 25 million years old) igneous intrusions which comprise the La Sal Mountains are considered to be structurally controlled by northwest-trending and northeast-trending faults in the Precambrian basement.[4] In particular, the southern intrusive complex intruded the northwest basement fault that is projected to underlie Moab-Spanish Valley. Northeast-trending basement faults are considered to segment the basement into blocks. The Moab-Spanish Valley basement fault (NW) and the Castle Valley-Paradox Valley basement fault (NW) are possibly connected by a northeast-trending basement fault, south of Wilson Mesa[4] (Friedman et al., 1994). The trace of these faults separates deeper basement (7,000-14,000 feet below sea level) of the northeast portion of the Paradox Basin, from shallower basement, to the south and west. The intrusives occur in and near the fault-controlled, steep, basement-elevation-gradient.

A recent review of the geophysical and geological evidence for northeast-trending structures in the basement (Friedman et al., 1994), suggested that such features are faults thousands of feet beneath the Colorado River and beneath the middle La Sal Mountains, among other places. In addition, some authors have suggested that basement faults were involved in the alignment of the Colorado River and the La Sal Mountains intrusions[4] (Friedman et al., 1994; Hite, 1975). Further, it has been suggested that the Colorado River seismic zone might be a manifestation of movement of a basement fault segment beneath the river (Wong and Humphrey, 1989). Two northeasterly faults transect the Moab fault, the Roberts Rift (Hite, 1975) and the Kane Springs graben system (Friedman et al., 1994). The Roberts Rift is brecciated and mineralized and considered to be deep-seated, though its displacement is small. The Kane Springs graben is at the southeastern terminus of the Moab fault. The Lisbon Valley fault also terminates at the graben. Several faults parallel to the Lisbon Valley fault, near Lisbon, may have last moved in the Holocene (Woodward-Clyde, 1982b). Evidence suggests that a fault in the Kane Springs graben system moved in the Pleistocene (Friedman et al., 1994). Should the Kane Springs graben or the Lisbon Valley fault system have a structural connection to the Moab fault system, then that would constitute evidence for presuming that the Moab fault is a capable fault.

The Paradox Basin structures have been considered to be compatible with a wrench tectonic system, and it has been suggested that part of the Basin is a pull-apart structure (Stevinson and Baars, 1986).

2.3.3.2 Salt Tectonics - Diapirism and Subsidence

Atlas has postulated that lower rates of subsidence related to salt dissolution are occurring now than have occurred in the past (Woodward-Clyde, 1994, p. 10). The only basis provided to support this statement is that "...[subsidence or dissolution] rates have probably slowed down since the time of Pinedale glaciation (roughly 15,000 to 25,000 years ago) due to a drier climate" (ibid., p. 10). Also, Atlas has asserted that "...there is no evidence for late Quaternary subsidence north of the Colorado River in the vicinity of the tailings pile" (ibid., p. 10). However, more than 400 feet of alluvium, some of it probably late Quaternary, observed by Atlas in a borehole beneath the tailings, suggests that subsidence may have occurred enabling sediments to accumulate there.

The thick alluvium beneath the southeastern edge of the pile (Dames and Moore, 1982; Canonie,1994b), the suggestion by Woodward-Clyde (1982a, p. 3-16), and Harden et al. (1985) that Moab Marsh might represent a broad subsidence basin, the beheading of Little Valley (Allison, 1994), the salt tectonic model of Baars and Doelling (1987) and Doelling (1988) that includes salt dissolution and landsliding beneath the tailings, and other information [such as the "buried scarp" (Section 2.4.1.2)] have not yet been considered by Atlas in its evaluation of the subsidence potential for the site.

Moreover, numerous breccia pipe collapse features attributed to a dissolutioning-stoping mechanism have been identified in the Spanish Valley (Suguira and Kitcho, 1981; Weir et al., 1961). Such a breccia has been mapped about 5 miles from the site at Arches N.P. entrance (Doelling et al., 1995). Also, sinkhole-like collapse features have been reported in the Salt Valley-

Cache Valley and Castle Valley areas (Doelling, 1988; Mulvey, 1992). These may be analogs for Moab Valley. Although some of these features may be of Tertiary age and, as a result, of no consequence to the site, their occurrence, or potential future occurrence, beneath or near the site, has not been investigated or analyzed by Atlas.

The UGS considers that subsidence in the vicinity of the Atlas site is continuing but has no site-specific data on the rate. Based on observations of relatively rapid and episodic types of collapse features (e.g., sinkholes, breccia pipes, landslides, and faults), and of relatively slow types of subsidence features (e.g., folds, syndepositional thickening, unconformities and faults), the UGS considers that a range of rates of future subsidence is possible in the site vicinity (Allison, 1994).

Several estimates of long-term average rates of subsidence, incision of the Colorado River, and denudation for drainage domains in the Colorado Plateau, have been made. They all fall in the range 0.3 to 3.1 feet per 1000 years (Allison, 1994; Friedman et al., 1994; Woodward-Clyde, 1982a, p. 3-20 to 3-21). Such rates, determined from outside the Moab area, will be considered in deliberations of long-term stability of Moab Valley. These average rate estimates say little about the potential for rapid subsidence-collapse hazards. It remains for Atlas to fully evaluate and estimate the subsidence hazard from all reasonable sources. This is further discussed in Section 2.4.1.3.

2.3.3.3 Moab Fault System

The location and nature of the Moab fault, especially near the Atlas site, has been subject to several interpretations. For example, McKnight (1940) mapped the fault along the base of the northeastern valley wall, not underlying the present Atlas site. Williams (1964) mapped the fault along the lower slope of the Poison Spider Mesa escarpment, near the current location of the West Branch fault, but not underlying the site. Huntoon et al. (1982) mapped one splay of the Moab fault trending toward but terminating just beyond the site boundary and another fault skirting the pile along the base of Poison Spider Mesa escarpment. Doelling (1985, 1993; Allison, 1994) mapped the main Moab fault trace (queried) under the pile and the West Branch of the Moab fault dipping under the pile (indicating the possibility of two faults underlying the site). Doelling et al. (1995) have mapped three faults within the site boundary: (1) the main Moab (queried) is considered to have overlain the site (it has been removed by erosion); (2) the West Branch fault which dips under the site; and (3) an unnamed arcuate fault which intersects the projection of the other two faults (this is the "buried fault" introduced earlier that is not presently considered part of the Moab fault system).

Atlas has not completed its response to the staff's request for an assessment of whether or not the Moab fault is a capable fault (Canonie, 1994a). In particular, specific knowledge of the fault's characteristics and history are needed to address the criteria for the identification of a capable fault. Atlas asserted that because the Moab does not appear to offset Quaternary sediments, such as at Bartlett Wash, the fault is not a capable fault. That conclusion was not adequately supported by field and lab analyses. Furthermore, the fault could, by definition, be considered a capable fault if macroseismicity is associated with it, or if it is structurally related to a feature that is capable. In June 1995, the UGS issued a preliminary geologic map of the Moab area which suggests that the Moab fault is rooted in the Moab salt-cored anticline and is not structurally connected to the basement. Such a fault would not meet the definition of a capable fault (10 CFR Part 100, Appendix A), however, it could still represent a hazard that would need to be assessed because of its proximity to the site. Atlas is implementing a plan to fully address the capable fault issue. This is further discussed in Section 2.4.1.1.

2.3.3.4 Joint Patterns and Rock Fracturing

Recent studies of joint sets that are exposed in the rim synclines and plateaus around Moab Valley and Arches N.P. show that some sets are related to the reactivation of basement structures. However, regional joint sets have produced the dominant fracture fabric of the exposed rocks. These sets more definitively reflect the paleostress fields that produced them (Cruikshank and Aydin, 1995). It is clear to some that the regional fracture sets are discreet spatially and temporally and were not produced by propagation upward from the basement[5] (Cruikshank and Aydin, 1995). Concepts of rock fractures are relevant to analyses of groundwater flow, mass wasting of slopes, and identification of stress fields that may be favorable for rejuvenation of joints or development of faults. The reports mentioned above form a sufficient basis for consideration of the effects of joints on rock mass characteristics and groundwater flow.

2.3.3.5 Volcanism

Volcanic ash from volcanoes in the Western United States fell within 15 miles of the site, in Salt Valley (Arches N.P.), from at least two major volcanic eruptions about 740,000 (Bishop Tuff) and 620,000 (Lava Creek B) years ago (Oviatt, 1988). Also, ash beds thought to be correlative to those in Salt Valley have been described from Fisher Valley (Coleman, 1983). The volcanic sources of these Utah ash deposits are active today: Long Valley caldera, CA (Bishop); and Yellowstone N.P., ID/WY (Lava Creek B).

2.3.4 Geomorphic Setting

2.3.4.1 Topography and Geomorphic Features

The Moab, Utah 15' topographic quadrangle is dominated by the Colorado River (NE to SW), Moab-Spanish Valley (NW to SE), and plateaus dissected by washes. The Atlas tailings pile is nestled in the northwest terminus of Moab Valley between the Colorado River and the escarpments that define the valley. It sits at the confluence of Moab Wash and the Colorado River and is on the floodplain of the river. The Colorado River is rock-defended, has no

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[5] Verbeek, E.R. and M.A. Grout, "Relation Between Basement Structures and Fracture Systems in Cover Rocks, Northeastern and Southwestern Colorado Plateau," U.S. Geol. Surv. Bull., Friedman, J.D. and A.C. Huffman, coord., Laccolith complexes of southeastern Utah: time of emplacement and tectonic setting--workshop proc., in press.

appreciable flood plain, just prior to entering and leaving Moab Valley. Across the river from the pile lies the Moab Marsh or slough, the largest marsh on the river. The Moab Valley's southeastern end is about 15 miles from the Colorado River at Kane Springs. The valley is about 1.5 miles wide where the Colorado River transects it, and the relief at the pile is about 1100 feet. The valley walls are fault line scarps. Linear (actually planar) topographic features in the rim plateaus north and south of Moab intersect the valley walls. The linears on the plateau south of town trend E-W and represent an eroded joint set. Within a mile north of town, NW-trending linears intersect the valley at the river. These linears are faults. Trending northwest from the site through Moab Canyon is Moab Wash that heads at Little Canyon and appears to have captured Little Canyon Wash. Moab Canyon marks the Moab fault trace. The Moab fault trace runs northwest along the foot of the increasingly subdued scarp to near Courthouse Rock and beyond. Courthouse Wash, which drains much of Arches N.P., joins the Colorado near and upstream from the Atlas mill. Terraces occur near the mouth of Courthouse Wash and at various locations along Mill Creek and Pack Creek southeast of town in Spanish Valley.

2.3.4.2 Colorado River and Its Tributaries

The Colorado River channel in its Moab Valley reach is the local base level of Moab-Spanish Valley because the Colorado is rock-defended at The Portal. Therefore, the tributaries to the Colorado (such as Pack and Mill Creeks, flowing northwest, and Courthouse and Moab Washes, flowing southeast) have been, and are likely to remain, in confluence with the Colorado at the elevation of The Portal when at grade.

UGS has provided its perspective on the issue of migration of the Colorado River to the northwest, where the site is located (Allison, 1994). The following is a summary of the UGS discussion.

UGS has mapped the modern flood plain of the Colorado River in the Moab 7.5' quadrangle (Doelling et al., 1995). Stream terraces that mark the former course and elevation of the Colorado River and its tributaries are also mapped. Colorado River terrace gravels are present on the east side of Courthouse Wash about 40 feet above the modern river channel. Atlas plans to conduct stream profiling and soil studies in this reach to gain an understanding of incision rates or subsidence rates. This is further discussed in Section 2.4.1.3.

Gravels are present west of the tailings about 90 feet above the modern river channel. If these are remnants of a former position of the Colorado River, then the Colorado River probably occupied the Atlas site (in Pleistocene time).

UGS considers it possible that the tailings may be affected by channel migration of the Colorado River and erosion within the next 1000 years. The UGS also considers the current river bank deposits from Moab and Courthouse Washes to be sufficiently heterogeneous in grain size (even with cobbles present) and laterally discontinuous to not be a reliable deterrent to river-bank erosion.

Vegetation is also a factor when considering the stability of the river bank. Because most of the modern flood plain was inundated in the early 1980s, the UGS considers it likely that upper flood plain deposits are Holocene. There is no conclusive data available which would indicate that subsidence caused by dissolution of salt affected the migration of the Colorado River in Moab Valley.

2.3.4.3 Geomorphic Processes

Running water, gravitational, and eolian processes are active in the vicinity of the site and have had an effect on impoundment design. With regard to running water, discharge from Moab Wash has been controlled by diversion channels, and a channel of the Colorado River was partially diverted by emplacement of a rock sill. Additional considerations of running water are evaluated in Section 4.0.

With regard to gravitational processes, the approximately 1100 feet of relief on Poison Spider Mesa escarpment adjacent to the site and near-vertical-joint sets and faults, such as the West Branch of the Moab fault system, have promoted mass wasting of the scarp. Rates of scarp retreat estimated for rock types like those holding up Poison Spider Mesa (mainly Triassic and Jurassic sedimentary rocks), based upon long-term erosion of a variety of rock faces, is about 0.8 feet to 1.8 feet per 1000 years (Woodward-Clyde, 1982a, p. 3-21). Rock falls have been considered by Atlas and are discussed in Section 4.5.1.3.2. The landslide potential is further discussed in Section 2.4.2.2. Salt diapirism is a gravitational process but is considered under the heading of structural geology (Section 2.3.3.2).

Wind, aridity, the availability of sand-size particles and nooks, crannies, and rock bastions have combined to promote the deposition of sand dunes, sand ramps and sand sheets in the Moab area (Doelling et al., 1995). Observations indicate that the eolian process continues to be active in the area. Sand may migrate onto the tailings or into drainage channels. This is further discussed in Section 2.4.2.1.

2.3.5 Seismicity

The licensee provided information on the seismicity of the site and environs in the Safety Analysis Report (SAR) in 1975 (Atlas, 1975). The seismic design of the reclamation plan approved by NRC in 1982 relied on information contained in the SAR. However, since issuance of the SAR, considerable geological and seismological data have been obtained in and around the Atlas mill tailings site. As a result, the staff concluded that it was necessary to reassess the seismicity of the Atlas site.

In its review, the staff has evaluated tectonic provinces and the association between earthquake activity and faulting to determine the vibratory ground motion corresponding to the maximum credible earthquake as required in Criterion 4 of Appendix A to 10 CFR Part 40. In the SAR, the licensee had indicated that there are two potential sources that could generate the maximum credible earthquake at the site. The first is a random earthquake in the northern Colorado Plateau of Intensity V (magnitude 4.0) generating an acceleration of about 0.02g at the site. The other source would be near the

Wasatch Front which could generate a maximum magnitude earthquake of 7.4 that would produce an acceleration of 0.02g at the site. The licensee further stated that introducing a margin of conservatism, to account for amplification and a possible locally larger earthquake, the design acceleration will be taken as 0.05g.

In addressing the potential for capable faults to exist in the site area, the licensee indicated that a postulated northeast-trending feature coinciding with the trend of the Colorado River, if it exists, is probably of Precambrian or Paleozoic age. Also, the SAR states on page 2.4-30 that "There has been no seismic activity associated with this trend." This statement is not supported by recent observations (Wong and Humphrey, 1989) which indicates that a swarm of seismic activity north of the confluence of the Colorado River and the Green River is associated with this trend.

In response to requests for additional information regarding several topics, and in particular about the capability of the Moab fault and the maximum credible earthquake for the Colorado Plateau, the licensee provided additional seismic information in its May 31, 1994, submittal. In that response the licensee indicated that the impoundment could withstand an earthquake that produced a horizontal acceleration of 0.25g at the site (see Section 3.3 for further discussion of the seismic stability of the impoundment). However, the licensee's response did not adequately address the seismicity in the vicinity of the site. The licensee has proposed a work plan to obtain additional data to address the staff comments on issues related to geology, seismology, and subsidence. The results from these additional investigations have not yet been submitted to NRC.

Geological, seismological, and geophysical information which has been developed since issuance of the SAR includes geological mapping and reports from the Utah Geological Survey, and geophysical surveys at the site.

In addition, the NRC staff has engaged in consultations and discussions with University of Utah faculty.

The analyses of the data have resulted in an increased understanding of the surface and subsurface conditions of the site and its vicinity. The new data dictated that the staff reevaluate the maximum credible earthquake that could be generated in the area and the resulting ground acceleration at the site.

The Atlas site is located at approximately 38° 36′ 13″ N and 109° 35′ 25″ W in Utah. Utah is subdivided into three major physiographic and tectonic provinces: 1) the Basin and Range; 2) Middle Rocky Mountains; and 3) the Colorado Plateau (Wong and Humphrey, 1989). The Atlas site is located in the Paradox Basin in the interior of the Colorado Plateau. The plateau is generally considered to be relatively stable. The historic record of seismicity in the plateau is very short, and adequate seismic coverage of the area did not occur until 1970. In 1970, the University of Utah, Los Alamos National Laboratory, and the United States Geological Survey installed a regional seismic network which improved the detection of earthquakes to those above magnitude 2.0. The boundaries of the Colorado Plateau are in part adjacent to major zones of recurrent seismic activity. For example, along the western margin of the plateau, there is a significant source of seismicity along the Intermountain Belt (IMB). This belt exhibits a moderate to high level of seismicity of magnitude up to 7.5. This belt is 75-100 km wide and forms a tectonic transition zone between Colorado Plateau and Basin and Range Tectonic Provinces. The IMB boundary is about 200 km from the Atlas site, so the contribution of a large seismic event in the IMB at the site will be negligible.

The Atlas site is located in an area characterized by infrequent, low-level, small magnitude earthquakes. Prior to 1961, the locations of earthquakes were based on the "felt" area. From 1853 to July 1979, 22 seismic events with magnitude greater than 3.0 occurred within the Paradox Basin. From July 29, 1979, to November 1980, a network of stations was installed around the Colorado River south of Moab.

The objective of the network is to identify active earthquake sources within the Paradox Basin. During this period, about 500 seismic events with magnitudes greater than 1.0 were recorded in the Paradox Basin. On July 29, 1979, a micro-earthquake swarm was located along the Colorado River about 10 km northeast of its confluence with the Green River. During the 15-month period, about 200 seismic events were recorded along 35 km of the Colorado River between the confluence and Moab. The earthquakes show a north-northeast linear trend along the Colorado River which terminates at Moab. The depth of these earthquakes range from shallow to 50 km. Ninety five percent of the micro-earthquakes occurring in the Paradox Basin are confined to the Colorado River.

From July 1979 to June 1987, about 1100 earthquakes up to magnitude 3.3 were recorded within a 200 km radius of Moab. Examination of temporal behavior of the micro-earthquakes showed an apparent increased level of activity during period of brine extraction.

Based on aeromagnetic data, the loop part of the Colorado River appears to be underlain by a fault or fault zone within Precambrian basement that has previous left-lateral slip displacement (Case and Joesting, 1972). Hite (1975) proposed that several northeast-trending physiographic features in the region, including the Colorado River below Moab, may be structurally controlled by basement shear zones or strike slip faults. Fault plane solutions from some of these earthquakes north of the confluence of the Colorado and Green Rivers show strike-slip movements. Also, it was suggested that the tectonic stresses in the Colorado Plateau appear to be at critical levels and could provide sufficient strain energy accumulation necessary to generate earthquakes associated with zones of weakness parallel to the Colorado River. Wong et al. (1983) concluded, based on their observations of the seismic activity in the Paradox Basin, that the tectonic state of stress in the area is such that some structural features may be near failure.The largest earthquake recorded in the Colorado Plateau is a magnitude 6.5 event (McGuire et al., 1982).

The seismic events in the Plateau appear to be the result of activation of pre-existing faults favorably oriented to the stress field. Earthquakes in the Plateau occur in the upper 20 km of the crust.

2.3.6 Natural Resources

There are natural resources on and around the Atlas site. Also, underground storage of liquid natural gas in cavities in salt has occurred in Moab. Groundwater is a resource in the area (see Section 5.0). There is an oil field about 12 miles away, and a solution potash mining operation about 8 miles away. Production of those resources is associated with salt strata or salt structures similar to those associated with the salt-cored anticline which underlies Moab Valley and the site. Atlas has addressed the matter of past, present, and potential future potash mining and extraction of oil and gas beneath the site for the purpose of assessing future tailings stability. The following is a summary of the natural resources setting derived from Atlas' reports (Norman, 1995a, 1995b), among others.

2.3.6.1 Potash

Salt layers 5 and 9 in the Paradox Formation are the main targets for potash minerals. These layers have been sought in borehole data (cuttings, geophysical, and lithologic logs) and in seismic reflection surveys. One of the test holes investigated was the Embar-Big Six, about 400 feet south of the Atlas site. Norman (1995a) reports that the salt layers were very thin, and concluded that "...there is no possibility for potash or other valuable salt minerals to be present under the current Atlas Tailing pile" (ibid., p. 35; it should be noted that the opposite conclusion was reached for the Bartlett Wash alternate site). It is not clear from Norman's report (ibid., p. 40-41) how the 500-feet-thick salt layers with interbedded clastics (his thin potash-poor salt section) under the site relate to the approximately 7000-feet-thick Paradox Formation under the site (Doelling et al., 1995, cross section B-B').

No surface subsidence is observed at the nearby Cane Creek potash mine where solution mining is in current use (Morton, 1995; Allison, 1994). However, subsurface collapses in this mine have generated earthquakes of magnitude up to 3.1 (Wong and Humphrey, 1989).

2.3.6.2 Oil and Gas

The Paradox Basin has been producing oil for about 70 years. The main targets have been the Mississippian (Leadville) limestone and the Cane Creek shale. Both occur in the Moab area (Morgan et al., 1991; Morgan, 1992). Norman (1995b) reports thinned upper salt layers, absence of lower salt layers which contains oil shale targets, absence of Mississippian rock targets and only traces of oil, gas or brine in the Embar well near the site and concluded that "There is no possible commercial oil and gas potential at, or in the near vicinity of Atlas Corporation's Moab tailings pile" (ibid., p. 4; note that the opposite conclusion was suggested for the Bartlett Wash alternate site).

Oil and gas prospecting in the Moab area appears likely to continue. New techniques, such as horizontal drilling, have increased success in recovering oil from shale in the area. However, improved casing and plugging technology will lessen solutioning and subsidence around boreholes and better contain the high fluid pressures in the producing units. Surface subsidence over oil wells in Grand County has not been noted (Allison, 1994, p. 14).

2.3.6.3 Underground Storage Space

Underground storage of liquid natural gas was attempted in the salt-cored anticline beneath the town of Moab (Woodward-Clyde, 1982a, p. 8-5). The liquid was not fully recovered, possibly due to migration into other cavities. However, mining-for-space could be rejuvenated in the Moab area.

2.4 Geologic and Seismologic Stability

In order for Atlas' reclamation plan to provide reasonable assurance of control of radiological hazards for 200 to 1000 years, the design has to account for all significant geologic and seismologic conditions and processes that might affect the long-term stability of the pile (NRC, 1993).

2.4.1 Bedrock Stability

The following potential sources of bedrock instabilities beneath the site have been identified: main Moab fault, West Branch of Moab fault, buried scarp, bedrock surface topography, ground subsidence, and earthquakes. Other sources, such as potential faults similar to those exposed across Highway 191 that are attributed to tension across the crest of the Moab anticline, are not specifically under consideration because the effects of instability sources under consideration are likely to be bounding, for purposes of attaining reasonable assurance of an acceptable design.

2.4.1.1 Moab Fault System

If the Moab fault system is tectonically active and it contains one capable fault, then all structurally related faults (e.g., West Branch and main Moab faults) would be considered capable faults (Part 100, Appendix A). Capable faults are considered to be capable of generating earthquakes and, in the case of the Atlas site, could offset the tailings and radon and erosion protective barriers.

If the Moab fault or the West Branch fault is a capable fault, then the resulting estimated seismic load on the pile would be larger than expected from other likely sources (Section 2.4.3). Secondary effects of faulting of such a capable fault would possibly include liquefaction. If neither of these faults is a capable fault, then they would not be considered in the seismic hazard analysis. However, they might generate displacements if they were reactivated by salt tectonics (i.e., landslide slip surfaces).

Recent mapping in the Moab quadrangle by UGS has suggested that the Moab fault and the West Branch of the Moab fault are rooted in the Moab salt-cored anticline (Doelling et al., in 1995). If this is so, the Moab fault (and related faults of the Moab fault system, such as the West Branch fault) would not be considered to be a capable fault by definition in 10 CFR Part 100, Appendix A. Nevertheless, the Moab Fault could still be a hazard to the site that must be assessed.

UGS and USGS geologists consider that surface subsidence by creep or dissolutioning is continuing, but at a rate reduced since the Pleistocene, when climate conditions were wetter. Doelling (in Allison, 1994) considers that subsidence by salt creep or dissolutioning is concentrated on faults near the margins of the salt anticlines. He cites V-synclines along valley margins as evidence for this. The West Branch fault is favorably situated for this type of movement. However, Atlas has not addressed the likelihood that the tailings pile will be subject to subsidence during the next 1000 years.

Future subsidence under the Atlas tailings by salt creep or dissolutioning could be concentrated on faults which apparently are rooted in the Moab salt-cored anticline (the Moab fault and the West Branch of the Moab fault could be examples of such faults). Such slip could produce landslides of the large magnitude described in Baars and Doelling (1987). Thus, the staff concludes that the Moab fault (if it exists beneath the pile) and the West Branch of the Moab fault (considered to exist beneath the pile) are potential candidates for solution-related displacement during the next 1000 years. This concern is included in the discussion of subsidence in Section 2.4.1.3.

The information that has been provided by Atlas and which the staff has obtained from other sources has not enabled the staff to reach a conclusion about whether or not the Moab fault is a capable fault. Atlas has presented its analyses of borehole data, historical photographs, field observations, seismic reflection surveys and the UGS's map of the Moab 7.5′ quadrangle, and indicated that it will integrate the results in a future submittal. Therefore, the staff considers it to be an **OPEN ISSUE** as to whether or not the Moab fault is a capable fault. However, the staff's analysis in Section 2.4.3, of the seismic potential, is based on the assumption that the Moab fault is not a capable fault. This analysis would have to be revised if the Moab fault was found to be a capable fault.

2.4.1.2 Buried Scarp

The potential occurrence of an arcuate buried fault scarp beneath the southern edge of the tailings, parallel to the Colorado River channel, faulted down to the east, was recently developed by UGS (Doelling et al., 1995). The evidence for this feature's existence is based on Atlas borehole logs (e.g., Dames and Moore, 1982; Canonie, 1994b). The staff reviewed the evidence and considers that alternative concepts of a bedrock-surface drop-off are feasible, for example, a buried erosional escarpment, a buried stream channel or wash. The scarp, if it exists, is a consideration for pile design regardless of its origin. The distribution of thickness of alluvium beneath the pile varies fairly abruptly at and above the location of the scarp. Alluvium thickness distribution (geometry of the alluvial wedge above bedrock) is a factor in the consideration of attenuation of vibratory ground motion and in assessing differential subsidence.

If the feature is a fault scarp, its identification as a capable fault or not, and its relationship to the Moab fault system, would need to be assessed. The nature of faulting under the pile would be complicated if this feature were a fault. Such a fault would likely intersect either or both the Moab fault and the West Branch, pressing the need to know the relative ages of the faults. Also, if it is trending northeasterly, it would be parallel to the Colorado River seismic zone, which is currently seismogenic. If the scarp is erosional, it would suggest considerable aggradation of the Colorado River or substantial local subsidence in the same period. However, such an origin would preclude it from being a seismic source or the locus of fault displacement.

The information provided by UGS on the buried fault under the site is insufficient for the staff to reach a conclusion on whether or not the buried fault is a capable fault and whether or not it is a fault at all. Atlas is currently analyzing borehole data and seismic reflection surveys, but has not presented that information to the staff. Therefore, the staff considers the nature and consequences of the buried fault or scarp to be an **OPEN ISSUE**.

2.4.1.3 Subsidence

Regional and local aseismic subsidence by rapid collapse or by slow downwarping or tilting is a consideration at the Atlas site (Canonie, 1994a). However, the various effects of subsidence, their rates and magnitudes, have not yet been assessed by Atlas.

The sinkhole-like features mapped by UGS and related to rapid collapse in Castle Valley are attributed to salt dissolution (Mulvey, 1992). The features are not widespread in Castle Valley and have not been described from Moab-Spanish Valley or any other salt-cored anticlinal valley in Utah. Such a phenomenon, should it occur, would be a hazard to radon and erosion barriers. However, the likelihood of such a phenomenon occurring in Moab Valley, under the pile and breaching the radon and erosion barriers causing significant adverse effects, appears to be low.

If regional rates of incision, denudation and subsidence described in Section 2.3.3.2 are applicable to Moab Valley, then a rate of about 1-3 feet per 1000 years would be an appropriate design consideration. The applicability of such an indirectly estimated rate, its significance for pile design, and its attendant uncertainties (e.g., they are long-term averages and may be non-conservative values; rates in Moab Valley could be notably higher for some reason not yet recognized) would need to be addressed.

The information provided by Atlas and that obtained from other sources suggests that subsidence under the pile is likely to occur during the next 1000 years. However, the information is not specific to the Atlas site. The staff is presently unable to conclude what an appropriate design basis for subsidence should be. Atlas is currently analyzing borehole data, terrace profiling, field observations of soils on stream terraces, and is reassessing other critical data, but has not presented that information to the staff. Therefore, the staff considers the nature and rate of future subsidence at the site to be an **OPEN ISSUE**.

2.4.2 Geomorphic Stability

The Atlas site is vulnerable to geomorphic hazards because it is: at the confluence of two active watercourses, Moab Wash and the Colorado River; at the base of an actively retreating 1100-feet-relief escarpment; in a basin of accumulating sediments, including those of eolian origin and infrequent volcanic ash falls. Also, in this category of hazards, the staff has considered the potential for subsidence due to future nearby mining, and oil and gas extraction. Atlas provided adequate information regarding migration of the Colorado River, diversion of Moab Wash, rock falls, potash mining, and oil and gas extraction. These have been reviewed, and the attendant issues have been satisfactorily resolved as discussed below and in Sections 4.4.4, 4.4.5, and 4.5.1. Migrating sand dunes and landslides are open issues that are discussed below. The potential of volcanic ash hazard has been resolved without need for input from Atlas.

2.4.2.1 Migrating Sand Dunes

Sand dunes, sand ramps, and sand sheets exist near the site. Observations of several sand ramps, including one near the entrance to Arches N.P., indicate lack of soil and vegetation and presence of ripples which imply that they are active. In the next 1000 years it is considered likely by the staff that similar dunes, ramps, and sheets will be deposited on or near the site, potentially affecting the performance of the erosion barrier or drainage of the pile, pile slopes or drainage systems related to pile stability.

Preliminary consideration by the staff suggests that the rates and amounts of transient and trapped sand could affect the design of the slopes, barriers and drainage system. The information that the staff has obtained on the issue of sand migration onto the site during the next 1000 years is insufficient to reach a conclusion about the rate and quantities that would likely be involved. Atlas is currently analyzing the future potential for sand migration but has not presented that information to the staff. Therefore, the staff considers this to be an **OPEN ISSUE**.

2.4.2.2 Mass Wasting: Rock Falls and Landslides

The retreat of the Poison Spider Mesa escarpment above the site apparently occurs mainly by rock falls and landslides followed by transport by running water of the rocks and debris that fell or slid to the base of the escarpment. Such geomorphic landslides need to be distinguished at this site from salt tectonic landslides (Section 2.4.1.1). The specific concern about geomorphic landslides is that slip could occur on the West Branch fault, or on other shears or extensive joints exposed on the Poison Spider Mesa escarpment. Such a landslide was mapped there by Huntoon et al. (1982), but has not been corroborated by subsequent mapping (Doelling et al., 1995). Landslides above the tailings, in addition to rock falls, might interfere with drainage systems around the pile, or possibly encroach onto the erosion barrier itself (Section 4.5.1.3.2). Atlas is assessing the geomorphic landslide hazard.

Information provided by Atlas on the issue of rock falls that might encroach upon the drainage channels has been evaluated by the staff. The staff concluded that the mitigative design measures proposed to alleviate the effects of the rock fall hazard are adequate and consider this issue resolved (see Section 4.5.1.3.2). However, the staff has insufficient information on which to reach a conclusion about the hazard from landslides from the escarpment. Atlas is currently analyzing its field observations and other information regarding landslide potential emanating from the escarpment adjacent to the pile, but has not presented that information to the staff. Therefore, landslide hazard is an **OPEN ISSUE**.

2.4.2.3 Volcanic Ash Fall

The Quaternary sources of volcanic ash that accumulated in Arches N.P., and possibly in Fisher Valley, are still active and could present potential volcanic ash hazards to the site. The potential that conditions at a volcanic source (e.g., large volume of ash having ascended to great height) and in the troposphere (e.g., sustained winds directed at Moab) would combine to produce significant ash fall onto the pile or into its drainage system is estimated to be low. Based on the geologic record, ash fall in this area has a low probability of recurrence (approximately twice in 740,000 years). The staff considers the likelihood of the volcanic ash hazard to be too low to be a significant concern at the Atlas site.

2.4.2.4 Potash Mining

The potential for potash exploration and solution mining and potential effects of related technologies on the tailings have been discussed by Atlas (Norman, 1995a). The report provided direct and indirect evidence that the presence of economic deposits of potash and related minerals beneath the site is unlikely. Furthermore, title to the reclaimed site will revert to DOE or the State of Utah (Section 83 of Atomic Energy Act). This title transfer provides NRC with the authority to disallow mineral mining rights or other uses of the subsurface. Therefore, should natural resources be discovered beneath or near the pile site in the future, the integrity of the pile foundation could be protected from any adverse impact of a mining operation by withdrawal or non-issuance of the surface mineral mining rights. The staff considers that potential future mining at or near the site need not be a design basis.

2.4.2.5 Oil and Gas

The potential for oil and gas exploration and extraction and potential effects of related technologies on the tailings have been discussed by Atlas (Norman, 1995b). This issue has a similar resolution as the potash mining issue discussed above (Section 2.4.2.4). Basically, there is little reason to consider direct intrusion into the pile, or subsidence at the pile from nearby extraction or dissolution of salt around boreholes, or that the future landowner (DOE or the State of Utah) would permit exploration or extraction. The staff considers that potential oil or gas exploration and extraction at or near the site need not be a design basis.

2.4.3 Seismotectonic Stability

As a result of NRC staff review and evaluation of the geologic and seismologic information, and discussions with individuals at the state, Federal, and private levels knowledgeable of the region, the staff has determined that the licensee has not adequately addressed the seismic issue nor identified the maximum credible earthquake that could occur at the site.

In order to identify the seismic design for the site, Criterion 4 of Appendix A to Part 40 requires consideration of the maximum credible earthquake as defined in Appendix A to Part 100. Criterion 6 of Appendix A to Part 40 requires that the disposal cell be designed to remain stable for 1000 years to the extent reasonably achievable but in any case for at least 200 years. The maximum credible earthquake will provide a design basis seismic event that also meets the Criterion 6 requirement.

The staff evaluated the seismicity of the area around the Atlas site and found that the earthquake of November 7, 1882 (McGuire et al., 1982), magnitude 6.5, in the northwest corner of Colorado is the largest floating earthquake within 200 km of the Atlas site. Based on McGuire et al. (1982) this earthquake could have occurred in the Colorado Plateau, in which case it would be relevant to the Atlas site. The licensee did not address this earthquake and did not identify the maximum random floating earthquake for the seismic design basis of the facility.

The other potentially significant seismic source of earthquakes is the northeast-trending feature along the Colorado River north of the confluence with the Green River. Wong and Humphrey (1989) located several seismic events in this area along the Colorado River. The focal depths of these earthquakes range from shallow up to about approximately 50 km. Considering that these earthquakes may be associated with basement faulting, the licensee should estimate the maximum earthquake that could be generated from this fault system.

In an independent study sponsored by NRC, Bernreuter et al. (1995) performed a simplified seismic hazard analysis for all Title II reclamation plans. The Atlas site was one of those examined. Bernreuter et al. (1995) reviewed published and unpublished data, and discussed several issues dealing with seismic hazards at Atlas with several organizations. Bernreuter et al. (1995) concluded that: 1) The Moab fault is a surficial expression of underlying salt solution and is a subsidence feature rather than a tectonic feature; and 2) The seismicity along the Colorado River suggests that a basement fault exists under the river that could generate an earthquake of magnitude ranging from 5.5 to 7.0. Bernreuter et al., estimated the peak ground acceleration at the Atlas site from such fault to range from 0.2g to 0.4g. Bernreuter, et al., used the Joyner and Boore (1982) attenuation model to estimate the acceleration at the site.

Geologic and seismologic information and investigations presented by the licensee as required by Part 40, Appendix A, did not provide sufficient information on the interrelation between seismicity and the basement fault north of the confluence of the Colorado and Green Rivers, nor address thoroughly the capability of the Moab fault. For example, the licensee did not identify or present the maximum earthquakes that could be generated from these faults. Also, the licensee did not discuss in its submittal, the maximum random floating earthquake in the Colorado Plateau.

Therefore, the staff considers the licensee's submittal to be incomplete and the seismic design basis for the Atlas site to be an **OPEN ISSUE**.

2.5 Conclusions

2.5.1 Bedrock Stability Conclusions

The staff can not conclude that bedrock stability has been adequately addressed in the proposed design to meet the requirements in Appendix A of

Part 40 until the following open issues are resolved:

1. CAPABLE FAULT. The issue of whether or not the Moab fault and the West Branch fault are capable faults.

2. BURIED SCARP. The issue of whether or not the buried scarp is a capable fault, an aseismic fault or an erosional feature.

3. SUBSIDENCE. The issue of what rate the pile is expected to subside during the next 1000 years, what cumulative amount, and how it will happen (e.g., on faults, by collapse, uniform settling).

2.5.2 Geomorphic Stability Conclusions

Based on its review, the staff concludes that Atlas provided adequate information regarding migration of the Colorado River, the diversion of Moab Wash, and potential rock falls to appropriately consider these potential hazards in the tailings impoundment design. The staff concludes that the likelihood of volcanic ash falls are too low to be considered in the design. The staff also concludes that the potential for potash mining and oil exploration and extraction to occur are sufficiently low that they do not present a design basis concern. However, the staff can not conclude that geomorphic stability has been adequately addressed in the proposed design to meet the requirements in Appendix A of Part 40 until the following open issues are resolved:

1. MIGRATING SAND DUNES. The issue of whether or not, or in what way, migrating sand dunes might adversely affect the tailings during the next 1000 years.

2. LANDSLIDES. For landslides that might emanate from Poison Spider Mesa escarpment, the issue of whether or not a potential landslide hazard exists, and to what extent landslides might disrupt the stability of the pile during the next 1000 years.

2.5.3 Seismotectonic Stability Conclusions

The staff concludes that the licensee has not provided sufficient information to evaluate the seismic design basis for the Atlas site and considers this to be an open issue.

3.0 GEOTECHNICAL STABILITY

3.1 Introduction

This section presents the results of the NRC staff review of the geotechnical engineering aspects of the closure action proposed at Atlas' Moab, Utah, mill site. The closure action consists of the consolidation of all contaminated materials from the processing site to the adjacent tailings pile near Moab, Utah. The final disposal cell will be an above-grade stabilized-in-place embankment extending to a maximum height of 110 feet above the prevailing surface grade. Contaminated material and mill debris will be added to the disposal cell. The cell will be recontoured as shown in Drawing No. 88-067-A112 (Canonie, 1995), and will be covered with a 7-foot-thick minimum sand cover, plus filter layer and rock armor on the embankment; a 39-inch-thick multiple layer cover plus rock armor over coarse tailings; and a 37-inch-thick multiple layer cover plus rock armor over at least seven feet of regraded coarse tailings over the fine tailings portions of the embankment.

The geotechnical engineering aspects reviewed include: (1) information related to the disposal and borrow sites; (2) materials associated with the closure action, including the foundation and excavation materials, tailings, and other contaminated materials; and (3) design and construction details related to the disposal site, disposal cell, and its cover. The staff evaluation of related topics such as geology, geomorphology, and seismic characterization, are presented in Section 2.

3.2 Site and Material Characterization

3.2.1 Site Description

The 130-acre impoundment (Figure 1-1) is adjacent to the former Atlas mill, about 3 miles northwest of the town of Moab, Utah. The site is located within the Moab Valley, and is drained by Moab Wash (an ephemeral channel) and the Colorado River. The uranium mill tailings were placed in a single pile consisting of approximately 10.5 million tons. The 130-acre pile forms a deposit with a maximum height of 110 feet. The Atlas Corporation has covered the sides of the pile with an interim soil cover of variable thickness. As the water in the pond atop the tailings has evaporated, additional interim cover has been placed on portions of the top of the pile, working from the edges inward toward the center.

The former mill area is 200 acres in size and contains building foundations and abandoned mill structures which have been partially demolished. Additional contaminated soil lies outside the confines of the tailings pile. The contaminated soil and building rubble generated from the mill demolition will be added to the disposal cell.

3.2.2 Geotechnical Investigations

3.2.2.1 Disposal Cell Area

Several subsurface investigations have been performed at the Atlas processing site in order to characterize the tailings and contaminated materials for geotechnical engineering and radiological aspects of the closure. The licensee submitted a report, dated May 29, 1981, by Dames & Moore (1981) that contained drawings illustrating the original test boring and test pit locations. Logs of soil and test pits were provided in the licensee's earlier submittals (Dames & Moore, 1977; and Dames & Moore, 1979). Additional test pits were excavated in August 1988, and January 1992, within the confines of the mill and the tailings embankment. Test pit logs of these borings were initially reported in Appendix A of the licensee's June 4, 1992, submittal (Canonie, 1992) and modified in a later submittal (Canonie, 1993).

Exploration to depth within the tailings embankment was not previously performed since an active evaporation pond provided an obstacle to drill rig access. To further characterize the tailings, and to evaluate the embankment with respect to stability and potential settlement, the licensee has agreed to perform piezocone tests during construction. The piezocone, or Cone Penetration Test (CPT), is an instrument which measures the piezometric pressure at a cone tip as the device penetrates a material. CPT pore pressures, thus measured, reflect both the soil type and the stress history of the material. CPT test data will be considered along with settlement records to better evaluate the time-rate of tailings consolidation.

3.2.2.2 Borrow Areas

The licensee submitted an evaluation of the proposed radon barrier clay soils to be obtained from the Klondike Flats area. The evaluation was documented in a report prepared by Canonie Environmental Services Corp. (Canonie, 19??). The Klondike Flats borrow area is located about 13.8 miles north of the tailings pile.

Sandy soil for the radon barrier will be obtained from material excavated during the reconfiguration of Moab Wash (see Section 4). In 1988 and 1992, 15 exploratory test pits were excavated in the Moab Wash area.

Finally, in addition to the sampling associated with the reconfiguration of Moab Wash, the licensee analyzed three additional samples taken from the proposed borrow area located west of the tailings cell on the Atlas property.

3.2.2.3 Geotechnical Investigation Conclusions

The NRC staff has reviewed the subsurface exploration discussed above. The staff concludes that, with the exception of tailings characterization, the geotechnical investigations conducted at the processing, disposal, and borrow sites satisfactorily establish the stratigraphy, that the explorations are in general conformance with applicable provisions of Chapter 2 of the SRP (NRC, 1993), and that they are adequate to support the assessment of the geotechnical stability of the stabilized tailings and contaminated material in the disposal cell. In order to complete the characterization of the tailings and the settlement analysis, the licensee needs to submit additional piezocone information. Prior to approval of the settlement evaluation, the licensee should submit a field exploration plan for the piezocone exploration program. This is an **OPEN ISSUE**.

3.2.3 Testing Program

Geotechnical engineering characteristics and strength parameters for the tailings, contaminated soil, and natural soils have been determined by the licensee through laboratory analysis of samples from these investigations. Early laboratory testing by Dames & Moore, and later testing by Canonie Environmental, included moisture-density (Proctor) determinations, gradation analyses, specific gravity, saturated hydraulic conductivity determinations, Atterberg Limits, capillary moisture, one-dimensional consolidation, static triaxial, and cyclic triaxial compression. The staff has reviewed the geotechnical engineering testing program for the Atlas site and concludes that the tests identified above were conducted on representative materials.

The licensee's laboratory testing of the Klondike Flats borrow material included gradation, Atterberg Limits, moisture-density determination, specific gravity, saturated hydraulic conductivity, capillary moisture relationships, dispersive tendencies, diffusion coefficient, and triaxial shear strength. The licensee states that additional tests will be made on the borrow soils during construction to confirm conformance with the project specifications. The construction specifications must be revised accordingly.

Within the Moab Wash area, one composite sample was made from the "affected" (contaminated) sandy soils. A second sample was made from "clean" soils (see Section 6.2.1 for additional information). The composite samples were then split into three subsamples, and were redivided for geotechnical and radiological sampling. Laboratory testing by the licensee included gradation, Atterberg Limits, moisture-density relationships, specific gravity, diffusion coefficient, and (for the "affected" soils) radium activity and emanation coefficient determination. Three composite samples from west of the tailings pile area were tested for gradation, Atterberg Limits, moisture-density relationships, specific gravity, diffusion coefficient, and capillary moisture relationship.

Proposed cover materials were evaluated for durability. Testing included Los Angeles Abrasion, sulfate soundness, absorption, specific gravity, Schmidt Hammer, and Brazilian disk tensile tests. Petrographic analyses were also conducted. Further discussion regarding the tests on proposed cover materials is presented in Section 4.

On the basis of the field exploration and laboratory testing programs, the licensee concluded that the proposed borrow sites contain suitable quantities of material acceptable for the proposed radon barrier. Testing indicated the soils are non-dispersive.

Based on the review, NRC staff finds that the number and type of tests conducted in the testing program were appropriate for the support of the engineering analyses performed and that the scope of the testing program and the utilization of the test results to define the material properties are in general agreement with the applicable provisions of the SRP (NRC, 1993).

3.3 Geotechnical Engineering Evaluation

3.3.1 Slope Stability

The evaluation of the geotechnical stability of the slopes of the disposal cell containing stabilized tailings and other contaminated materials is presented in this section. The staff has reviewed the exploration data, test results, slope characteristics, and methods of analyses pertinent to the slope stability aspects of the reclamation plan. The analyzed cross-sections with 10 horizontal to 3 vertical side slopes have been compared with the exploratory records and design details. The staff finds that the characteristics of the slopes have been satisfactorily represented and that the most critical slope sections have been considered for stability analyses.

Soil parameters for the various materials in the disposal cell slope have been adequately established by appropriate testing of representative materials. Soil parameter values have been assigned to other layers (riprap, gravel bedding, bedrock, etc.) by the licensee, on the basis of data obtained from geotechnical explorations at the site and data published in the literature. The staff finds that the determinations of these parameters for slope stability evaluation follow conventional geotechnical engineering practice, and are also in compliance with the applicable provisions of Chapter 2 of the SRP (NRC, 1993). The staff also finds that an appropriate method of stability analysis (Simplified Bishop method) has been employed by the licensee to address the likely extreme adverse conditions to which the slope might be subjected for the static case.

Factors of safety against failure of the slope for static and seismic loading conditions have been determined by the licensee for both short-term (end of construction) and long-term states. Factors of safety for the static loading conditions were calculated by the licensee to be 1.6 (short- and long-term) which are in excess of minimum required values of 1.3 and 1.5, respectively.

The seismic stability of the slope was investigated by the licensee using the pseudo-static method of analysis, with horizontal seismic coefficients of 0.21g for both the end-of-construction case and for the long-term case. The values of the seismic coefficients were selected by considering the design ground acceleration value used for the nearby Green River Title I site. In actuality, a horizontal seismic coefficient equal to 0.67 times the maximum ground acceleration, or 0.14g, would be used in a pseudo-static evaluation.

In addition, slope stability was evaluated by the Licensee using the pseudo-static method and a horizontal seismic coefficient of 0.25g. The use of a horizontal seismic coefficient of 0.25g would imply a maximum ground acceleration of about 0.38g; however, the pseudo-static method of analysis is inappropriate for that high an acceleration. If the stability design based on a Peak Ground Acceleration (PGA) value in excess of 0.3g is necessary (see Section 2.4.3), then the pseudo-static analysis is invalid for this case, and a deformation analysis would be required.

Based on review of these analyses and the results, the staff cannot conclude that the slopes of the disposal cell are designed to endure the effects of the geologic processes and events, including resistance to earthquake and settlement, to which they may reasonably be subjected during the design life and that the analyses have been made in a manner consistent with Chapter 2 of the SRP (NRC, 1993). This is an **OPEN ISSUE**. The licensee has indicated that it is in the process of conducting a deformation analysis. Staff approval of this aspect of design will depend on a satisfactory review of the deformation analysis work now in progress.

3.3.2 Settlement and Cover Cracking

Long-term settlement of materials in the disposal cell, which could result in either local depressions or cracks on top of the cover, was addressed by the licensee in Canonie Environmental's report of June 4, 1992. A proposed settlement monitoring program was provided. Settlement monuments will be installed directly on the tailings prior to the initiation of regrading activities. Construction equipment will be required to maintain a minimum distance of 5 feet from all monuments.

The monuments will be surveyed for vertical displacement on a daily basis for the first 2 weeks of initial fill placement, weekly for the following 2 months, and then monthly for the final 2 months. When the licensee has concluded that 90 percent of the consolidation settlement is complete, and with NRC's concurrence, final soil cover placement operations can begin.

Settlement monuments will be located in areas where consolidation is expected to be the greatest, including areas believed to have maximum thicknesses of fine tailings. Such an arrangement should assure that differential settlement will not adversely affect the integrity of the cover. Additionally, the final soil cover will be spread and compacted in a uniform manner to minimize the effects of settlement due to the weight of the final soil cover materials. The licensee concluded that 90 percent of the primary consolidation should take 1 to 2 years, based on the fact that there has been no disposal of tailings since 1984 and that the pumping program conducted at the site has accelerated the dewatering process.

In addition, the licensee will conduct an exploration program within the embankment using piezocones. The piezocone data will be evaluated along with settlement records to confirm the conclusion that 90 percent of the expected settlement has occurred. The piezocone test results can also be used to assess the potential for cover cracking. Subject to confirmation testing in the piezocone exploration stage, the proposed settlement monitoring program is considered sufficient to satisfy applicable portions of Criteria 1, 6, and 12, of Part 40, Appendix A, regarding reclamation design to control radiological hazards for the design life without active maintenance after reclamation is complete.

3.3.3 Liquefaction Potential

The liquefaction potential for the Atlas site was initially evaluated by Dames & Moore, as reported in their correspondence dated February 16, 1979. Dames & Moore evaluated the liquefaction potential based on empirical techniques and on the basis of a laboratory evaluation. Minimum factors of safety of 1.69 (empirical) and 1.90 (laboratory) were derived in the Dames & Moore study. Based on the similarity in results, and considering minimum acceptable safety factors of 1.5, Dames & Moore concluded that no major problem related to liquefaction would occur during the postulated seismic event, which they considered to be a Magnitude 6 event with a hypocentral distance of approximately 50 km and a maximum ground acceleration of 0.08g.

Our understanding of the seismic hazard and liquefaction process has improved since 1979. Based on more recent interpretations of potential seismic events, and in accordance with a November 4, 1994, request from the NRC, the licensee is currently reevaluating the liquefaction potential for the site. The licensee stated on January 24, 1995, that liquefaction would be re-evaluated using existing blowcounts, gradation, and sample descriptions from previous analyses with updated empirical relationships for liquefaction potential. The induced stresses will be estimated from simplified procedures and/or from one- or two-dimensional response analyses. If required, the computer programs SHAKE or FLUSH will be used. The staff's liquefaction analysis review has been suspended until the licensee's reevaluation is complete and the results are made available. Thus, staff cannot conclude that there is adequate assurance of safety with respect to liquefaction damage. This is an **OPEN ISSUE**.

3.3.4 Cover Design

The licensee has proposed three different embankment cover sections, depending on location:

1) The proposed final cover profile for the embankment will consist of 7 feet (minimum) of sandy soil above the regraded coarse tailings. The sandy soil will be capped by a filter layer and rock armor of variable thickness.

2) The proposed cover profile over coarse tailings will consist of:

   6 inches (minimum) of low-grade ore from the mill area,
   16 inches (minimum) of affected soil,
   8 inches (minimum) of compacted clay,
   9 inches of sandy soil

   The coarse tailings areas will be covered with rock armor of variable thickness.

3) The proposed cover profile over fine tailings will include:

   7 feet (minimum) of regraded coarse tailings,
   16 inches (minimum) of affected soil,
   12 inches (minimum) of compacted clay,
   9 inches (minimum) of sandy soil

   A rock armor of variable thickness will cover the sandy soil.

The cover system described above will provide a minimum of 37 inches of cover above tailings on the top and sides of the cell. The system has been designed to limit the infiltration of precipitation, protect the pile from erosion, and to control the release of radon from the tailings below. Details of the staff's review of the cover's performance related to limiting infiltration are addressed in Section 5 of this report; the review of the cover's erosion protection features is presented in Section 4, and the review of the radon attenuation aspects of the cover is presented in Section 6. Certain other design aspects of the proposed cover are discussed herein.

Tests on the compacted clay from Klondike Flats indicate that hydraulic conductivities will be near 10^{-7} cm/sec at placement conditions. In addition, the physical shape and surface grading of the reclaimed tailings embankment will effectively remove surface water resulting from precipitation which falls on the area. The relatively low permeability of the cover materials and the low annual rainfall with high evaporation rate will serve to prevent significant tailings recharge.

The licensee has evaluated the potential for frost penetration using the BERGGREN.BAS computer code developed at the U.S. Army Corps of Engineers (COE, 1968). The code has been used on several other uranium mill tailings remediation projects. In order to evaluate the potential for frost penetration, temperature data including the freezing index, mean annual air temperature, length of freezing season, and geotechnical parameters are considered. The model calculates the heat capacity, thermal conductivity, and latent heat of fusion for the soil layers unless these data are entered manually.

Values used in the computer analysis included the mean and worst-case situations based on 31 years of weather records. In the worst-case scenario, the licensee determined that the depth of frost penetration would be 10.2 inches. By thickening the sand layer to 9 inches, and in conjunction with the exterior rock armor, the potential for frost penetration into the clay layer is eliminated, and the cover integrity should not be substantially affected.

The staff has reviewed the input data used in determining the total frost penetration depth and concludes that these values are a reasonable representation of the extreme site conditions to be expected. Therefore, the licensee's evaluation of the frost penetration depth is acceptable to the staff.

The cover design has been evaluated by the staff for geotechnical long-term stability and the design is acceptable; however, it is required that the licensee perform materials testing during construction and revise the cover design if needed. The radon attenuation ability of the cover is discussed in Section 6 and the hydraulic conductivity aspects of the cover in Section 5.

3.4 Geotechnical Construction Details

3.4.1 Construction Methods and Features

The staff has reviewed and evaluated the geotechnical construction criteria provided in the Reclamation Plan. Based on this review, the staff concludes that, with the exception noted in the following paragraphs, the plans and drawings clearly convey the proposed closure action design features. In addition, the excavation and placement methods and specifications are consistent with accepted standard practice.

The quality control program should ensure that adequate measures are taken during construction to prevent excessive drying of the clay and should include sufficient documentation to confirm the moisture content of the placed clay material. To address the concern for drying of the clay during construction, Atlas agreed (March 1995) to cover each lift of clay within seven days of placement, or else to moisture-condition and retest prior to covering. Atlas also committed to provide a summary sheet of quality control testing of all components of the radon barrier during construction. In addition, Atlas stated that the construction specifications will be revised to indicate that the clay is required to have an average in-place moisture content greater than 17 percent.

Staff considers that the Atlas-proposed seven day limit before placing another layer over the clay may be too long, depending on the weather and the clay placement moisture. Therefore, when successive lifts of fill are placed with interruption sufficient to cause drying, field tests must be performed to confirm that moisture contents have not been adversely affected prior to resuming placement. If excessive drying is noted, the surface must be scarified, moisture-conditioned, and recompacted.

Final resolution of the issue requires that Atlas provide detailed construction specifications or a quality assurance program incorporating criteria (temperature, time interval, placement moisture) for field testing the moisture content of the radon barrier soils between lift placement. Alternatively, Atlas can designate a conservative 2-day limit on lift placement interruption without testing the moisture content. This is an **OPEN ISSUE**.

3.4.2 Testing and Inspection

The staff has reviewed and evaluated the testing and inspection quality control requirements provided in the Technical Specifications (Canonie, 1992) in the Reclamation Plan. Although the plan is found to provide a program for testing and inspection that is generally consistent with the Staff Technical Position on Testing and Inspection (NRC, 1989), certain aspects are deficient. Portions of the technical specifications have been superseded by later submittals, such as the revised cover design; however, the specifications have not been updated to reflect these revisions. The technical specifications need to be consistent with the reclamation design. This is an **OPEN ISSUE**.

Section 4 of the technical specifications permits the placement of fill in 18-inch-thick lifts; however, such lift thicknesses make uniform compaction difficult to achieve. For this reason, the licensee should either specify more workable lift thicknesses or describe applicable procedures for verifying that thorough compaction has been achieved. This is an **OPEN ISSUE**.

3.5 Conclusions

Based on the review of the geotechnical engineering aspects of the design of the Atlas closure action as presented in the Reclamation Plan, the staff concludes that the embankment and proposed borrow soils have been adequately characterized, with the exception of confirming settlement potential within the embankment. Furthermore, the cover system appears to be adequately designed to resist the effects of freezing conditions which can reasonably be expected. However, the staff can not conclude that the geotechnical engineering aspects of the proposed design meet the requirements in Appendix A of Part 40 until the following open items are resolved:

1. In order to complete the characterization of the tailings and the settlement analysis, the licensee needs to submit additional piezocone information. Prior to approval of the settlement evaluation, the licensee should submit a field exploration plan for the piezocone exploration program.

2. The staff cannot conclude that the slopes of the disposal cell are designed to endure the effects of the geologic processes and events, including resistance to earthquake and settlement, to which they may reasonably be subjected during the design life and that the analyses have been made in a manner consistent with Chapter 2 of the SRP (NRC, 1993).

3. The licensee is currently reevaluating the liquefaction potential for the site. The staff's liquefaction analysis review has been suspended until the licensee's reevaluation is complete and the results are made available. Thus, the staff cannot conclude that there is adequate assurance of safety with respect to liquefaction damage.

4. The licensee should provide adequate, detailed construction specifications (or a quality assurance program) for field testing the moisture content of the radon barrier soils when lift placement is interrupted.

5. Portions of the technical specifications have been superseded by later submittals, such as the revised cover design; however, the specifications have not been updated to reflect these revisions. The technical specifications need to be consistent with the reclamation design.

6. The specifications permit the placement of fill in 18-inch-thick lifts; however, such lift thicknesses make uniform compaction difficult to achieve. The licensee should either specify more workable lift thicknesses or describe applicable procedures for verifying that thorough compaction has been achieved.

4.0 SURFACE WATER HYDROLOGY AND EROSION PROTECTION

4.1 Introduction

This section of the TER describes the staff's review of surface water hydrology and erosion protection issues related to long-term stability. In this section, the staff provides the technical bases for the acceptability of the licensee's reclamation design. Review areas that are covered include: estimates of flood magnitudes; water surface elevations and velocities; sizing of riprap to be used for erosion protection; long-term durability of the erosion protection; and testing and inspection procedures to be implemented during construction.

4.2 Hydrologic Description and Site Conceptual Design

The Atlas tailings disposal area is located on a river terrace approximately 500 to 700 feet from the Colorado River and approximately 3 miles north of the town of Moab, Utah. Moab Wash, an ephemeral stream with a drainage area of about 5 square miles, is located along the north and east sides of the tailings impoundment. The site is surrounded by the near-vertical sandstone cliffs of the Moab Valley.

To comply with Criterion 6 of 10 CFR 40, Appendix A, which requires stability of the tailings for 1000 years to the extent reasonably achievable and in any case for 200 years, the licensee proposes to reclaim the tailings impoundment in place and to protect the tailings from flooding and erosion. The design basis events for design of erosion protection include the Probable Maximum Precipitation (PMP) and the Probable Maximum Flood (PMF) events, both of which are considered to have very low probabilities of occurring during the 1000-year stabilization period.

As shown in Figure 4-1, the top surface of the tailings impoundment will be reconfigured to drain toward three collection ditches, and the embankment side slopes will be flattened to 10H:3V except at the southwest corner where the slopes will be 10H:1V. The three collection ditches on the top surface will merge to form the Upper Impoundment Drainage Channel. This channel will convey flood runoff into the Lower Impoundment Drainage Channel, which will then discharge into Moab Wash. Moab Wash will be reconfigured to convey flood flows into the Colorado River east of the tailings pile. The Southwest Runoff Drainage Channel will divert runoff from the side slopes on the southwest side of the reclaimed impoundment and from the sandstone bluffs southwest of the channel.

To protect against erosion, the top and side slopes of the tailings impoundment will be covered with layers of rock riprap. At the toes of the side slopes, a riprap apron/toe will be constructed to provide protection against the potential migration of Moab Wash and the Colorado River. The collection ditches and drainage channels will also be protected with riprap.

For Moab Wash, the licensee proposes to excavate a new channel as far away from tailings as possible. The reconfigured channel will flow eastward across

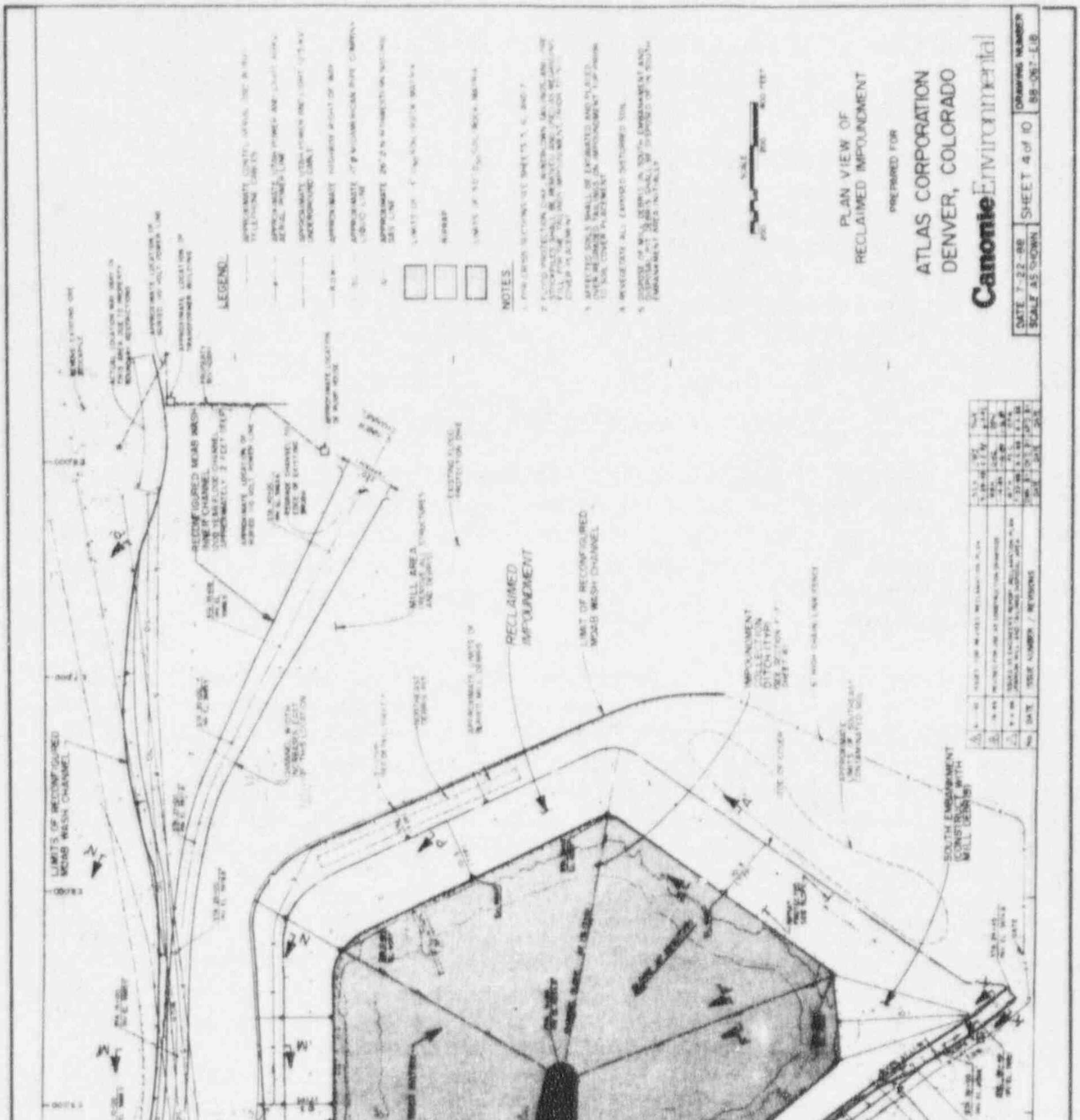

Figure 4-1: Atlas erosion control features

the floodplain and into the Colorado River upstream of the site. The design will provide a shallow trapezoidal channel designed for the PMF. At approximately the center of the main channel, a low-flow channel will be constructed to convey flows up to the 200-year flood.

4.3 Flooding Determinations

The computation of peak flood discharges for various site design features and nearby hydrologic features was performed by the licensee in several steps. These steps included: (1) selection of a design rainfall event; (2) determination of infiltration losses; (3) determination of times of concentration; (4) determination of appropriate rainfall distributions, corresponding to the computed times of concentration; and (5) calculation of flood discharge. Input parameters were derived from each of these steps and were then used to determine the peak flood discharges to be used in water surface profile modelling (Section 4.4) and in the final determination of rock sizes for erosion protection (Section 4.5).

4.3.1 Selection of Design Rainfall Event

One of the phenomena most likely to affect long-term stability is surface water erosion. To mitigate the potential effects of surface water erosion, the staff considers that it is very important to select an appropriately conservative rainfall event on which to base the flood protection designs. Further, the staff considers that the selection of a design flood event should not be based on the extrapolation of limited historical flood data, due to the unknown level of accuracy associated with such an extrapolation. The licensee utilized a PMP computed by deterministic methods (rather than statistical methods) and based on site-specific hydrometeorological characteristics. The PMP has been defined as the most severe reasonably possible rainfall event that could occur as a result of a combination of the most severe meteorological conditions occurring over a watershed. No recurrence interval is normally assigned to the PMP; however, the staff has concluded that the probability of such an event being equalled or exceeded during the 1000-year stability period is very low. Accordingly, the PMP is considered by the NRC staff to provide an acceptable design basis.

Prior to determining the runoff from the drainage basin, the flooding analysis requires the determination of PMP amounts for the specific site location. Techniques for determining the PMP have been developed for the United States by Federal agencies in the form of hydrometeorological reports for specific regions. These techniques are widely used and provide straightforward procedures with minimal variability. The staff, therefore, concludes that use of these reports to derive PMP estimates is acceptable.

PMP values were estimated by the licensee using Hydrometeorological Report No. 49 (HMR-49) (NOAA, 1977). The report provides information on distributing the rainfall that falls over a particular drainage area; during a PMP event these rainfall amounts vary inversely with the size of the area (the smaller the area the larger the average rainfall). A 1-hour PMP of 7.4 inches and a 6-hour PMP of 9.36 inches were used by the licensee as a basis for estimating a PMF for Moab Wash which has a drainage area of 5 square miles. For the smaller areas at the site such as the pile top, embankment side slopes, and the discharge channels, a 1-hour PMP of 8.25 inches was used. For the Colorado River, the licensee did not calculate the PMF using PMP values; rather, the licensee used existing PMF studies to estimate the PMF (See Section 4.3.5.5).

The licensee's procedures for estimating PMP values were reviewed, and it was concluded that a 1-hour PMP of 7.4 inches and a 6-hour PMP of 9.36 inches are acceptable for Moab Wash. For the other small drainage areas at the site, it was concluded that a 1-hour PMP of 8.25 inches was acceptable. Based on staff review of the rainfall computations, the staff concludes that the PMP was acceptably derived for this site.

4.3.2 Infiltration Losses

In addition to the amount of precipitation, the determination of the peak runoff rate is also dependent on the amount of precipitation that infiltrates into the ground during its occurrence and therefore does not contribute to flood flows. If the ground is saturated from previous rains, very little of the rainfall will infiltrate and most of it will become surface runoff. The loss rate is highly variable, depending on the vegetation and soil characteristics of the watershed. Typically, all runoff models incorporate a variable runoff coefficient or variable runoff rates. Commonly-used models such as the U.S. Bureau of Reclamation (USBR) Rational Formula (USBR, 1977) incorporate a runoff coefficient (C); a C value of 1 represents 100% runoff and no infiltration. Other models such as the U.S. Army Corps of Engineers Flood Hydrograph Package HEC-1 (COE, 1988) separately compute infiltration losses within a certain period of time to arrive at a runoff amount during that time period.

In computing the peak flow rate for the small drainage areas at the site, the licensee used the Rational Formula (USBR, 1977). In this formula, the runoff coefficient was assumed to be unity; that is, the licensee assumed that no infiltration would occur. Based on a review of the computations, the staff concludes that this is a conservative assumption and is, therefore, acceptable.

The licensee used HEC-1 to estimate PMF values for larger drainage areas such as the drainage channels and Moab Wash. Basin characteristics used as input parameters to HEC-1 were determined by the licensee using the U.S. Soil Conservation Service Curve Number (CN) Method (USBR, 1977). The CN of an area is an indication of the amount of precipitation that will result in runoff. It is based on the soil and vegetation characteristics of a drainage area and on the soil moisture levels existing prior to the design storm event. In estimating CN values, the licensee assumed that the soil moisture at the beginning of the PMP event would be close to saturation. This resulted in conservative PMFs, because saturated soil conditions limit the amount of infiltration that will occur and maximize the amount of runoff.

4.3.3 Times of Concentration

The time of concentration (t_c) is the amount of time required for runoff to reach the outlet of a drainage basin from the most remote point in that basin. The peak runoff for a given drainage basin is inversely proportional to the time of concentration. If the time of concentration is computed to be small, the peak discharge will be conservatively large. Times of concentration and/or lag times are typically computed using empirical relationships such as those developed by Federal agencies (USBR, 1977). Velocity-based approaches are also used when accurate estimates are needed. Such approaches rely on estimates of actual flow velocities to determine the time of concentration of a drainage basin.

Times of concentration for the riprap design were estimated by the licensee using several methods, such as the Kirpich Method (USBR, 1977) and the Manning's Equation (Chow, 1959). Such methods are generally accepted in engineering practice and are considered by the staff to be appropriate for estimating times of concentration. Based a review of the calculations provided, the staff concludes that the t_c values used by the licensee were acceptably derived.

4.3.4 Rainfall Distributions

After the PMP is determined, it is necessary to determine the rainfall intensities corresponding to shorter rainfall durations and times of concentration. A typical PMP value is derived for periods of about one hour. If the time of concentration is less than one hour, it is necessary to extrapolate the data presented in the various hydrometeorological reports to shorter time periods. The licensee utilized a procedure recommended in HMR-49 (NOAA, 1977) and by the NRC staff (NRC, 1990). This procedure involves the determination of rainfall amounts as a percentage of the one-hour PMP, and computes rainfall amounts and intensities for very short periods of time.

To determine peak flood flows for the pile (for a PMP of 8.25 inches), approximate PMP rainfall intensities were derived by the licensee as shown in Table 4-1.

Table 4-1: PMP Rainfall Intensity

Rainfall Duration (minutes)	Rainfall Intensity (inches/hr)
2.5	54.5
5.0	44.5
15.0	24.4
60.0	8.25

The staff checked the rainfall intensities for the short durations associated with small drainage basins. Based on a review of this aspect of the flooding determination, the staff concludes that the computed peak rainfall intensities are acceptable.

The temporal distribution of rainfall is the sequence in which a storm occurs. For example, in some storms, such as the PMP in HMR-49, the largest increments of rainfall occur at the beginning of the storm and taper off as the rainfall continues. In other storms, rainfall begins slowly, increasing in intensity to a peak near the center of the storm duration before it begins to taper off. It has been shown that a rainfall distribution that peaks near the center of the storm duration results in the most conservative (largest) PMF peak discharge. In order to obtain conservative PMF estimates, the licensee resequenced the incremental rainfall amounts from HMR-49 so that the largest rainfall increments occurred near the center of the storm duration. The resequenced PMP amounts, CN values, t_c estimates and other parameters were then used in the HEC-1 computer program for calculating appropriate PMF peak discharges for the collection ditches, drainage channels, and Moab Wash. Based on its review of these aspects of the flood determinations, the staff concludes that appropriate rainfall distributions were used.

4.3.5 Computation of PMF

Various methods are used to determine peak PMF flows, depending on the location of the feature, the drainage area, and other factors.

4.3.5.1 Top and Side Slopes

To estimate PMF peak discharges for the impoundment top and embankment side slopes, the licensee used the Rational Method (Chow, 1959). This method is a simple procedure for estimating flood discharges that is recommended in the Staff Technical Position (STP) on Erosion Protection (NRC, 1990). In using the Rational Method, the licensee conservatively assumed a runoff coefficient equal to one. This means that the entire PMP would result in runoff, i.e., there would be no losses due to infiltration and evapotranspiration.

For a maximum top slope length of 1440 feet (with a slope of 0.018) and a side slope length of 310 feet (with a slope of 0.3), the licensee estimated the peak flow rates to be about 1.0 cubic feet per second per foot of width (cfs/ft) for the top slope and 0.4 cfs/ft for the side slope. For the 10 percent slope at the extreme southern end of the pile, the peak flow rate was estimated to be 0.7 cfs/ft. Based on a review of the calculations, including the time of concentration, rainfall intensity, and runoff, the staff concludes that the estimates are acceptable.

4.3.5.2 Apron/Toe

PMF flow rates for overland flow for the downstream apron were estimated by the licensee and are similar to the flow rates for the side slopes. As discussed above, the flow rates are considered to be acceptable.

4.3.5.3 Collection Ditches and Drainage Channels

Peak PMF discharges for the collection ditches and drainage channels were estimated by the licensee using the HEC-1 computer program. The program was developed by the U.S. Army Corps of Engineers (COE, 1988), and is a widely used and accepted procedure for estimating flood peak discharges. The method is recommended by the NRC staff (NRC, 1990) and is therefore, acceptable.

Table 4-2 contains a summary of the licensee's calculated PMF peak discharges for the collection ditches, the Upper Impoundment Drainage Channel (UIDC), the Lower Impoundment Drainage Channel (LIDC), and the Southwest Diversion Channel (SWDC).

Table 4-2: PMF Peak Discharge

Channel	Drainage Area (square miles)	PMF (cfs)
Collection Ditch 1	.02	376
Collection Ditch 2	.03	482
Collection Ditch 3	.04	614
UIDC	.08	1638
LIDC	.09	1640
SWDC	.09	1723

The flow rate for the LIDC, for example, represents a discharge of about 18,000 cfs/mi^2. These flow rates were compared with published historic maximum flood rates (Crippen and Bue, 1977). Based on a review of the calculations and comparison with historic floods, the licensee's estimates are acceptable.

4.3.5.4 Moab Wash

To evaluate the adequacy of the licensee's estimated PMF peak discharge for Moab Wash, an independent calculation was performed by the NRC staff. Using the 1:24,000 scale map provided by the licensee, the staff first verified the licensee's estimate of the Moab Wash drainage area (5 square miles). The incremental PMP values were then arranged to provide the largest possible flood peak discharge. A curve number of 93 was then selected (see discussion of curve numbers above; a CN=100 would mean that 100 percent of the rainfall would result in runoff). Using HEC-1, the staff estimated a PMF peak discharge of 16,069 cfs. This compares favorably with the licensee's estimate of 16,129 cfs. Based on this close comparison, it was concluded that the licensee's PMF estimate for Moab Wash is acceptable.

4.3.5.5 Colorado River

The licensee did not independently estimate a PMF peak discharge for the Colorado River. Instead, existing flood data were reviewed and a search was conducted for additional studies of floods in the area. The review provided a range of Colorado River flood events that included the highest recorded flood, the 100-year, 200-year, and 500-year floods, and two estimates of the PMF. The highest recorded flow, as reported by the U.S. Geological Survey (USGS) for Moab, Utah, was 77,000 cfs in 1917. The USGS estimated 100-year, 200-year, and 500-year flood discharges of 99,500 cfs, 109,500 cfs, and 123,500 cfs, respectively. However, these estimates are for the nearest stream gaging station which is at Cisco, Utah, located about 35 miles upstream of Moab.

A PMF peak discharge (300,000 cfs) was previously estimated by the NRC staff. This estimate was developed by adjusting the Standard Project Flood estimate of the Corps of Engineers. As a result, it was recognized that the estimate was likely to be conservative. It was significantly higher, however, than the 178,000 cfs estimated by Dames & Moore and reported by Atlas in the May 1984 renewal application.

In reviewing the licensee's reported historic and estimated extreme flood peak discharges for the Colorado River, the NRC staff contacted the USBR. The USBR reported that they have not performed any comprehensive flood studies of the Colorado River at Moab, Utah. However, PMF reports are available for Hoover and Glen Canyon Dams, which are located on the Colorado River downstream of Moab (USBR, 1990). The PMF developed for the Colorado River at Glen Canyon Dam had a peak discharge of 697,000 cfs. This is more than twice as large as the largest recorded flood in the Colorado River which occurred at the site of Hoover Dam in July of 1884. That flood had a peak discharge of about 300,000 cfs. The NRC staff recognizes that these studies are not applicable to the Moab site since the drainage areas at these dam sites are considerably larger; however, they can be used to obtain a rough estimate of a PMF at Moab. Chow states that, "In some homogeneous areas where t_c is a simple function of area, the peak rates will vary directly with some power of the area, usually 0.5 (Chow, 1959)." The Colorado River at Glen Canyon Dam has a drainage area of 108,000 square miles (USBR, 1990). By comparison, the drainage area for the Colorado River at Moab, Utah is about 25,000 square miles, according to the licensee's May 1984 renewal application. Using the Chow relationship, a rough estimate of the PMF for the Colorado River at Moab would be 335,300 cfs. Therefore, assuming a PMF peak discharge of 300,000 at Moab appears to be reasonable and acceptable. This estimate was used by the licensee.

The staff's assessment of flood potential also included a review of paleoflood data for the Colorado River basin. These data were presented in "Paleoflood Evidence for a Natural Upper Bound to Flood Magnitudes in the Colorado River Basin" (Enzel et al., 1993). In this report, the authors indicate that the largest flood on the Colorado River occurred about 4000 years ago. This flood had a magnitude of about 495,000 cfs (14,000 cubic meters per second) at Lee's Ferry (Glen Canyon Dam), where the drainage area is about 108,000 square miles (279,000 square kilometers). This flood magnitude is less than the estimated PMF peak discharge of 697,000 cfs. No data were presented to estimate the magnitude of this historical flood at the site; however, using similar relationships to those discussed by Chow (1959) and discussed above, an approximate estimate of the maximum historical flood at the site (where the drainage area is about 25,000 square miles) would be approximately 238,000 cfs. This discharge is also less than the PMF estimate of 300,000 cfs.

4.4 Water Surface Profiles and Channel Velocities

Following the determination of the peak flood discharge, it is necessary to determine the resulting water levels, velocities, and shear stresses associated with that discharge. These parameters then provide the basis for the determination of the required riprap size and layer thickness needed to ensure stability during the occurrence of the design event.

4.4.1 Top and Side Slopes

In determining riprap requirements for the top and side slopes, the licensee used the Safety Factors Method (Stevens et al., 1976) and the Stephenson Method (Stephenson, 1979), respectively. The Safety Factors Method is used for relatively flat slopes of less than 10 percent; the Stephenson Method is used for slopes greater than 10 percent. The validity of these design approaches has been verified by the NRC staff through the use of flume tests at Colorado State University. It was determined that the selection of an appropriate design procedure depends on the magnitude of the slope (Abt et al., 1987). The staff, therefore, concludes that the procedures and design approaches used by the licensee are acceptable and reflect state-of-the-art methods for designing riprap erosion protection. Input parameters and design methods for riprap sizing are discussed further in Section 4.5.

4.4.2 Apron/Toe

The design of the apron/toe for this site must be adequate to withstand forces from several different phenomena and is based on the following general concepts: (1) provide riprap of adequate size to be stable against overland (downslope) flows produced by the design storm (PMP), with allowances for turbulence along the downstream portion of the toe; (2) provide uniform and/or gentle grades along the apron and the adjacent ground surface such that runoff is distributed uniformly onto natural ground at a relatively low velocity, minimizing the potential for flow concentration and erosion; (3) provide riprap of adequate size to withstand expected peak flow velocities and scour in Moab Wash, assuming that the channel has eroded and is located in the immediate area of the toe; (4) provide riprap to resist the highest velocities and shear forces expected in the Colorado River channel (such velocities and shear forces may not occur during the PMF, but may occur at lesser river flows where the backwater effects of the Portal area are not present); and (5) provide an adequate apron length and quantity of rock to allow the rock apron to collapse into a stable configuration if the main channel of the Colorado River eroded toward the site.

Several analytical methods were used for designing the riprap for the apron/toe, depending on its location relative to Moab Wash and the Colorado River. Additional detailed discussion of the riprap design of various components of the apron/toe can be found in Section 4.5.1.2, below.

4.4.3 Collection Ditches and Drainage Channels

Using the PMF peak discharges discussed above, flood control features such as collection ditches and drainage channels were designed by the licensee. For the trapezoidal-shaped ditches and channels with little variation in slope or shape, the licensee determined water surface elevations and flow velocities associated with the PMF peak discharges by calculating normal depth (Chow, 1959). Normal depth calculations are generally acceptable for the design of riprap erosion protection. In some cases, flow profiles and velocities were calculated by the licensee using the computer program HEC-2 (COE, 1991). This method is considered to be an acceptable computational method for estimating water surface elevations, flow depths, and flow velocities and is recommended by the staff (NRC, 1990). Based on a review of the licensee's computations, the staff concludes that the estimates of flow velocity and depth of flow are acceptable.

4.4.4 Moab Wash

There is a potential for the migration of the main channel of Moab Wash toward the tailings pile. The NRC staff reviewed information and analyses provided by the licensee related to channel migration and conducted independent field investigations in the Moab Wash channel and overbank area. Based on available information, the staff is concerned that during the 1000-year design life, Moab Wash may vary its location periodically and unpredictably, and the licensee has provided no basis to conclude that Moab Wash cannot move to a location adjacent to the reclaimed tailings impoundment. To prevent erosion into the tailings embankment, the licensee proposes to provide a large rock toe/apron along the toe of the embankment adjacent to Moab Wash.

Assuming migration of the channel to the toe of the pile, the licensee estimated water surface elevations and flow velocities using HEC-2. The staff reviewed the HEC-2 output files that were provided by the licensee. These files provided information regarding maximum water surface elevations and velocities and included both subcritical and supercritical flow profiles for Moab Wash. Since the supercritical profile resulted in the highest velocities, this profile was used by the licensee to estimate the depth of scour and the configuration of the buried rock wall. Based on staff review of both the supercritical profile and the subcritical profile, the staff concludes that the profiles and velocities were acceptably derived.

In developing the profiles, the licensee used various conservative assumptions regarding the location and configuration of Moab Wash. In addition to the technical bases established by the calculations associated with PMF flows, there are several qualitative reasons for the staff to conclude that the design is acceptable.

First, it is not likely that the channel will migrate all the way to the toe of the pile. A positive slope of about one percent will be maintained from the toe of the embankment toward the main low-flow channel. A large amount of soil will need to be eroded before complete channel migration or avulsion occurs.

Second, the main channel of Moab Wash was assumed to have the same elevation in a migrated condition as its design condition. It is more likely that the channel will have a higher elevation, since it will be eroding into a mass of natural stream deposits in the overbank area that are at a higher elevation. The licensee's estimates of scour depth (See Section 4.5.1.2.2) are therefore conservative, since the migrated channel invert is assumed to be the same as the design condition.

Third, velocities were calculated assuming that the channel retained the same configuration following migration. Such an assumption is conservative, since the eroded channel is likely to be less uniform and have a higher Manning's 'n' value, resulting in a decrease in velocities.

Fourth, the proposed location of Moab Wash is roughly equivalent to the location of the channel prior to initial construction of the Atlas facility. The existing (relocated) channel of Moab Wash adjacent to the tailings pile was realigned to allow for construction of the mill buildings. Based on review of the information provided by the licensee, the channel is more likely to remain in its undisturbed location, rather than migrate.

Fifth, this area is an aggrading alluvial fan area (Mussetter and Harvey, 1994), and deposition along Moab Wash will continue to occur. Such increases in elevation will increase the conservatisms associated with scour depth and the bottom elevation of the buried riprap wall.

4.4.5 Colorado River

The licensee provided detailed information and analyses (Mussetter and Harvey, 1994) and used the HEC-2 computer program to evaluate the hydraulic characteristics of the Colorado River in the immediate vicinity of the reclaimed pile. The study area extended from the Portal area (downstream of the pile) to a location upstream of the U. S. Highway 191 bridge (upstream of the pile).

For these water surface profile analyses, the licensee surveyed fourteen cross sections of the river. The surveyed sections were tied to the State Plane Coordinate System and were extended into the overbank area using data from available topographic maps. Construction drawings for the Route 191 highway bridge were obtained from the Utah Department of Highways and Transportation.

The licensee first calibrated the HEC-2 model by comparing model results to observed high water marks for known discharges. This calibration was done to verify that input parameters to the model, such as Manning's 'n' value, were appropriate. Comparisons were performed for discharges ranging from 4000 cfs to 48,900 cfs. In addition, the predicted water surface elevation at the toe of the tailings pile for a discharge of 70,300 (peak flow rate of the 1984 flood) was consistent with local observations in 1984 that the flood reached the toe of the tailings pile.

Following calibration of the HEC-2 model, the licensee analyzed water surface profiles and velocities for various discharges up to the magnitude of the PMF. A summary of the analyses is provided in Table 4-3 for cross section 5, which is located near the upstream end of the pile.

For explanation purposes, the event is a brief description of the flow that was analyzed; the flow rate is the flood discharge in cubic feet per second (cfs) for that event; the water surface elevation is the water surface elevation in feet above mean sea level (ft msl) at cross section 5; the channel velocity is the average velocity in feet per second (ft/sec) in the main channel of the Colorado River at cross section 5; and the overbank velocity is the average velocity in ft/sec in the overbank area adjacent to the pile at cross section 5 and is used to conservatively represent the maximum velocity that will occur on the pile side slopes. Cross section 5 was chosen because the computed channel velocities are higher than those at cross section 6.

Table 4-3: Water Surface Profiles and Velocities

	Flow Rate (cfs)	Water Surface Elevation (ft msl)	Channel Velocity (ft/sec)	Overbank Velocity (ft/sec)
Calibration	4000	3952.0	2.51	---
Calibration	20,000	3959.1	4.08	---
1993 Flood	48,900	3964.7	6.03	0.17
1984 Flood	70,300	3967.6	6.91	0.56
500-year Flood	123,500	3975.8	5.75	0.98
PMF (Atlas)	178,000	3983.1	4.61	0.90
PMF (NRC)	300,000	3996.7	3.14	0.71

The HEC-2 analysis performed by the licensee indicated that a peak discharge of 300,000 cfs in the Colorado River would result in an elevation of about 3996.7 ft msl. The maximum flow velocity occurred at a discharge of about 70,000 cfs and was about 7 ft/sec. The toe of the tailings impoundment is at an elevation of about 3968 feet. Therefore, a PMF discharge of 300,000 cfs would result in a depth of water of about 29 feet against the tailings impoundment. The maximum flow velocity (in the overbank against the side slope) of about one foot per second is well below the velocity considered to cause erosion to the rock armored impoundment side slopes. The licensee concluded that the riprap proposed for the impoundment side slopes is adequate for resisting extreme floods in the Colorado River (See Section 4.5, below).

To independently verify the licensee's conclusions, a sensitivity study was performed assuming a larger flood discharge in the Colorado River. This analysis indicated that even a discharge of 600,000 cfs (the approximate PMF at Hoover Dam) would not result in erosive flow velocities against the tailings impoundment. Such a discharge would have a maximum flow velocity against the reclaimed tailings of about 1.6 feet per second (fps), even though the toe of the pile would be inundated by about 50 feet of water.

Such low flow velocities result from a narrow gorge 2 miles downstream of the mill site called the Portal. This channel constriction has limited flood carrying capacity; consequently, during an extreme flood event, floodwaters will pond in the wide river channel and overbank areas upstream of the Portal. This situation is analogous to that of a dam which ponds water in the upper end of its reservoir due to the limited capacity of the outlet. For example, during routine flows, a river channel flowing into the reservoir may have flow velocities in excess of 10 ft/sec; however, if reservoir ponding occurs to inundate the channel, the velocity could be less than one ft/sec in the same channel for a larger flow rate. This is essentially what happens on the Colorado River near the Atlas site during large floods. The river channel at the Portal is capable of discharging only a relatively low (compared to areas upstream) flow, and when that flow rate is exceeded, ponding occurs, reducing velocities upstream of the Portal.

In spite of the low velocities that are produced during the occurrence of major flood flows, the staff is concerned that there is a potential for the Colorado River to migrate and possibly reach the toe of the reclaimed tailings disposal area. These concerns are based on staff observations and review of licensee analyses which indicate that erosion will occur during lesser flood events and this erosion is currently on-going in the immediate site area. Further, the Colorado river may have once been located north of the pile, and there is no assurance that it could not migrate northward to this location again. The licensee has indicated that the potential for migration is very low and that there are several bases supporting this low probability. The staff requested that Atlas provide quantitative evidence to support this conclusion; however, Atlas was not able to do so. Therefore, Atlas intends to provide a large rock apron at the toe of the disposal cell to protect the pile from erosion. The apron will be located on the southeastern side of the pile and will be designed to collapse into the channel, if migration occurs. The staff concludes that providing such a design measure is appropriate, since quantitative proof of channel stability cannot be provided.

However, the staff reviewed the licensee's qualitative information and generally concludes that the potential for migration is very low during a 200-1000 year period. Several site-specific factors need to be considered.

First, channel migration is normally the result of the meandering of a freely-adjustable stream. The ability of the Colorado River to meander across the Moab Valley is restricted by bedrock controls upstream at the valley entrance and downstream at the Portal.

Second, the rate of bank retreat is dependent upon the forces exerted and the resistance of the bank material to erosion. The maximum velocity of the river is about 7 ft/sec, which is generally not extremely erosive. Further, the overbank area between the river and the disposal area is heavily vegetated with grass, weeds, and tamarisks. Such heavy vegetation provides a considerable amount of erosional stability for both erosion and bank sloughing.

Third, the presence of mid-channel bars would tend to indicate that the river is probably aggrading more than it is eroding. This indicates that velocities in the area are low, tending to cause deposition rather than erosion.

Fourth, a considerable amount of aggradation caused by sediments from Moab Wash and Courthouse Wash appears to be occurring. There is some evidence to suggest that 2.5 feet of aggradation have occurred over the last 20 years (Mussetter and Harvey, 1994).

Fifth, aerial photographs indicate that lateral accretion has occurred along the river bank downstream of the site. Photographs taken between 1960 and 1985 indicate that some accretion has occurred in this area.

In summary, the staff concludes that it is unlikely that the river will migrate as far as the tailings pile within the next 200-1000 years. However, because quantitative proof of bank stability was not provided, it is prudent to design the pile for such an occurrence. The licensee intends to provide an erosion protection apron for the pile and this measure is considered by the staff to be a conservative method for addressing Colorado River erosion concerns. A detailed discussion of the design of the apron may be found in Section 4.5.1.2.3.

4.5 Erosion Protection

The ability of a riprap layer to resist the velocities and shear forces associated with surface flows over the layer is related to the size and weight of the stones which make up the layer. Typically, riprap layers consist of a mass of well-graded rocks which vary in size. Because of the variation in rock sizes, design criteria are generally expressed in terms of the median stone size, D_{50}, where the numerical subscript denotes the percentage of the graded material that contains stones of less weight. For example, a rock layer with a D_{50} of 4 inches could contain rocks ranging in size from 0.75 inches to 6 inches; however, at least 50% of the weight of the layer will be provided by rocks that are 4 inches or larger.

Depending on the rock source, variations occur in the sizes of rock available for production and placement on the reclaimed pile. It is necessary to ensure that the variation in rock sizes is not extreme, and design criteria for developing acceptable gradations are provided by various sources (e.g., COE, 1971, and Simons and Li, 1982).

4.5.1 Sizing of Erosion Protection

Riprap layers of various sizes and thicknesses are proposed for use at the site. The design of each layer is dependent on its location and purpose. The licensee proposes to use several different sizes and layer thicknesses, depending on the location and erosive forces that could occur. To reduce the number of gradations that need to be produced, the licensee will place larger rock in some areas than is required. For example, rock to be used on the upper portion of the top slope has a average size of 1.3 inches. However, in the extreme upper portion of this upper slope, rock requirements are much less than 1.3 inches. For ease of construction and to minimize the number of gradations, the licensee has purposely overdesigned several areas of the reclaimed surfaces. Table 4-4 summarizes the riprap to be used at the Atlas site.

Discussion of the design of each of these features is provided in the sections that follow below.

For ease of construction, the licensee intends to minimize the number of different rock sizes and gradations to be produced at the quarries that are eventually selected. It should be emphasized that the riprap sizes in the above table and in the following sections are based on recent information that was informally transmitted by the licensee to the NRC staff. At the present time, some of this information conflicts with information presented in tables and calculations previously submitted. The licensee intends to modify the rock sizes, layer thicknesses, and gradations in formal submittals to be provided at a later date. Until those submittals are provided, the staff cannot conclude that the overall riprap design is adequate.

Table 4-4: Riprap sizes and thicknesses

Location/Feature	D50 (inches)	Layer Thickness (inches)
Upper Top Slope	1.3	4
Lower Top Slope	3.0	6
Side Slope (3V:10H)	4.4	9
Moab Wash Buried Rock Wall	4.4	9
Collection Ditches	4.4	9
Upper Impoundment Drainage Channel	4.4	9
Moab Wash Buried Rock Wall	9.0	13.5
Southwest Drainage Channel	9.0	13.5
Apron along Colorado River	11.2	30
Southwest Drainage Channel	11.2	17
Southwest Drainage Channel	17.4	26
Lower Impoundment Drainage Channel	17.4	26
Lower Southwest Drainage Channel	27.6	52

Staff review has focused principally on the D_{50} sizes informally proposed by the licensee, and this review has been done to determine that the D_{50} size is adequate for each of the different locations in the design. However, details of layer thicknesses and gradations have not been provided. Final approval of the layer thicknesses and gradations can be given only after that information is provided for staff review. Therefore, the overall riprap design is considered an **OPEN ISSUE**, pending formal submittal of the riprap design.

4.5.1.1 Top and Side Slopes

The riprap on the top slope has been sized to withstand the erosive velocities resulting from an on-cell PMP, as discussed in previous sections. The licensee proposes to use a 4-inch rock layer with a minimum D_{50} rock size of 1.3 inches at the upper portion of the cell. For the lower portion of the top slope, a 6-inch layer with a minimum D_{50} of 3 inches will be used. The Safety Factors Method was used to determine the rock sizes. Based on staff review of the calculations, we conclude that the design is acceptable.

The riprap for the side slopes is also designed for an occurrence of the local PMP. The licensee proposes to use a 9-inch layer of rock with a minimum D_{50} of 4.4 inches. The rock layer will be placed on a 6-inch bedding layer. Stephenson's Method was used to determine the required rock size. Conservative values were used for the specific gravity of the rock, the rock angle of internal friction, and porosity. Based on staff review of the licensee's analyses and the acceptability of using design methods recommended by the NRC staff, as discussed in Section 4.4 of this report, the staff concludes that the proposed rock size for the side slope is adequate.

The riprap proposed for the side slopes of the tailings embankment could be subjected to shear stresses from the PMF in the Colorado River. In addition, the tailings impoundment is located on the outside bend of the Colorado River where the river turns from a westerly to a southerly direction. Because the potential for erosion is greater at the outside bend of a channel, an analysis was performed using the COE procedures (COE, 1970) to determine if the riprap proposed for the embankment side slopes was of sufficient size to resist the erosion potential at the outside river bend. Based on the use of COE procedures, the staff concludes that the estimated flow velocity of about one ft/sec is well below the velocity that the riprap on the embankment side slopes can withstand. On this basis, it was concluded that a PMF in the Colorado River will not adversely affect the stability of the reclaimed tailings pile.

As discussed in Section 4.4.5, there is a potential for the Colorado River to migrate towards the tailings pile. For conservatism, the staff assumed that the river channel will migrate to a location immediately adjacent to the embankment side slope and that the peak channel flow velocity of about 7 ft/sec will occur. The staff considers this scenario to be extremely unlikely, even in a 1000-year design lifetime. However, based on review of the velocity adjacent to the side slope, the proposed riprap size of 4.4 inches is also capable of resisting this peak channel velocity. As discussed in Section 4.5.1.2.3, the controlling hydraulic design force results from overland flows directly down the pile side slope.

4.5.1.2 Apron/Toe

As previously discussed, the design of the apron/toe area must be capable of withstanding various phenomena. The riprap design is dependent on the specific location of the toe, and erosion protection needs to be provided against (1) overland flows down the side slope onto the toe, (2) Moab Wash, and (3) the Colorado River.

4.5.1.2.1 Overland Flows

In those areas where the embankment side slopes or toes are not affected by the Colorado River or by Moab Wash, the licensee has designed the side slopes to simply transition to natural ground. The riprap on the pile side slope will be extended and the toe will consist of rock extended 3 feet below the surface of the ground. This depth is greater than the estimated scour of 0.92 foot, which was estimated using accepted procedures (DOT, 1975). This method for estimating scour depth is recommended in the STP on Erosion Protection (NRC, 1990). Based on review of the calculations provided by the licensee, the staff concludes that this aspect of the toe design is acceptable.

4.5.1.2.2 Moab Wash

As discussed in Section 4.4.4, above, the licensee provided designs and analyses of the riprap to be placed along the sides and toe of the pile, assuming that the main channel of Moab Wash had migrated to a new location immediately adjacent to the toe of the side slope embankment. The design included consideration of the: (1) potential future location of the channel; (2) estimated depth of scour; and (3) PMF water surface elevations.

To determine the areal extent of the apron/toe erosion protection, it was necessary for the licensee to analyze the hydraulic characteristics, assuming migration of the main channel of Moab Wash. The licensee developed water surface profiles and velocity estimates for such a channel configuration (See Section 4.4.4). Based on the velocity estimates and an evaluation of the potential for scour, erosion, and deposition, the licensee will construct a buried riprap wall along the toe of the pile, with the rock extending downward to the expected depth of scour. The buried wall will be constructed from the mouth of the lower impoundment drainage channel eastward to the point where the northeast debris pit begins. From there, the buried wall will extend southeastward to a point where the wall joins the rock apron that protects the pile from Colorado River migration (See Section 4.5.1.2.3).

The licensee concluded that the potential for channel migration toward the pile was greatest along the north side of the pile, where Moab Wash could be expected to meander and encroach upon the toe of the slope. In this area, the cross-sectional flow area is smallest, and velocities will be highest. Along the east side of the pile, beginning at the northeast debris pit, the flow area becomes much larger and the flow velocities are much lower. Therefore, the potential for channel migration in this area is lower.

The depth of scour was estimated by the licensee using four different methods, as recommended by Pemberton and Lara (1984). Using the field measurement method, the Regime Equation method, the mean velocity method, and limiting scour control method, the licensee estimated the average scour depth to be about 7-8 feet at most locations along the northern portion of the disposal cell. Along the northeastern portion of the cell in the area of the debris pit, a scour depth averaging about 3.6 feet was estimated. Based on a review of computations provided by the licensee, the staff concludes that the estimates are acceptable.

The riprap to be provided in the toe area was estimated by the licensee using the Corps of Engineers allowable shear stress method (COE, 1994). This method is appropriate when flow depths are larger than the rock size. The staff reviewed computations provided by the licensee and independently estimated the rock size using methods discussed in NUREG/CR-4651 (Abt et al., 1987). Based on this review, the staff concludes that the proposed D_{50} rock sizes of 9 inches and 4.4 inches are acceptable for the northern and northeastern toe areas, respectively.

4.5.1.2.3 Colorado River

As discussed in Section 4.4.5, above, the licensee provided designs and analyses for the riprap to be placed along the sides and toe of the pile, assuming that the channel of the Colorado River had migrated to a new location immediately adjacent to the toe of the side slope embankment. The revised design included consideration of the: (1) assumed future location of the channel; (2) estimated depth of scour; and (3) required volume and size of the riprap.

To determine the areal extent of the apron/toe erosion protection, the licensee simply assumed that the main channel of the river would erode toward the pile and would ultimately exist immediately adjacent to the toe of the pile at all points along the southeastern side. The staff considers this to be an unlikely situation and a conservative assumption. Based on a geomorphic evaluation (Mussetter and Harvey, 1994) of the potential for scour, erosion, and deposition, the licensee will construct a large rock apron along the toe of the pile. The apron will be provided from the mouth of the southwest drainage channel northeastward to the point where it joins the Moab Wash toe protection in the area of the debris pit.

To estimate the depth of scour associated with migration of the river, the licensee conservatively assumed that the river channel would retain essentially the same elevations and configuration in its migrated state as in its current state. The current minimum river bottom elevation was assumed to be the maximum depth of scour. This assumption resulted in an estimated scour depth of about 21 feet. Based a review of the information provided, the staff concludes that the assumptions are acceptable.

To provide adequate erosion protection and to prevent erosion of the embankment side slope, the licensee will provide a large essentially horizontal, rock apron, designed to collapse onto the side slope of the migrated river channel. The rock volume will be sufficient to cover the channel bank and to prevent further erosion of the river bank and the pile side slope. The riprap to be provided for the rock apron was estimated by the licensee using methods developed by the COE (COE, 1994). The staff reviewed computations provided by the licensee. Based on this review, the staff concludes that the proposed apron length and thickness will provide an adequate volume of rock to protect the side slope from further migration of the Colorado River.

The size of the riprap to be placed in the apron is not controlled by flow velocities in the Colorado River. As discussed above, the maximum flow velocity of the river (using the extremely conservative assumption that the main channel, rather than the overbank, is adjacent to the pile side slope) is about 7 ft/sec, produced by a flow of about 70,000 cfs. If this were the controlling case, the side slope rock size of 4.4 inches would be more than adequate to prevent further erosion. Actually, the size of the apron rock is controlled by overland flows directly down the side slope. The licensee assumed that when the rock collapses into the scoured area, it will collapse onto the river bank in a configuration where the side slope is 1V on 2H. Flows directly down a 1V on 2H slope will require a rock size larger than 4.4 inches, which would be adequate for the 3V on 10H side slope. To provide the required protection, the licensee used the Stephenson Method to determine that the riprap apron will need an average rock size of 11.2 inches. Based on review of the computations provided by the licensee, the staff concludes that this rock size is acceptable.

4.5.1.3 Collection Ditches and Drainage Channels

Median rock diameters (D_{50}) for the collection ditches and drainage channels were estimated by the licensee using either the Corps of Engineers' Shear Stress Method (COE, 1994) or the Safety Factors Method (Stevens et al., 1976). The COE method was used in cases where channel flow depths are large, relative to the median rock diameter. For shallow channels, the Safety Factors Method was used. The methods used by the licensee for designing erosion protection are those recommended in the STP on Erosion Protection (NRC, 1990), and are therefore acceptable.

To verify the licensee's riprap design for the collection ditches and channels, independent analyses were performed using methods developed by NRC contractors (Abt et al., 1987), the Safety Factors Method, and the Corps of Engineers' Shear Stress Method. These independent analyses indicated that the D_{50} values proposed by the licensee are adequate. Therefore, the staff concludes that the riprap sizes proposed by the licensee are acceptable.

4.5.1.3.1 Ditch Outlets

The licensee proposes to construct heavily-armored rock sections at the outlets of both the Southwest Runoff Drainage Channel (SWDC) and the Lower Impoundment Drainage Channel (LIDC). Their purpose is to protect the outlets of these channels from headcutting that may result from scour and may propagate upstream, potentially impinging on tailings. The depth of the proposed rock protection is equal to the expected depth of scour, which was estimated by the licensee to be approximately 8 feet. The outlet sections were assumed to collapse due to either: 1) gully headward erosion over a long period of time, or 2) the PMF flows in the ditches. In order to reduce the rock size required at the outlets, the licensee proposes to construct outlet slopes of 1V on 9H. In this design case, the scoured configuration is pre-constructed, rather than assumed to have collapsed randomly into a steeper configuration requiring much larger rock.

The D_{50} sizes of the rock in the outlet sections are proposed by the licensee to be 17.4 inches for both the SWDC (for a discharge of 1723 cfs and bottom width of 100 feet) and the LIDC (for a discharge of 1640 cfs and bottom width of 100 feet). This size is larger than the required size of about 16 inches computed by the licensee using the Stephenson Method. Based on a review of the calculations by the staff, the designs of the outlet sections are considered to be acceptable.

The licensee does not propose to provide outlet protection at the outlet of Moab Wash because the elevation of the outlet is controlled by the Colorado River. It is highly unlikely that the base level of the Colorado River will change during the performance period (Mussetter and Harvey, 1994). Therefore, the outlet of Moab Wash should remain fairly stable. The NRC staff agrees that outlet protection is not required for Moab Wash.

4.5.1.3.2 Sediment Considerations

In general, sediment deposition can be a problem in diversion ditches when the slope of the diversion ditch is less than the slope of the natural ground where flows enter the ditch. It is usually necessary to provide sufficient slope and capacity in the diversion ditch to flush or store any sediments which will enter the ditch. Concentrated flows and high velocities could transport large quantities of sediment, and the size of the particles transported by the natural gully may be larger than the man-made diversion ditch can effectively flush out.

For this site, a considerable amount of sediment from the upland drainage area can be expected to enter the Southwest Diversion Channel (SWDC), for the following reasons:

1. The upland drainage area has an extremely steep slope in the vicinity of the ditch, whereas the diversion ditch itself has been designed with a relatively flat slope in the reaches adjacent to the tailings embankment. Flow velocities in the ditches may not be as high as those occurring on the natural ground. Therefore, sediment, cobbles, and boulders may be transported to the ditch and may not be easily be flushed out by the lower velocities in the ditch.

2. The potential for gully development (and resulting high flow velocities) in the upland drainage area and subsequent transport of material into the diversion ditch is high. Gullies and areas of flow concentration are evident upstream of the diversion ditch, based on review of topographic maps of the area and a staff site visit to the area. Flows moving towards the diversion ditch will tend to concentrate in these gullies, increasing the potential for gully incision and transport of sediment.

To document the acceptability of the ditch design, the licensee demonstrated that the ditch will be capable of discharging the design flows, even if blockage occurs. The licensee assumed that sediment, debris, and large rocks would be deposited in the SWDC. The licensee determined that this channel would have adequate flow capacity, even if a significant amount of blockage (50%) occurred. The licensee performed analyses using HEC-2 and determined the effects of blockage on flow velocities and water surface profiles. The licensee determined that the blockage would raise PMF water surface elevations in the channel. The licensee proposes to vertically extend the required riprap to the increased elevations. Also, the blockage will increase the velocities, and the licensee will provide riprap of adequate size to resist those increased velocities. The proposed riprap varies in size from 9 inches in the upper reaches of the channel to 17 inches in the lower portions of the channel and was sized using COE design methods (COE, 1994) and the Safety Factors Method (Stevens et al., 1976).

Further, the licensee determined that the increased velocities will increase the depth of scour along the side slope, and therefore proposes to extend the side slope riprap vertically downward to the expected scour depth. The scour depth was determined using procedures discussed by Pemberton and Lara (1984); the acceptability of these scour analyses is discussed in Section 4.5.1.2.2.

Based on a review of the calculations provided, including the water surface profiles and riprap sizing techniques, the staff concludes that the SWDC will effectively accommodate a large amount of rock and debris entering the channel. The staff further concludes that the channel will convey PMF flows in a manner that will not affect the stability of the pile.

At the present time, it is not clear if a severe landslide potential exists in the site area. This issue is currently being evaluated by the staff and is further discussed in Section 2.4. If a landslide potential exists, design changes may be needed to the SWDC to accommodate the expected sediment input into the channel. This is an **OPEN ISSUE**.

4.5.2 Riprap Gradations

The various estimated D_{50} values were used as the basis for the design of well graded mixtures of rock to resist the shear forces of the PMF peak discharge. Riprap gradations and layer thicknesses were developed by the licensee using the criteria outlined in Surface Mining Water Diversions Design Manual (Simons and Li, 1982). To verify the adequacy of the licensee's proposed riprap gradations, independent spot checks were made by the staff using design methods presented in NUREG/CR-4620 (Nelson et al., 1986). These checks indicated that the gradations proposed by the licensee are acceptable.

The licensee estimated many riprap sizes for the various applications. However, to reduce the number of different riprap sizes and gradations, the licensee elected to use larger rock than required in many areas. Thus, additional conservatisms are added to the design in those areas where larger rock than required is used.

4.5.3 Rock Durability

NRC regulations require that control of residual radioactive materials be effective for up to 1000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. The previous sections of this TER examined the ability of the erosion protection to withstand flooding events reasonably expected to occur in 1000 years. In this section, rock durability is considered to determine if there is reasonable assurance that the rock itself will survive and remain effective for 1000 years.

Rock durability is defined as the ability of a material to withstand the forces of weathering. Factors that affect rock durability are 1) chemical reactions with water, 2) saturation time, 3) temperature of the water, 4) scour by sediments, 5) windblown scour, 6) wetting and drying, and 7) freezing and thawing.

To assure that the rock used for erosion protection remains effective for up to 1000 years as required by Criterion 6 of 10 CFR Part 40, Appendix A, potential rock sources must be tested and evaluated to identify acceptable sources of riprap. A procedure for determining the acceptability of a rock source is presented in Appendix D of the STP on Erosion Protection (NRC, 1990). The procedure discussed in the STP includes the following steps:

Step 1. Test results from representative samples are scored on a scale of 0 to 10. Results of 8 to 10 are considered "good"; results of 5 to 8 are considered "fair"; and results of 0 to 5 are considered "poor."

Step 2. The score is multiplied by a weighting factor. The effect of the weighting factor is to focus the scoring on those tests that are the most applicable for the particular rock type being tested.

Step 3. The weighted scores are totaled, divided by the maximum possible score, and multiplied by 100 to determine the rating.

Step 4. The rock quality scores are then compared to the criteria which determines its acceptability, as defined in the NRC scoring procedures.

After these tests are conducted, a rock quality score is determined. Different minimum scores, depending on the location where the rock will be placed, are recommended in the STP. Rock scoring 80 percent or greater indicates high quality rock that can be used for any application. Rock scores between 65 and 80 percent indicate less durable rock that can also be used for most applications, provided that the riprap is appropriately oversized. Rock scoring less than 65 percent cannot be used for critical areas such as diversion ditches or poorly drained toes and aprons. Rock scoring between 50 and 65 percent can be used in non-critical areas such as well drained tailings pile tops and side slopes provided it is oversized as recommended in the STP on Erosion Protection (NRC, 1990). Rock scoring less than 50 percent is not recommended for use in any application.

In general, rock durability testing is performed using standard test procedures, such as those developed by the American Society for Testing and Materials (ASTM). The ASTM publishes and updates an Annual Book of ASTM Standards (ASTM, 1995), and rock durability testing is usually performed using these standardized test methods.

Initially, the licensee identified seven potential rock sources in the proximity of the Atlas Mill. Four of the sources were rounded igneous alluvial rock, two sources were sedimentary rock, and one source was an igneous outcrop. Petrographic analyses using ASTM C 295 were performed by the licensee on samples from the sedimentary sources and on samples of alluvial rock. These analyses indicated that some of the sources could be considered for further physical testing. Rock samples were then tested for Bulk Specific Gravity and Absorption (ASTM C 127), Sodium Sulfate Soundness (ASTM C 88), Los Angeles Abrasion (ASTM C 131 or C 535) and Tensile Strength. The results of these tests were then evaluated using procedures recommended in the STP on Erosion Protection (NRC, 1990). This evaluation indicated to the licensee that the sedimentary rock weathered very rapidly, scoring only 37 and 45 percent. These rock sources are not useable since they scored less than 50 percent. Two samples of the igneous alluvial rock scored 65 and 68 percent. This rock can be used for any application if it is oversized as recommended in the STP on Erosion Protection (NRC, 1990). Use of the alluvial rock source may be limited, because the maximum D_{50} is probably less than 3 inches. The sample from the igneous rock outcrop was the most durable, having scored 78 percent. Atlas reserves the right to either use the tested rock or an alternate source. Regardless of the rock source used, the licensee has committed to meet the durability and oversizing recommendations of the STP on Erosion Protection.

Based on a review of the rock durability analysis provided by Atlas, and considering the commitment to comply with the STP on Erosion Protection (NRC, 1990), it was concluded that acceptable rock will be used for erosion protection.

4.5.4 Testing and Inspection of Erosion Protection

The staff reviewed and evaluated the testing, inspection, and quality control procedures proposed by the licensee for the erosion protection materials and design features. The review included evaluations of programs for durability testing, gradation testing, rock placement, and verification of rock layer thicknesses.

4.5.4.1 Durability Testing

The licensee's proposed rock durability testing will include the following tests, shown with their ASTM designation:

1. Bulk Specific Gravity - ASTM C 127
2. Absorption - ASTM C 127
3. Sodium Sulfate Soundness - ASTM C 88
4. L.A. Abrasion at 100 cycles - ASTM C 131 or ASTM C 535

Durability test results will be used by the licensee to determine a rock durability rating in accordance with Table D-1 of the STP on Erosion Protection (NRC, 1990). The licensee proposes that the following criteria will be used to determine acceptable uses of rock, based on its durability rating:

1. Rock having a durability rating of greater than or equal to 80 may be used as riprap or filter material.

2. Rock having a durability rating of less than 80 and greater than or equal to 65 may be placed in surface water control ditches, and used as riprap or filter material only after being oversized in accordance with the STP.

3. Rock having a durability rating of less than 80 and greater than or equal to 50 may be used on the top or side slopes, only after being oversized in accordance with the STP.

4. Rock having a durability rating of less than 65 may not be used for riprap or filter material in a drainage channel. Rock having a durability rating of less than 50 may not be used for any application.

5. In addition to oversizing the rock according to the durability ratings, an additional oversizing factor of 20 percent will be added if rounded alluvial rock is used.

The licensee proposes that a minimum of one initial test series will be performed prior to using rock for riprap or filter material. Additional test series will be performed when approximately one-third and two-thirds of the total volume of each type of riprap or filter material have been delivered. When the total volume of any type of riprap or filter material exceeds 30,000 cubic yards, the licensee will conduct an additional test series for each additional 10,000 cubic yards delivered. The licensee also committed to performing additional tests when the rock characteristics (i.e., color or texture) in the rock borrow source vary significantly from the rock that was previously tested.

Based on a review of the proposed procedures, the staff concludes that the durability testing program will ensure that rock of acceptable quality is provided. The testing program is equivalent to several which were approved by the staff and have been implemented at other reclaimed sites during construction.

4.5.4.2 Gradation Testing

The licensee proposes that riprap, rock mulch, and the filter material gradations will be verified during reclamation using the following procedures:

1. Filter gradations will be tested using ASTM C 136, Standard Method for Sieve Analysis of Fine and Coarse Aggregates, or ASTM D 422, Standard Test Method for Particle-Size Analysis of Soils, as appropriate.

2. For riprap having a maximum nominal diameter (D_{100}) of less than or equal to 6 inches, ASTM C 136, Standard Method for Sieve Analysis of Fine and Coarse Aggregates, will be used to verify that gradations comply with the specifications.

3. Gradation testing will be performed at the same frequency as rock durability testing.

Based on a review of the proposed procedures, the staff concludes that the gradation testing program will ensure that rock layers with acceptable gradations are provided. The testing program is equivalent to several which were approved by the staff and have been implemented at other reclaimed sites during construction.

4.5.4.3 Riprap Placement

The licensee proposes a placement program where: (1) riprap will be placed to the depths and grades shown on the drawings; (2) riprap will be placed in a manner to ensure that the larger rock fragments are uniformly distributed and the smaller rock fragments serve to fill the void spaces between the larger rock fragments, so that a densely packed, uniform layer of riprap of the specified thickness will result; (3) hand placing will be used, as necessary, to ensure proper results; and (4) material that does not meet these specifications will be either reworked or removed and replaced as necessary.

Based on a review of the licensee's proposal, the staff concludes that the procedures will ensure acceptable placement. The placement procedures are equivalent to several which were approved by the staff and have been implemented at other reclaimed sites during construction.

4.5.4.4 Rock Layer Thickness Testing

The licensee proposes that the thickness of the rock layers will be verified by establishing a 200-foot by 200-foot grid over the tailings impoundment and using specific procedures for measuring and recording depths. Visual examinations will also be conducted to verify the uniformity of depths.

Based on a review of the information provided, the staff concludes that the proposed testing program is acceptable. Combined with the rock placement procedures discussed in Section 4.5.4.3, above, the program conforms to other previously-approved programs that have been implemented at other Title I and Title II sites.

4.5.5 Wind erosion

The tailings impoundment is located in an area that provides some wind protection due to the local topography. Cliffs on the western side of the impoundment rise abruptly for 1000 feet. To the north and east of the site are 500 to 600 ft high barren sandstone formations. The staff considers that the site will be adequately protected from wind erosion by placement of engineered riprap layers that protect the tailings from surface water erosion. Studies performed for the NRC (Voorhees et al., 1983) have shown that an engineered riprap layer designed to protect against water erosion will be capable of providing adequate protection against wind erosion.

4.6 Upstream Dam Failures

There are no impoundments near the site whose failure could potentially affect the site.

4.7 Conclusions

Based on review of the information submitted by the licensee and on independent calculations, the NRC staff concludes that the licensee has identified the appropriate floods for the design of erosion protection features at the site. The staff further concludes that water surface profiles and channel velocities were appropriately derived and are acceptable as a basis for the design of erosion protection features. Based on the most recent informal licensee information, the erosion protection design appears to be adequate to provide reasonable assurance of protection for 1000 years, as required in Criterion 6 of 10 CFR Part 40, Appendix A. However, recent information related to rock sizes and layer thicknesses conflicts with information presented in tables and calculations previously submitted. The staff understands that the licensee intends to modify the rock sizes, layer thicknesses, and gradations in formal submittals to be provided at a later date. Until those submittals are provided, the staff cannot conclude that the overall riprap design is adequate. Furthermore, it is not clear if a severe landslide potential exists in the site area. This issue is currently being evaluated in the staff's geology review. If a landslide potential exists, design changes may be needed to the Southwest Runoff Diversion Channel to accommodate the expected sediment input into the channel.

5.0 WATER RESOURCE PROTECTION

5.1 Introduction

The initial monitoring of the water resources at the site, for which there are reliable records, began in 1976 after approximately 20 years of mill operation. This monitoring program was designed to collect surface water samples from the Colorado River and groundwater samples from the alluvial aquifer situated beneath tailings impoundment. These data were used to support the license renewal, which was initiated by an August 31, 1983 licensee application.

New groundwater regulations for uranium mills were codified in 10 CFR 40, Appendix A, shortly after the license renewal. These regulations required detection monitoring, compliance monitoring, and corrective action programs for tailings impoundments at operating mills. Definitions of hazardous constituents in groundwater and associated limits were also established in the regulation. The groundwater protection provisions are contained within Criteria 5, 7, and 13 of 10 CFR 40, Appendix A.

At the time regulations became effective, little or no data on the constituents types and concentrations had been measured in tailings impoundments. Consequently, the NRC initiated a sampling program to collect and analyze tailings solutions from all active uranium milling facilities under NRC license. Analyses were performed on both the dissolved and total constituent load of each sample. Laboratory analyses for this program were conducted by Oak Ridge National Laboratory.

Laboratory results were obtained for the 375 hazardous constituents listed in 40 CFR Part 261, Appendix VIII. The analyses included a gas chromatograph scan for volatile and semi-volatile organics, with specific compound identification of detected peaks; total and dissolved metals; total and dissolved radionuclides; total organic carbon; cyanide; sulfides; various nitrogen containing species; as well as selected anions and cations. The sampling program encompassed the constituents listed in Criterion 13 of 10 CFR Part 40, Appendix A.

Samples were collected from the Atlas tailings impoundment during July, 1987. Analytical results indicated the occurrence of hazardous constituents in the Atlas mill tailings impoundment. As a result, the licensee was required to implement a detection monitoring program to determine if groundwater had been impacted by the impoundment. The monitoring points associated with this program indicated that some of the hazardous constituents had leached from the tailings and moved into the aquifer adjacent to the tailings impoundment. Compliance limits were then determined for released hazardous constituents and a corrective action program was implemented.

The NRC recognizes that remediating contaminated groundwater may require a substantially longer time than the that involved in surface reclamation of a tailings impoundment. Consequently, surface reclamation and groundwater reclamation are considered separately by the NRC for demonstrating compliance with the license and appropriate regulations. The information and conclusions described in this chapter address compliance with the surface reclamation plan. Groundwater clean-up compliance will be addressed by the licensee in future revisions of the Corrective Action Plan (CAP), which is outside the scope of this review. Regardless of the timing, compliance with the groundwater standards must be demonstrated before the license can be terminated.

5.2 Hydrogeologic Characterization

The hydrogeology of the site has been investigated by the licensee over several years through drilling, well installation, and groundwater sampling and analysis programs for the purposes of expanding the tailings impoundment and complying with regulatory requirements during mill operations. Studies and site investigations had been conducted by Dames & Moore (1975, 1982); EnecoTech (1988); Western Technologies, Inc. (1989); and Canonie Environmental Services Corp. (1994). Descriptions of the site hydrogeologic characterization in the following sections are based on the data and information presented in these reports, along with other information contained in the NRC docket file. Specific conclusions made by NRC staff are noted as such.

5.2.1 Hydrogeologic Setting

The Atlas site is adjacent to an outside meander of the Colorado River, located at the northwestern end of Spanish Valley. The town of Moab, Utah is located approximately 5 km (3 miles) southeast of the site. The northern end of the valley is flanked to the east and west by high cliffs of the Wingate Sandstone; and a gradually sloping upland area to the north, which contains the ephemeral drainage of Moab Wash. Arches National Park is situated in the upland areas east and northeast of the site. Courthouse Wash drains much of the area of Arches and flows into the Colorado River approximately 1200 m (3900 feet) east of the tailings pile. The upland areas west of the site comprise the Poison Spider Mesa. Figure 1-1 depicts the physiographic features associated with the Atlas site.

The mill and tailings impoundment are situated on the relatively level bottom lands along the river. Portions of these bottom lands are within the historical flood plain of the Colorado River. Moab Wash flows through the Atlas property, east of the tailings impoundment. The channel of Moab Wash was rerouted east of the mill during operations at the site to mitigate flooding potential during peak flows.

The area surrounding the Atlas site and Spanish Valley constitute a unique and complex geological setting. The Spanish Valley outwardly resembles a trough; however, the valley morphology largely resulted from the non-tectonic movement of salt and other evaporites, dissolution of soluble salts and collapse of overlying rock (Blanchard, 1990). Spanish Valley contains a considerable thickness of silt, sand, and gravel deposited from streams and rivers. These and other geological episodes created the present geological setting that influences the occurrence, movement, and characteristics of groundwater in the area. Section 2.3 provides additional detail of the geologic episodes in this area.

5.2.2 Identification of Hydrogeologic Units

Three general hydrogeologic units have been identified for the purpose of describing the groundwater conditions at and surrounding the Atlas site. It is important to note that hydrogeologic units may consist of several distinctive geological, stratigraphical, or lithological rock units, but may be categorized as a single hydrogeologic unit by virtue of common hydraulic or chemical properties that influence groundwater occurrence and characteristics. The three hydrogeological units designated for this evaluation are: (1) Unconsolidated Alluvium, associated largely with the valley floor and river (2) Bedrock Units, situated beneath the alluvium, and (3) Mesa and Upland Units, located east, west, and northwest of the site.

Unconsolidated Alluvium

The shallowest hydrogeologic unit beneath the Atlas site is unconsolidated alluvium of Quaternary age. The alluvium is exposed in the flood plane of the Colorado River, and is described as being a mixture of alluvial fan deposits from the Moab Wash and Courthouse Wash, colluvial deposits from the cliffs located west of the site, and fluvial deposits from the Colorado River. The shallow portions of the alluvium adjacent to the Colorado River, consist of interbedded and intermixed poorly-sorted silt and sand, with some gravel and clay. The deeper alluvium consists of well-sorted, interbedded sand and gravel.

The alluvial depth appears to vary considerably across the site and has been verified by drilling information at several locations. Bedrock has been encountered at depths ranging from about 8.5 m (28 ft) on the north side of the tailings pile (boring B-4), to about 36.6 m (120 ft) near the northeastern end of the tailings (boring TH-28), and to about 18.3 m (60 ft) near the upgradient well at the northeastern end of the Atlas property (well AMM-1). One drilling location near the eastern corner of the tailings pile (ATP-1) reached a depth of 124 m (406 ft) without encountering bedrock. Bedrock was encountered at a depth of about 30 m (97 ft) in a boring (ATP-2) situated approximately 245 m (800 ft) southwest of ATP-1.

The alluvium in other portions of Spanish Valley lying southeast of the site is also described as consisting of unconsolidated sediments of diverse origin. The alluvial thickness in the majority of the valley is described as being slightly more than 110 m (360 ft), where penetrated by wells, and rests on an irregular bedrock floor with probable faulting concealed by the alluvium. The average thickness of the saturated alluvium in the valley is estimated at about 21 m (70 ft; Sumsion, 1971).

The alluvium contains the shallowest groundwater at the site and comprises the uppermost aquifer as defined in 10 CFR 40, Appendix A. Alluvial groundwater is generally encountered between about 2.4 and 4.6 m (8 and 15 ft) of depth.

Bedrock Units

Several stratigraphic units are believed to comprise the bedrock system beneath the alluvium at the site. Much of the information on the bedrock is derived from limited drilling information and the outcrop exposures along the sides of the valley. Displacement of rock units by salt movement, and potential faulting have likely added complexity to the bedrock configuration beneath the site. Based on best available evidence, the bedrock likely consists of units of the Moenkopi Formation of Triassic age, the Cutler Group of Permian age, and the Chinle Formation of Triassic age. A detailed discussion of these lithologic units is provided in Section 2.3.2.

Mesas and Upland Units

The cliffs to the east of the site and the mesa areas to the west are largely composed of the Wingate Sandstone and Kayenta Formation of the Triassic/ Jurassic Glen Canyon Group. The mesa area east of the site, within Arches National Park, also contains large areas of the Triassic Navajo Sandstone, which is also within the Glen Canyon Group, and the Jurassic Entrada Sandstone. Descriptions of these units are derived from published technical reports from the Utah Department of Natural Resources (Blanchard, 1990; and Sumsion, 1971).

The Wingate Sandstone is described as a massive, fine-grained, thickly cross-bedded eolian sandstone with a thickness ranging from 91 to 122 m (300 to 400 ft). The Kayenta Formation is described as irregularly interbedded fluvial fine-to coarse-grained sandstone, siltstone an shale. The thickness of the Kayenta Formation varies from about 73 m (240 ft) in western Grand County to nearly zero in the eastern part of the county. The Navajo Sandstone is described as a massive, fine-grained, thickly cross-bedded, eolian sandstone with a thickness of about 122 m (400 ft) in western Grand County. The Entrada Sandstone has been classified as three distinctive members in this area, the Dewey Bridge Member, the Slick Rock Member, and the Moab Sandstone Member. The Entrada Sandstone achieves thickness of about 168 m (550 ft) in the western portion of the county. A detailed description of these lithologic units is provided in Section 2.3.2.

5.2.3 Hydraulic and Transport Properties

Unconsolidated Alluvium

The hydraulic conductivity of the shallow alluvium at the site has been investigated by the licensee by performing laboratory and field permeability tests in various boreholes at depths above 21.3 m (70 ft) below land surface (bls). Slug tests in three piezometers in the Moab Wash alluvium north of the alluvium have also been conducted. Table 5-1 provides a tabulation of these hydraulic conductivity measurements, as reported by Atlas.

The available hydraulic data shown in Table 5-1 include 20 independent measurements from ten site locations for a depth ranging from 2.4 to 21.3 m (8 to 70 ft). An evaluation by NRC staff shows that the measurements range from 1.26×10^{-6} to 7.73×10^{-3} cm/sec (0.0036 to 21.9 ft/day), with a mean of 8.64×10^{-4} cm/sec (2.4 ft/day) and a median of 2.47×10^{-4} cm/sec (0.7 ft/day). No information on the alluvial hydraulic properties below a depth of 21.3 m (70 ft) is available, other than grain size descriptions from drilling logs.

Table 5-1 Summary of Available Hydraulic Conductivity Data

SUMMARY OF AVAILABLE HYDRAULIC CONDUCTIVITY DATA FOR THE ALLUVIAL AQUIFER ATLAS MILL SITE				
Borehole/ well	Depth in m bls (ft)	Description of Material	Type of Testing*	Hydraulic Conductivity in cm/sec
8	1.7 (5.5)	Fine sand w/ silt	L	1.26×10^{-5}
15	2.4 (8)	Fine sand w/ silt	F	2.47×10^{-4}
15	2.6 (8.5)	Fine sand w/ silt	L	3.58×10^{-4}
8	4 (13)	Fine to coarse sand and gravel	F	8.21×10^{-4}
15	4 (13)	Fine to coarse sand w/ silt	F	4.16×10^{-4}
15	4.1 (13.5)	Fine to coarse sand w/ silt	L	1.06×10^{-4}
8	5.5 (18)	Fine to coarse sand and gravel	F	1.35×10^{-3}
15	5.5 (18)	Fine to coarse sand and gravel	F	2.13×10^{-4}
8	5.6 (18.5)	Fine to coarse sand and gravel	L	9.57×10^{-5}
15	5.6 (18.5)	Fine to coarse sand w/ silt	L	2.22×10^{-4}
8	8.5 (28)	Fine to coarse sand and gravel	F	7.73×10^{-3}
15	12 (39.5)	Fine to coarse sand w/ silt	L	$1.74 X 10^{-4}$
A-3	13.1 (43)	Fine to coarse sand w/ gravel	L	8.50×10^{-5}
13	15.1 (49.5)	Fine sand w/ silt	L	4.73×10^{-4}
TH-21	7.3 to 18.3 (24 to 60)	Sand	S	2.06×10^{-3}**
TH-24	11.6 to 18.3 (38 to 60)	Sand	S	5.61×10^{-4}**
TH-26	7 to 18.3 (23 to 60)	Sand	S	1.24×10^{-4}**
A-1	18.4 (60.5)	Medium Sand	L	1.26×10^{-6}

SUMMARY OF AVAILABLE HYDRAULIC CONDUCTIVITY DATA FOR THE ALLUVIAL AQUIFER ATLAS MILL SITE				
Borehole/ well	Depth in m bls (ft)	Description of Material	Type of Testing*	Hydraulic Conductivity in cm/sec
A-6	18.9 (62)	Fine to coarse sand w/ gravel	L	1.93×10^{-3}
11	21.2 (69.5)	Fine sand w/ silt	L	3.00×10^{-4}

* L = Laboratory measurements of collected soil samples
F = Field testing of boreholes
S = Slug testing of piezometers
** Represents the average of repeated tests in same piezometer

Sumsion (1971) reported hydraulic conductivities of domestic wells in the Spanish Valley alluvium ranging from about 1.02×10^{-2} to 4.66×10^{-2} cm/sec (29 to 132 ft/day), with an average of about 2.82×10^{-2} cm/sec (80 ft/day). It is assumed that the hydraulic conductivity values reported by Sumsion (1971) are for wells completed over substantially larger aquifer thickness and likely in deeper horizons than the Atlas monitoring wells.

Bedrock Units

No information is available on the hydraulic properties of the bedrock units beneath the alluvium at the site. Blanchard (1990) describes the groundwater conditions in the Paradox Member in portions of Grand County, which would likely correspond to some of the bedrock units beneath the alluvium. Groundwater in this units is referred to as the lower groundwater system. Although no hydraulic information is available for this lower groundwater system, uranium and petroleum exploratory holes have reportedly been drilled to the top of the Paradox Member and encountered groundwater with total dissolved solids (TDS) concentrations ranging from 160,000 to 300,000 milligrams per liter (mg/L) (Blanchard, 1990).

Mesas and Upland Units

No specific site information was developed by the licensee for the hydraulic properties of rock units in the adjacent mesas and uplands. NRC staff recognizes that these areas are outside the site limits, and the licensee is not required to characterize adjoining properties. However, an evaluation of available published information is warranted to determine if these areas have the potential to influence groundwater conditions at the Atlas site.

Blanchard (1990) and Sumsion (1971) describe the Entrada Sandstone, the Wingate Sandstone, and the Navajo Sandstone as the principal aquifers in the mesas and upland areas. In the area of Mill Creek and Spanish Valley, east of Moab, Blanchard (1990) designates the Wingate Sandstone, Kayenta Formation, and Navajo Sandstone as the Glen Canyon aquifer, because the Kayenta Formation is largely sandstone in this area and the three formations are jointed and fractured, providing hydraulic connection.

The rock strata of the Glen Canyon aquifer generally dips from east to west, making the eastern side of Spanish Valley the discharge point of the aquifer. An aquifer test conducted in the Glen Canyon aquifer (City of Moab wellfield) indicated the presence of impermeable boundaries within the aquifer, with hydraulic properties varying considerably over a short distance. No specific estimates of total aquifer hydraulic properties could be determined from the test; however, specific capacity values for 14 wells completed in the Glen Canyon aquifer ranged from 250 to 167,135 m^2/day (0.25 to 167 gallons per minute-per foot [gpm/ft]) of drawdown. The largest specific capacity value (167,135 m^2/day) was measured in a well where the Glen Canyon aquifer is overlain by about 11 m (36 ft) of alluvial material, which may indicate significant hydraulic connection between the alluvium and the Glen Canyon aquifer.

The Wingate Sandstone, the Navajo Sandstone, and the Entrada Sandstone are separate aquifers over other portions of the area. Sumsion (1971) reports that the intrinsic permeability of the Wingate aquifer is not great because of the fine-grained nature of the sand. The Wingate sandstone generally outcrops in canyon walls and floors, where discharge can occur as springs. The Wingate is overlain by the less permeable Kayenta Formation, which restricts recharge. Where highly fractured, the Wingate yields moderate quantities of water to wells and springs. One well completed in Wingate aquifer is used for water supply in Arches National Park (Blanchard, 1990).

The Navajo aquifer is described by Sumsion (1971) as being of similar grain-size and intrinsic permeability as the Wingate aquifer. The Navajo Sandstone outcrops extensively throughout the Arches National Park. Two water supply wells in the park are completed in the Navajo aquifer (Blanchard, 1990).

The Entrada Sandstone also outcrops in Arches National Park, and provides groundwater to several springs. One of the principal areas of spring discharge from the Entrada aquifer is in Courthouse Wash. Hydraulic conductivity ranging between 0.1 ft/day to more than 1.1 ft/day have been estimated for portions of the Entrada aquifer (Blanchard, 1990).

5.2.4 Groundwater Flow

Unconsolidated Alluvium

Groundwater flow within the alluvial aquifer at the site has been evaluated by the licensee through the installation of piezometers, monitoring wells, and water level measurements collected over various time periods. Information and data for the site groundwater conditions are summarized in Canonie (1994). NRC staff has reviewed these data and developed the following conclusions.

Generally, the shallow alluvial groundwater flows from the northwest to the southeast, toward the Colorado River, mimicking the surface topography. The exception to this generality occurs near the tailings pile. The measured water level within the tailings pile is approximately 12 to 18 m (40 to 60 ft) above the alluvial groundwater level, which greatly influences the direction and gradient of flow near the tailings pile. The horizontal hydraulic gradient near the former mill area is estimated to average 0.0039. The estimated gradient near the tailings pile ranges from 0.02 east of the pile to 0.0071 southeast of the pile.

Groundwater flow directions and gradients are likely variable throughout the year, because of Colorado River stage influences. Hydrographs of shallow and deep monitoring wells in the alluvium show a distinct hydraulic connection between the river stage and groundwater levels. During much of the year, the well hydrographs show that groundwater elevations are above the river stage, demonstrating that the river is gaining flow from groundwater influence. However, during periods of spring run-off, the river stage exceeds the groundwater elevation in the alluvial wells. Consequently, the river contributes flow to the alluvial groundwater during high stage episodes. The hydrograph and river stage information provided by the licensee is not adequate for calculating an estimate of hydraulic diffusivity for the alluvium.

Based on the available information, NRC staff concludes that the licensee's interpretation of groundwater flow direction and gradient is reasonable, with the exception of the area associated with the southern extent of the tailings, near the southern property boundary. The licensee interprets that alluvial groundwater flows nearly perpendicular from the upland area southwest of the site, toward the river. Monitoring well and piezometer data in this area are limited to piezometer B-7 in the tailings pile and monitoring wells AMM-3 and MW-1-R situated near the embankment toe.

The licensee's interpretations of groundwater flow direction and gradient near the southern property boundary are not supported by available site data. In order for groundwater to flow from the upland area to the river along a flow path perpendicular to the upland, a significant flow contribution from the upland area would be required. A significant upland flow contribution would also be required to support the interpreted groundwater gradient near the alluvium - upland contact. Information from Blanchard (1990) and Western Technologies (1989) documents that the rock units outcropping at the base of the uplands southwest of the site are the Hermosa Formation, the Moenkopi Formation, and the Chinle Formation. These units are characterized by extensive shale and clay beds, which are not conducive to transmitting significant quantities of water. Additionally, the interpreted flow directions in this area are not corroborated by the contaminant concentration contours presented by the licensee. Section 5.2.5 provides a detailed discussion of the contamination extent and distribution associated with seepage from the tailings pile. Atlas must provide additional data to support its interpretation of groundwater flow directions and gradients in the alluvial aquifer near the southern property boundary of the site. This is an **OPEN ISSUE**.

Groundwater within the deeper alluvium exhibits a TDS concentration in excess of 100,000 mg/L below a depth of about 24 m (80 ft). The brine is characterized as predominately sodium chloride in nature and is likely the result of groundwater contacting the evaporites of the Paradox Formation beneath the alluvium (Dames & Moore, 1982). The occurrence of the deeper alluvial brine has been confirmed by four deeper monitoring wells situated at two locations on site. No information is available on groundwater flow directions or gradients within the deeper brine.

Groundwater within the Spanish Valley alluvium is described by Sumsion (1971) as generally flowing down-valley from southeast to north west, toward the Colorado River. Sumsion (1971) also states that although Spanish Valley is underlain by evaporites of the Paradox Member, no saline water or brine has been observed in the alluvium of Spanish Valley. A driller's log from one well indicates a thick, black shale separating the alluvium from the deeper evaporites.

Bedrock Units

No information is available on the groundwater flow of the bedrock units beneath the alluvium at the site; however, given the occurrence of the higher specific-gravity brine within the lower portions of the alluvial aquifer at the site, NRC staff considers that any groundwater flow within the bedrock units are likely hydraulically separate from the groundwater flow in the shallower alluvium. The partitioning of flow between relatively fresh water and salt water is well documented in groundwater literature. Davis and DeWiest (1966), Freeze and Cherry (1979) and other textbooks describe the mechanism of flow separation due to density differences.

Blanchard (1990) identifies some locations within Grand County where the lower groundwater system may be influencing shallower groundwater through upward migration through poorly abandoned exploratory boreholes. Blanchard (1990) further indicates that potentiometric surface from the lower groundwater system may be as much as 61 m (200 ft) in some areas. Additionally, groundwater in the deeper bedrock units is shown (Blanchard, 1990) to flow southwesterly throughout the southern and southwestern portions of Grand County.

Mesas and Upland Units

Blanchard (1990) describes groundwater movement in the Glen Canyon aquifer as generally westward and southwestward toward Spanish Valley, with the principal area of discharge occurring in Spanish Valley, near the City of Moab. Groundwater movement in the Navajo Sandstone and Wingate Sandstone situated north and west of Spanish Valley is shown by Blanchard (1990, Figure 16) to flow southeasterly. Regionally, groundwater in these aquifers appears discharge in the canyon cut by the Colorado River.

5.2.5 Geochemical Conditions and Contamination Extent

Background Conditions

Pre-operational groundwater quality data are not available at the Atlas site, because site operations began long before many environmental monitoring requirements were initiated. Consequently, groundwater quality in the uppermost aquifer, which represent pre-milling conditions, has been characterized by sampling wells hydraulically upgradient of the facility.

Originally, background conditions were established in monitoring well ATP-3, which is completed within the Moab Wash alluvium, up slope of the tailings pile and mill area. Water quality measurements from the well showed TDS concentrations of about 1300 to 1400 mg/L, but ranging as high as about 7000 mg/L. However, water quality in this well did not appear representative of site conditions within the alluvium near the river, where the tailings pile is located. Additionally, this well periodically remained dry during a portion of the year. A new background well was established for the site in 1988 as part of the licensee demonstrating compliance with the new detection monitoring provisions the 10 CFR 40, Appendix A.

Well AMM-1 was established as the NRC-approved background well for the facility. The well is situated approximately at the far northeastern corner of the property, about 244 m (800 ft) northeast of the former mill area. Groundwater samples have been collected from AMM-1 since 1988 and show concentrations of selenium, combined radium-226 and -228 above the NRC maximum concentration limits (MCLs) and elevated concentrations of uranium. TDS concentrations in this well range from about 6500 to 7500 mg/L.

A review of site maps and historical aerial photographs of the site show a former ore storage pad situated about 61 m (200 ft) west of the background monitoring well location. NRC staff recognizes that placement of an upgradient, background monitoring well had previous presented technical challenges to the licensee, due to size of the milling area and the lack of sufficient groundwater in the previous upgradient well completed in the Moab Wash alluvium. Although the location for this well had previously been approved by the NRC, the licensee must provide data showing that monitoring well AMM-1 is not influenced by contaminants from the former ore storage pad. This is an **OPEN ISSUE**.

Contaminant Characterization

The NRC initiated a sampling and laboratory analysis program in 1987 to evaluate hazardous constituents at uranium mills under NRC license, because little or no comprehensive information was previously available on the types of potential hazardous constituents associated with uranium mill tailings impoundments. Both dissolved and total analysis were conducted for the collected tailings solutions, along with a gas chromatograph screening for volatile and semi-volatile organic compounds. Analytical services were contracted with Oak Ridge National Laboratory, an EPA certified laboratory.

Tailings fluids from the Atlas facility were sampled in July, 1987. The information developed from this sampling program was used to define the contaminant source and constituents of concern for later groundwater detection and compliance monitoring programs at the site. The results of this testing indicated that several metallic and radiological compounds designated as hazardous constituents were present in the tailings solution. Table 5-2 summarizes the results of this sampling.

Contaminant Extent

The licensee has collected and analyzed groundwater samples from the alluvial aquifer downgradient of the tailings pile on a sporadic basis from 1976 to 1977. The monitoring program has changed several times over the years, and the collected data lack consistency in the sampling points, constituents analyzed, and laboratory methods used. These monitoring program changes make a complete evaluation of the contaminant impact history at the site difficult. Detailed descriptions of the current groundwater monitoring program are provided in section 5.4.3. The surface water monitoring program has remained essentially unchanged over the period of record.

The monitoring program largely consisted of three wells completed in the alluvium between the tailings impoundment and the Colorado River. Water-quality monitoring were originally conducted on a regular basis from 1982 to 1987, in monitoring wells ATP-1-S, ATP-2, ATP-3, MW-1-R, MW-2-R, and MW-3. These wells along with an upgradient monitoring well have been used to evaluate the impacts of the tailings impoundment on the shallow alluvial groundwater and determine the extent of contamination.

Three new wells were installed in 1990 for evaluating groundwater conditions at the site. These wells: AMM-1, AMM-2, and AMM-3 were all located in the river alluvium adjacent to the Colorado River. Monitoring well AMM-1 was designated as the background well, while wells AMM-2 and AMM-3 were designated as point of compliance wells. In addition, the upper completion of well ATP-2 was retained in the new groundwater monitoring program. Figure 5-1 shows the locations of the previous and current site monitoring wells.

Results of the monitoring program indicated that constituents from the impoundment had been seeping into the alluvium soils beneath the tailings pile and impacted the shallow groundwater in the alluvium. Consequently, the constituents that entered the alluvial groundwater will either be attenuated or retarded in the soil materials or discharged to the Colorado River. TDS concentrations for the previously monitored wells are shown below in Table 5-3. Table 5-4 shows the TDS concentrations from monitoring wells from the current monitoring program.

Atlas concluded that contaminated groundwater largely extends from the tailings pile eastward to the Colorado River (Western Technologies, 1989; Canonie, 1994); however, contour maps of contaminant concentrations indicate the likelihood that contaminants may have impacted the areas south and southeast of the tailings pile. Section 5.2.4 discusses the apparent inconsistency between the interpretation of groundwater flow directions with the distribution of geologic materials at the site. Additionally, contaminant concentrations measured at the site are consistent with solute transport by advective flow. Other transport mechanisms such as density gradients are not indicated by the site data. The location and measured concentrations within the alluvial monitoring wells appears to provide adequate data control to support the direction of contaminant flow provided by the licensee's documentation. NRC staff concludes that the lateral extent of contamination within the alluvial aquifer is not adequately determined. This is an open issue encompassed by the open issue identified in section 5.2.4.

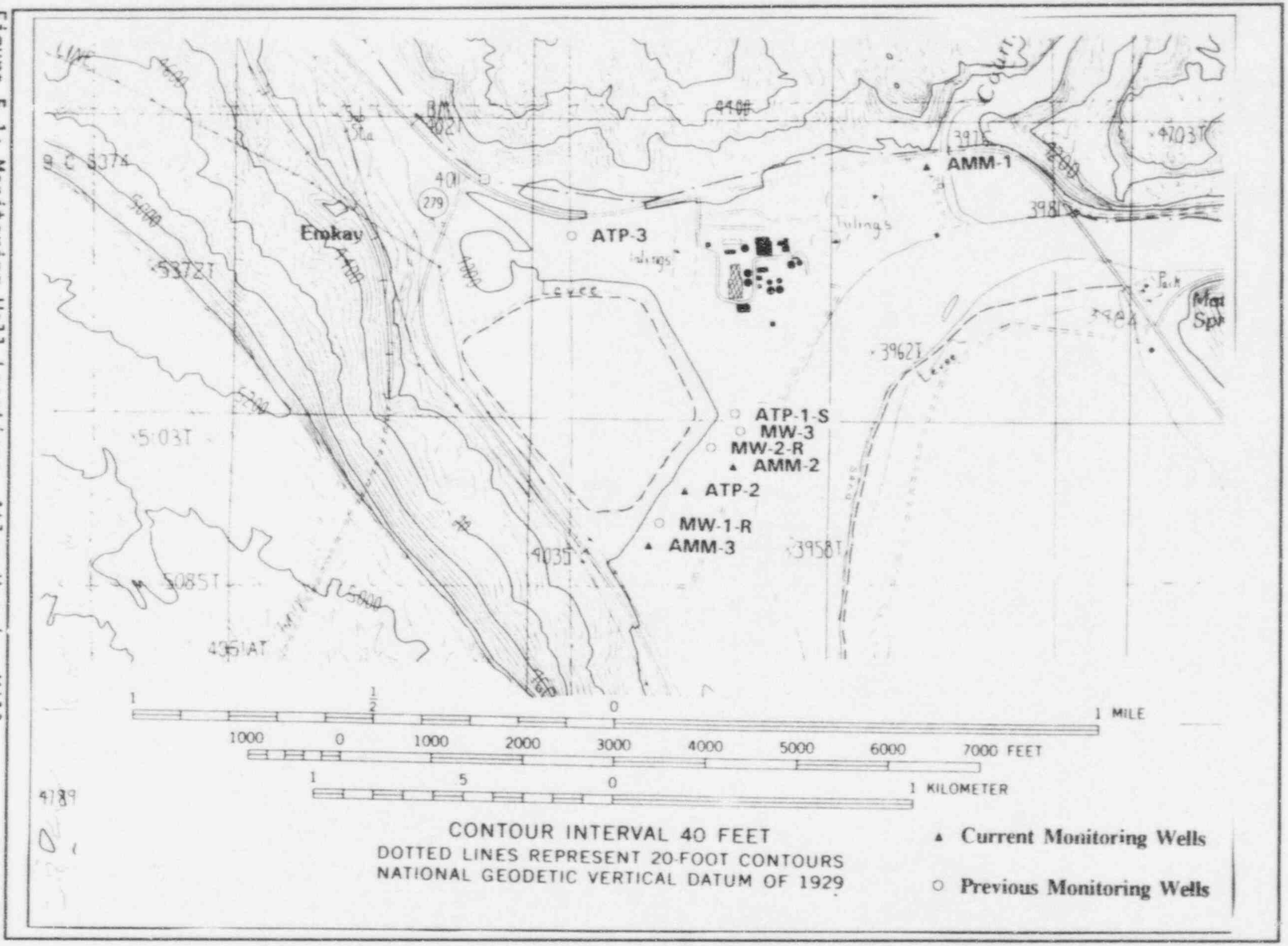

Figure 5-1: Monitoring Well Locations, Atlas Uranium Mill

Table 5-2: Analytical Results

Analytical Results Dissolved Constituents Atlas Minerals Site			
Compound	Concentration*	Compound	Concentration
Aluminum	450	Silicon	24
Antimony	<2.0	Sodium	1800
Arsenic	1.8	Strontium	3.6
Boron	<0.8	Tin	<2.0
Barium	0.25	Titanium	0.58
Beryllium	0.14	Uranium	8.9
Bromine	<500	Vanadium	53
Calcium	310	Zinc	5.9
Cadmium	0.49	Zirconium	<0.2
Cobalt	1.3	Ammonium	2400
Chromium	1.3	Bicarbonate	<5
Copper	11	Carbonate	<5
Iron	650	Chloride	410
Gallium	<3.0	Cyanide	0.006
Mercury	<0.005	Fluoride	<100
Lead	<2.0	Nitrite	<100
Lithium	3.7	Nitrate	<500
Magnesium	500	pH	2.19 SU
Manganese	28	Phosphate	<500
Molybdenum	0.52	Sulfate	30,000
Nickel	1.1	Sulfide	<5
Phosphorous	5.1	Total Dissolved Solids	23,900
Selenium	0.45	Total Suspended Solids	10
Silver	<0.5		

* Concentrations expressed in mg/L, unless otherwise indicated

Table 5-3: Total Dissolved Solids; Previous Monitoring Program

Total Dissolved Solids (mg/L)* Atlas Groundwater Previous Monitoring Program						
	Month and Year					
Well	5/82	8/83	3/84	8/85	8/86	10/87
ATP-1-S	106409	111860	92200	110000	109000	112000
ATP-2	12359	49053	58500	59300	43600	44300
ATP-3	1386	7440	1300	1420	1350	1360
MW-1-R	19966	19522	21900	23000	22500	35400
MW-2-R	24604	16788	20500	20300	23200	22500
MW-3	17482	21465	26300	31000	27600	30300
*all data from Atlas environmental monitoring reports						

Table 5-4: Total Dissolved Solids; Current Monitoring Program

Total Dissolved Solids (mg/L)* Atlas Groundwater Current Monitoring Program						
	Sampling Quarter and Year					
Well	2-90	4-90	2-91	4-91	2-92	4-92
AMM-1	6720	6710	6950	6980	6810	6570
AMM-2	22800	23200	22500	19400	19594	19300
AMM-3	12100	12100	13300	12300	12712	13400
ATP-2	32100	32200	17500	28200	15552	26000
	Sampling Quarter and Year					
Well	2-93	4-93	2-94	4-94	2-95	
AMM-1	6830	6660	6940	6450	7500	
AMM-2	17100	18600	18700	18150	19400	
AMM-3	12400	13200	16800	13730	18400	
ATP-2	20100	23100	13800	20930	17000	
*all data from Atlas environmental monitoring reports						

The vertical extent of contaminated groundwater was evaluated in a series of nested wells completed to various depth intervals. From the collected data, Atlas concludes that contamination from tailings seepage is restricted to the shallow portions of the alluvial aquifer. This conclusion is based on comparisons of water quality within the aquifer at various depths and the occurrence of brine at depths below about 24 m (80 ft) bls. The NRC staff agrees with the conclusion that the vertical extent of contamination is restricted to the relatively fresh groundwater within the upper portion of the alluvial aquifer.

Additionally, surface water samples have been collected from the Colorado River to evaluate the impact of the tailings seepage since about 1976. Figure 5-1 also shows the locations of the surface water sampling locations.

The surface water samples consisted of one sampling location upstream of the mill and five sampling locations below the mill site. Surface water data at similar locations have been periodically collected to the present. Tables 5-5 and 5-6 show the summaries of average concentrations for uranium, radium-226, and thorium-230 in the Colorado River and in the groundwater associated with the various sampling episodes.

Table 5-5: Average Concentrations; 1976 to 1977

Average Concentrations (pCi/l)* 1976 to 1977			
Samples	U-nat	Ra-226	Th-230
Colorado River upstream	20	0.72	2.8
Colorado River downstream	24	0.8	5.1
Atlas Groundwater	3200	2.4	18
*all data from Atlas environmental monitoring reports			

Table 5-6: Average Concentrations; 1979 to 1987

Average Concentrations (pCi/l)* 1979 to 1987			
Samples	U-nat	Ra-226	Th-230
Colorado River upstream	14	0.14	17
Colorado River downstream	9	0.15	5.0
Atlas Groundwater	1171	0.95	3.1
*all data from Atlas environmental monitoring reports			

Additional water quality data for TDS concentrations in the Colorado River have been collected for several years. Grab samples were taken on quarterly frequencies at both upstream and downstream stations. These sample results, for the period of 1989 to 1993 are shown in Table 5-7. These data show essentially no change between upstream and downstream TDS concentrations over the period of record.

Table 5-7: Total Dissolved Solids; Colorado River

Total Dissolved Solids (mg/L)*
Colorado River Samples

	Sampling Quarter and Year				
Location	1-86**	3-87	2-88	3-89	1-90
Upstream	695	577	987	800	823
Downstream	734	611	841	850	850

	Sampling Quarter and Year				
Location	1-91	1-92	1-93	1-94	2-95
Upstream	880	910	756	700	750
Downstream	880	970	742	720	790

* all data from Atlas environmental monitoring reports
** Measurements reported for this sampling did not distinguish between upstream and downstream locations. Measurements are reported in the order presented in the licensee's report.

A comparison between data collected from 1976 and 1977 to those from 1979 to 1987 indicates that the alluvial groundwater continued to receive seepage from the tailings impoundment, but the measured concentrations of uranium, radium-226, and thorium-230 in the alluvial materials had significantly decreased over that period. Concentrations of these same radionuclides in the Colorado River do not indicate any sort of trend. It should be noted that upstream concentrations of uranium and thorium are larger than those that are measured downstream from the mill. The concentration of radium is essentially the same above and below the mill site.

The initial findings from this sampling indicated that constituents entering the river from the site were not detectable in the water column, because of the mixing and dilution with the river water. Consequently, impacts to the downstream uses of river water was concluded to be insignificant.

Additional sampling in the Colorado River has recently been performed to support review efforts for the Environmental Impact Statement (EIS). The recent sampling efforts have focused on sediments and biota, in addition to surface-water samples. Details and discussions this recent surface water and sediment sampling are presented in the EIS.

5.2.6 Water Use

Water use in the vicinity of the site is described in a report by Western Technologies (1989). The report states that there are no existing groundwater supply wells on the property or hydraulically downgradient of the property. Atlas reported that a water well located approximately 300 meters (900 feet) east of monitoring well AMM-1, which is upgradient of the mill site, as "not fit for human use."

The Utah Division of Radiation Control, Department of Environmental Quality conducted a computer search of Water Rights records for northern Moab Valley, in the vicinity of the Atlas site. This search provided a listing of water rights diversions; which includes both surface water and groundwater uses. These records were provided to NRC staff for the purpose of making an independent verification of the water use inventory conducted by Atlas in 1989. Table 5-8 provides a summary of registered water rights in the vicinity of the Atlas site. The state's records show three registered water right within an approximate 0.8 km (½ mile) radius of the tailings pile and 14 water rights within an approximate 1.6 km (1 mile) radius of the tailings pile.

Table 5-8 lists one registered groundwater user (#168/Trapax) near the location mentioned in the Western Technologies report. Additionally, water users of Colorado River water and other surface water are identified from the state's water rights records. Most water registered water users are situated upgradient or upstream of the tailings pile; however, three water rights (#629,#1458, and #16590) are situated on the east bank of the Colorado River across from the site and one water right (#1046) is located approximately 1.1 km downstream of the site. The only other groundwater user within a 1.6 km (1 mi) radius is the National Parks Service at Arches National Park. This well is upgradient of the tailings pile.

5.3 Conceptual Design Features to Protect Water Resources

The Atlas reclamation plan describes the regraded tailings and engineered soil cover as the primary design components that will minimized water infiltration in the tailings pile (Canonie, 1992). The plan states that regrading the tailings and placement of a contoured soil cover will covey precipitation runoff away from the reclaimed tailings area, thus minimizing infiltration and provide groundwater protection. Atlas also states that infiltration will be reduced 2 to 3 orders of magnitude over the present uncovered condition of the pile, because a layer of Mancos Shale clay (radon barrier borrow material) will be included in the final cover design. The current design specifies 20.3 to 30.5 cm (8 to 12 in) of compacted clay for the radon barrier. Atlas states that assumed permeabilities of 1×10^{-4} to 1×10^{-5} cm/s and 1×10^{-7} cm/s were considered in the cover design (Canonie, 1992 pg. 22); however, no calculation or analysis is provided to support this statement. Furthermore, the reclamation plan does not indicate that a specified permeability was used to determine evaluate compliance with the groundwater protection standards for the site.

Because surface reclamation and groundwater compliance are not integrated into one plan, the licensee must clarify whether it plans to take engineering credit for any disposal cell component for meeting compliance with the

Table 5-8: Water Rights Inventory

Water Rights Inventory in Vicinity of Atlas Site					
Location Twn Rng Sec	Water Right # / Owner	Water Right Description	Approx. Distance	Water Use*	Hydraulic Relation
25S 21E 27	629/Utah Div. of Wildlife Res.	Colorado River	0.64 km (0.4 mi)	I,S	cross-stream
25S 21E 27	1458/Grand County Con. Dist.	Colorado River	0.64 km (0.4 mi)	I	cross-stream
25S 21E 27	16590/Utah Div. of Wildlife Res.	Colorado River	0.64 km (0.4 mi)	I,O	cross-stream
25S 21E 27	56/McClatchy, Warren & Millie	Colorado River	0.92 km (0.57 mi)	O	upstream
25S 21E 34	1046/U.S. Bureau of Land Mgmt.	Colorado River	1.1 km (0.69 mi)	S,O	down-stream
25S 21E 27	168/Trapax	groundwater	1.2 km (0.7 mi)	D,S	up-gradient
25S 21E 26	629/Utah Div. of Wildlife Res.	Colorado River	1.2 km (0.75 mi)	I,S	upstream
25S 21E 26	1458/Grand County Con. Dist.	Colorado River	1.2 km (0.75 mi)	I	upstream
25S 21E 26	16590/Utah Div. of Wildlife Res.	Colorado River	1.2 km (0.75 mi)	I,O	upstream
25S 21E 26	1612/Utah Div. of Wildlife Res.	groundwater	1.4 km (0.85 mi)	I,O	upstream
25S 21E 26	16591/Utah Div. of Wildlife Res.	groundwater	1.4 km (0.85 mi)	I,O	upstream
25S 21E 26	1055/Canyonland Cattle Co. Ltd.	Colorado River	1.5 km (0.95 mi)	S	upstream
25S 21E 26	17961/Oliver, Delbert O.	groundwater	1.5 km (0.95 mi)	I	upstream
25S 21E 26	1089/Columbia Gas Dev. Corp.	Colorado River	1.6 km (1 mi)	O	upstream
25S 21E 26	18444/Canyonland Cattle Co. Ltd.	Colorado R Pack Creek	1.6 km (1 mi)	S	upstream
25S 21E 21	166/U.S. Nat. Parks Ser.	groundwater	1.6 km (1 mi)	D,O	up-gradient

* D= Domestic, I=Irrigation, S=Stock Watering, O=Other(not specified),

groundwater protection standards for the site. If engineering credit is taken, costs associated with achieving the necessary cover permeability must be incorporated into the reclamation plan. This is an **OPEN ISSUE**.

5.4 Groundwater Protection Standards and Regulatory Requirements

5.4.1 Water Resource Protection Standards

Criterion 5 and Criterion 13 of 10 CFR 40, Appendix A encompass the basic groundwater protection standards for uranium mill tailings impoundments. Paragraph 5B(5) requires that compliance limits for hazardous constituents are set at the background concentration, the Maximum Values listed in Paragraph 5C if the background limit is below the listed value for a particular constituent, or an alternate concentration limit (ACL) based on chemical-specific and site-specific considerations.

5.4.2 Performance Assessment

A performance assessment of the disposal cell for meeting the groundwater protection standards is not required by 10 CFR 40. However, a performance evaluation for meeting proposed ACLs is an integral part of the regulatory review for approving ACLs. If the licensee plans to apply for ACLs, as part of its CAP revisions, then a performance evaluation must be included in the ACL application.

5.4.3 Groundwater Monitoring and Corrective Action

Groundwater Monitoring Program

The requirement to implement a detection monitoring program was incorporated into the Atlas license by Amendment No. 1, dated June 15, 1988. This amendment required the licensee to monitor appropriate hazardous constituents, establish compliance points and a background well, as well as determine the extent and concentration of hazardous constituents in the alluvial aquifer. The groundwater compliance program did not include an examination of deeper aquifers, since existing data indicated that a brine layer exists in the lower portion of the alluvium.

In response to Amendment No. 1, the licensee prepared a March 1989 submittal that compiled groundwater monitoring data, proposed a modified groundwater monitoring program, discussed the extent and concentrations of hazardous constituents in the aquifer, assessed risk and hazards, and evaluated alternative corrective actions. An NRC review of this submittal determined that it was responsive to regulatory requirements relative to groundwater compliance. The major consideration in this report was to determine if there were any impacts at the point of exposure, which is the Colorado River.

License condition 17 established the compliance monitoring program and the compliance limits for certain constituents detected in the groundwater at the site. Table 5-9 lists the compliance points, constituents, compliance limits, and sampling frequencies for the Atlas monitoring program. Monitoring well locations are shown in Figure 5-1.

Table 5-9: Groundwater Protection Standards

Groundwater Protection Standards Atlas Uranium Mill Tailings Pile			
Sampling Frequency and Wells	Parameter or Constituent	Compliance Limit	Compliance Standard Applied
Quarterly sampling of wells AMM-1, AMM-2, AMM-3, and ATP-2-S	chloride	None	N/A
	nitrate		
	sodium		
	sulfate		
	pH		
	TDS		
	water level		
Semi-annual sampling of wells AMM-1, AMM-2, AMM-3, and ATP-2-S	chromium	0.08 mg/L	background
	gross alpha	33 pCi/L	background
	molybdenum	0.05 mg/L	background
	nickel	0.06 mg/L	background
	radium-226 & -228	5 pCi/L	paragraph 5C
	selenium	0.01 mg/L	paragraph 5C
	vanadium	0.04 mg/L	background
	uranium	4.0 mg/L	background

Corrective Action Program

The licensee was required to develop a corrective action program for mitigating contaminated groundwater at the site, in response to the detection of hazardous constituents in excess of the compliance standards. Atlas prepared two submittals that characterized the geology, evaluated the data, and discussed alternative corrective actions. The geology characterization, as well as the collected groundwater data, confirmed that leakage from the tailings impoundment had impacted the alluvial groundwater, and that hazardous constituents eventually traveled to the Colorado River.

The initial conclusion of the water quality data review was that any impacts to the Colorado River were insignificant, because no measurable concentration differences in the Colorado River could be detected over the period of record. Although the site information indicates that tailings seepage was discharging to the River, the contaminant dilution by relatively large volume of the Colorado River appeared to mitigate any potential health impacts.

The study also estimated a leakage rate of approximately 95 L/min (25 gpm), based on a water balance study. This leakage rate correlates well with the surface area of the tailings impoundment and the estimated hydraulic conductivity of the alluvium, based on soil materials encountered during well drilling. The estimated rate was predicted to diminish to about 30 L/min (8 gpm) over the next 20 years and then maintain that rate for an undetermined period.

The licensee submitted a license amendment request which evaluated several corrective action alternatives for mitigating contaminated groundwater. The evaluated corrective actions were divided into two groups. One group of alternatives, which largely focused on altering the tailings pile included:

- moving the tailings to an alternate site,
- mechanically dewatering the tailings,
- constructing a hydraulic barrier wall into the alluvium, and
- constructing a bottom seal for the tailings.

All of these alternatives were considered unreasonably costly, when comparing the risks to benefits. NRC staff concurred with the licensee's conclusion that these alternatives were unreasonable when considering the risks as well as the costs and associated benefits.

The licensee also evaluated five other corrective action alternatives, which primarily focused on groundwater remediation. These alternatives included:

- pumping and treating groundwater using in situ precipitation of metals,
- pumping and treating of groundwater using biomass removal of metals,
- a gravity feed groundwater treatment system with in situ precipitation of metals,
- pressure feed of groundwater and tailings treatment with in situ precipitation of metals, and
- minimizing recharge to the tailings.

The licensee ultimately recommended the minimizing recharge alternative as the preferred alternative. An NRC assessment of all nine alternative corrective actions indicated that the later five potential corrective actions showed that cost effective alternatives existed.

The licensee proposed to minimize the tailings recharge by constructing an enhanced evaporation system on top of the tailings pile. This system would pump solution from the tailings surface pool, spray it into the atmosphere and onto dry tailings beaches, and thereby rapidly reduce the solution level in the tailings impoundment. Additionally, the licensee agreed to construct and operate a tailings dewatering system that consisted of wells completed into the saturated portion of the tailings.

NRC approved construction and operation of the enhanced evaporation system, which operated for roughly three years at an annual pumping rate of about 7600 kL (20 Mgal). This system eliminated most of the ponded surface water on the tailings by the later part of 1992, although a small pond existed until 1995. A decline in the water level within the tailings also accompanied the removal of the ponded water. Any water that intermittently is found on the tailings impoundment is from precipitation and either recharges the tailings or evaporates to the atmosphere.

The tailings dewatering system was constructed on a test scale in 1990. It consisted of a series of wells in the tailings installed at locations accessible to drilling equipment. Each well was equipped with a pump, which would route tailings solution to the surface of the impoundment for spraying to the atmosphere.

The dewatering system operated for a short period of time, when it became apparent that a combination of poor yields, corrosive solutions, and small particle sizes would be stressful on the equipment and make the feasibility of continuous pumping questionable. However, the NRC considered intermittent pumping feasible, which had been utilized in these wells since their installation. The amounts of solution that were recovered from these wells and the rate of recovery are shown in Table 5-10.

Table 5-10: Operation Data: Tailings Dewatering System

Operational Data Tailings Dewatering System Atlas Tailings Pile			
Operational Year	Volume Recovered in kL (gal)	Total System Yield in L/min (gpm)	Total Dissolved Solids (mg/L)
1990	3173 (838,276)	14.5 (3.83)	24,700
1991	7442 (1,966,000)	14.2 (3.74)	25,065
1992	6038 (1,595,000)	12.5 (3.03)	30,250

Table 5-10 shows that approximately 16,653 kL (4.4 Mgal) of solution were removed from the tailings pile. It should also be noted that the rate at which the dewatering is taking place has shown a slight decline over the period of record. Additionally, the TDS concentration of the recovered solution is continued to rise, likely in response to the reduced recharge in the tailings areas being dewatered.

5.5 Cleanup and Control of Existing Contamination

The approved CAP has eliminated the residual ponded water on the tailings pile and reduced the level of saturation within the tailings. In addition, contaminant concentrations within the alluvial aquifer have been reduced over the same time period. However, contaminant concentrations within the aquifer still remain above the groundwater compliance limits established in the license. Currently, the licensee has not implemented any corrective action to directly reduce the contaminant levels in the uppermost aquifer. The licensee must address compliance with the groundwater standards in 10 CFR 40, Appendix A through revisions of the CAP.

5.6 Conclusions

Water resource information for the Atlas Uranium Mill Tailings Reclamation Plan have been evaluated by NRC staff to determine compliance with the appropriate regulations in 10 CFR 40, Appendix A. Data and technical information that is directly applicable to surface reclamation were examined. Other information and data pertaining to groundwater corrective action were not evaluated for compliance, since NRC determines groundwater cleanup compliance under a separate Corrective Action Plan.

It is apparent that seepage from the tailings impoundment is impacting groundwater quality in the shallow alluvial aquifer, based on the collected water quality data. The seepage is traveling as a dissolved contaminant plume which discharges to the Colorado River. The seepage rate from the tailings pile appears to have declined over the past several years. Currently the leakage rate is estimated to be 95 L/min (25 gpm) and is further expected to decrease to 30 L/min (8 gpm).

Impacts to the property immediately south of the Atlas property have not been adequately determined by the licensee. Geological information and contaminant concentration contours indicate a potential impact to the adjacent property. This is and **OPEN ISSUE**.

Surface water monitoring for the last 20 years indicates there is no measurable increase of the contaminants in the waters of the Colorado River, due in large part to dilution. This finding was originally predicted to occur in the EIS for license renewal and has been confirmed by upstream and downstream monitoring in the Colorado River. However, monitoring of the Colorado River near the site indicates the presence of a mixing zone with higher concentrations of some contaminants. Additional evaluations of seepage impacts to sediment and biota in the river are assessed in the EIS for reclamation.

Ambient groundwater quality in the alluvial (uppermost) aquifer appears poor, given the moderately elevated TDS concentrations and elevated concentrations of selenium, combined radium-226 & -228, and uranium; however, the proximity of the upgradient background well AMM-1 to a former ore storage pad raises a question to the representativeness of this water quality information. The licensee must provide information showing that this well location is representative of background water quality conditions in the uppermost aquifer. This is an **OPEN ISSUE**.

Sixteen registered water rights are located within a 1.6 km radius of the tailings pile. Fifteen of these water rights are allocated for the Colorado River or other surface water points. Only two water rights are designated for groundwater use. Four of the surface water users are situated either cross-stream or downstream of the tailings pile. Water samples collected in the Colorado River do not indicate that the tailings seepage is impacting the river water quality, other than in a small mixing zone. Both groundwater users are situated upgradient of the tailings pile.

The licensee indicates that construction of an engineered clay cover and contoured top slope will reduce precipitation infiltration into the tailings by 2 to 3 orders of magnitude; however, it is not clear from the information provided in the reclamation plan whether the licensee plans to take engineering credit for these design features for demonstrating groundwater compliance at the site. If engineering is taken, the associated costs with achieving the necessary cover permeability must be incorporated into the reclamation plan. This is an **OPEN ISSUE**.

The licensee must revise the current Corrective Action Plan to demonstrate compliance with the groundwater cleanup standards in the license. This will be evaluated by NRC staff as part of the groundwater corrective action program.

6.0 RADON ATTENUATION

6.1 Introduction

This section presents the staff evaluation of the radon barrier design aspects of the Reclamation Plan and Specifications, and its revisions (June 1992, April 1993, and May 1994) for the Moab, Utah, Title II Project site. The staff review was conducted in accordance with guidance in the SRP (NRC 1993). The staff review of the radon attenuation design of the disposal cell cover is to ensure compliance with the radon flux design standard of 20 picocuries per square meter per second (pCi/m^2s) averaged over the impoundment, required by Criterion 6 (1) of Appendix A to 10 CFR Part 40. In addition, the other radiological requirements of Criterion 6 (e.g., gamma levels, cover radionuclide concentration) are considered in this review.

EPA has identified radon-222 (Rn-222) as the main health hazard from uranium mill tailings. Rn-222 is an inert gas resulting from the radioactive decay of radium-226 (Ra-226). Because Rn-222 has a short half-life (3.8 days), the amount of radon from uranium mill tailings reaching the atmosphere is reduced by restricting the gas movement long enough so that radon decays to a solid daughter which remains within the disposal cell. The staff, in its review, evaluates the estimation of the long-term (at least 200 years from now) radon emanation rate (flux) from the disposal cell cover averaged over at least a one-year period by utilizing a computer code (RAECOM or RADON). Fundamental to the use of the code is development of a radon flux model which is based on parameter values derived during characterization of the various materials that will make up the pile and/or the use of conservative estimates. Therefore, the staff's review addressed the adequacy of the parameter values (i.e., code inputs) and the overall radon flux model by evaluating the justification and assumptions made for each value to confirm that each was representative of the material or conservative, consistent with site construction specifications, and based on long-term (at least 200 years) conditions.

Also included in the NRC staff review was an evaluation of the pertinent aspects of design related to the contaminated materials and radon barrier soil. For example, layers of the cover (6-inch filter/bedding on side slopes and 4 to 9-inch rock erosion protection) were evaluated for their ability to protect the radon barrier layer from drying and disruption by considering the long-term effects of freeze-thaw damage and biointrusion. In addition, the review included consideration of the fact that the barrier layer thickness is also designed to satisfy criteria for construction, settlement, cracking, and infiltration of surface water. These aspects of cell design are discussed in Section 3 of this report. Erosion protection aspects of the cover design are discussed in Section 4.

The staff's evaluation of the information provided in the Reclamation Plan on the parameter values and the resulting radon flux model are discussed below.

6.2 Evaluation of Model Parameters

This section provides the results of the staff review of the radon flux model parameter values derived by Atlas. Section 6.2.1 provides staff comments on the approaches to parameter characterization (sampling and testing of materials) followed by Atlas, Section 6.2.2 provides staff comments on Atlas' parameter values derived for contaminated materials at the site, and Section 6.2.3 provides staff comments on Atlas' parameter values for radon barrier soils.

In order to assess the appropriate thickness of the earthen cover required to limit radon emission to meet the 20 pCi/m^2s standard, the characteristics (physical and radiological) of the radon barrier soils and approximately the upper 15 feet of contaminated materials must be established. Material parameters that affect radon diffusion and that are used in the computer code include: material thickness, density, porosity, long-term moisture content, and radon diffusion coefficient. In addition, Ra-226 activity concentration and radon emanation fraction of the various types of contaminated materials are parameters of the radon model. These are the parameters evaluated in this review. The parameter values utilized by Atlas are identified in Table 6-1.

6.2.1 Characterization of Materials

Radiological characterization programs for the site were conducted in 1988 and 1992. Sampling locations are shown on sheet 2 of 10, Drawing 88-067-E64 (April 23, 1993). All borehole logs and pertinent data used in the cover design are contained in Appendix A of the June 4, 1992, submittal (except the Ra-226 data for the "affected" material), as modified by the April 14, 1993, submittal. Laboratory testing included specific gravity, diffusion coefficient, in-place density and moisture, gradation, and capillary moisture relationships. The porosity value for materials was calculated from the dry density and the measured specific gravity. In addition, analysis for radium activity and emanation coefficient was performed for the contaminated material. Staff considers that all testing methods appear to be appropriate but concerns regarding the limited number and composition of some samples are discussed below.

Tailings and Ore Material

The characterization program for the tailings pile (1992) consisted of six test borings on the top slope to depths up to 8 feet. The samples collected were grouped into three material types; ore (3 samples), coarse sand tailings (16 samples), and fine tailings (12 samples). The Reclamation Plan indicates that samples for each material type were composited and three samples for each type were tested. The limited number of samples and the method of compositing has the most impact on the Ra-226 value of the tailings and is discussed in Section 6.2.2. In response to a previously identified staff concern regarding the appropriateness of the composite sampling technique, Atlas provided the written procedure (March 1995) that indicates each composite sample was formed from different samples. Atlas also committed to revising pages B7 and B8 of the Reclamation Plan to clarify how the composite tailings and ore samples were constructed.

Table 6-1: Atlas Radon Input Summary

March 1995 submittal spec. gravity: 2.7-2.9 measured

AREA/ MATERIAL	THICK-NESS (cm.)	POROS-ITY	DRY DENSITY (g/cm^2)	Ra-226 (pCi/g)	EMANAT. FRACT.	MOISTURE Percent (by wt.)	DIFF. COEFF. (cm^2/s)
FINE T.							
fines	123	.5057	1.44	893	.35	24	.00185
fines	129	.5057	1.44	1339	.35	24	.00185
fines	56	.5057	1.44	1938	.35	24	.00185
coarse	213.4	.435	1.53	241	.23	4.4	.0247
affected	40.6	.295	1.91	19.5	.28	2.8	.0197
clay	30.5	.3897	1.71	0	0	14.7	.00168
sandy	22.9	.3368	1.79	0	0	2.8	.021
FLUX 19.8							
COARSE T.							
coarse	500	.435	1.53	241	.23	4.4	.0247
ore	15.2	.3637	1.72	212.7	.28	9.0	.0083
affected	40.6	.2954	1.91	19.5	.28	2.8	.0197
clay	20.3	.3897	1.71	0	0	14.7	.00168
sandy	22.9	.3368	1.79	0	0	2.8	.021
FLUX 18.5							
SIDE SLOPE							
coarse	500	.435	1.53	241	.23	4.4	.0247
sandy	213.4	.3368	1.79	0	0	2.8	.021
FLUX 19.15							

Staff considers that the Reclamation Plan needs to be revised to accurately describe the sampling program. Revision of the Reclamation Plan is considered a **CONFIRMATORY ITEM**.

"Affected" and Radon Barrier Sandy Soils

In the characterization of soils, samples from Moab Wash were obtained from 15 pits and grouped, based on the radium concentration, into "affected" and "clean" soils. The licensee defines "affected" soil as any soil in the mill area, boneyard, or outlying area that exceeds the radium concentration of 5 picoCuries per gram (pCi/g) above background in soil that will remain in the upper 15 cm of soil, or exceeds 10 pCi/g above background in the 15 cm layers of soil that will be below the surface after reclamation. The clean (i.e., uncontaminated) sandy soil obtained from the reconfiguration of Moab Wash will be used for the upper layer of the radon barrier.

A composite sample was constructed from three samples of "affected" (contaminated) soils, and another composite sample was constructed from eight samples of clean soils. Atlas indicated that the samples selected were coarser than the average Moab Wash soils to provide conservative test results. The composite samples were divided into three splits, and each of these was then divided in half for geotechnical and radiological testing. In addition, the licensee collected and tested three composite samples of soil from a proposed borrow area (assumed to be uncontaminated) located on Atlas property west of the tailings disposal area. This material represents an alternative source of sandy soil for the radon barrier.

Staff considers that the characterization efforts for the sandy soil of the radon barrier is limited but adequate for fairly homogeneous material. However, the "affected" soil probably is not homogenous in either physical or radiological characteristics. Therefore, some of the parameter values of "affected" soil from the mill site (to 6 feet deep) could vary significantly from the "affected" windblown surface material in Moab Wash. Specific staff concerns regarding the characterization program for "affected" soils are identified in Section 6.2.2.

Radon Barrier Clay Material

The design of the Atlas radon barrier utilizes a clay layer for the lower portion of the barrier. Three clay samples were collected at the Klondike Flat area, a potential source of this clay material, located approximately 13.8 miles north of the facility. However, the exact location of the clay borrow site has not been chosen. As discussed in detail in Section 6.2.3 of this report, staff determined that additional testing of the final clay borrow material is required.

6.2.2 Parameters for Contaminated Materials

Tailings and Ore Material

The dry density parameter value derived by the licensee for fine tailings is the average in-place dry density adjusted to account for the overburden stress from the relocated coarse sands and the cover system. The measured dry density of the coarse tailings was not adjusted as the effect of overburden stress would be insignificant for this material. Staff considers the values acceptable and notes that the density value is somewhat conservative for the 7 feet of coarse tailings that will be compacted to 90 percent on top of the fine tailings.

The Ra-226 values for top slope fine and coarse tailings were derived by the licensee from samples composited over various depth intervals, an appropriate method only if there is evidence that the Ra-226 concentration is fairly homogeneous. This restriction on the sampling technique is necessary because the computer code used to calculate the estimated long-term radon flux is sensitive to the vertical distribution of Ra-226 in approximately the upper 15 feet of contaminated material, reflecting the attenuation of radon in deeper layers. Based on the annual processed ore grade data submitted by Atlas, NRC staff calculated that the upper 2 feet of tailings should have approximately twice the concentration of Ra-226 as some lower layers. Atlas subsequently provided a radon model (March 1995, Appendix G) that reflects this layering by Ra-226 concentration in the fine tailings.

Atlas did not revise the Ra-226 value for coarse tailings because it was assumed that sufficient mixing of these tailings should occur during recontouring of the cell. The results of the staff analysis suggests that the Ra-226 input value for the coarse tailings should be 291 pCi/g instead of the 241 pCi/g value used by Atlas. The staff's value was derived by assuming that the upper 6 feet of coarse tailings on the top slope are mixed during reconfiguration of the cell (calculated from the ore grade processed from 1980 to 1984). To address this issue, the Atlas sampling plan for Ra-226 analysis should include the upper 3 to 4 feet of coarse tailings. In addition, Atlas should provide the technical basis for modeling the coarse tailings on the sideslopes as being homogenous (i.e., a single layer) for Ra-226 concentration. Therefore, until the commitment to perform the Ra-226 analysis for the coarse tailings and the noted technical basis are provided in the Reclamation Plan, the Ra-226 value for the coarse tailings is an **OPEN ISSUE**.

The licensee's long-term moisture content value for the coarse tailings was based on the results from capillary moisture testing. The average value of 4.4 percent is conservative and, therefore, acceptable. The in-place moisture content reported for the fine tailings was 27.7 percent and the resulting average moisture of 30.9 percent under 15 bar pressure indicates that the test procedure and/or test results may not be appropriate to estimate the long-term moisture content for fine-grained materials. Based on a review of available data from similar sites, NRC staff recommended that 24 percent moisture be used for fine tailings in the model. The licensee agreed (March 1995) and provided a normalized diffusion coefficient value corresponding to this moisture level for the fine tailings, as suggested by staff. Therefore, this previous issue is considered closed.

The measured diffusion coefficient values for the tailings used in the model are not as conservative as the long-term moisture values and are not conservative (low) when compared to the code-calculated diffusion coefficient. This lack of conservatism is not an open issue because of other conservative aspects of the Atlas radon flux model and the small impact of this parameter (for material in deep layers) on the flux calculation result.

The ore layer in the disposal cell (periphery of top slope) consists of pieces of ore up to 6 inches in diameter. Staff determined that this thin layer of ore is of limited importance for the radon model and the parameter values chosen by Atlas appear reasonable.

"Affected" Soils

The licensee's parameter input values for the "affected" soil are based on average test values from composited samples. The staff had previously questioned this approach because the sampling procedure may not have provided representative material. In particular, staff was concerned that a Ra-226 value based on a composite of three samples might not adequately characterize the large amount of "affected" soil which includes tailings slurry spillage and deep deposits on the mill site. Atlas responded that the particle size and saturation of the "affected" soil are more critical parameters in the radon model than the Ra-226 concentration and that the volume of soil with high levels of Ra-226 will be small when compared to the large volume of windblown soil with near background levels of Ra-226. Atlas also indicated that the three samples tested were the coarsest samples taken so that the values would be conservative. Staff agrees with Atlas that soil saturation and the large volume of windblown material are important, but considers that coarse samples do not yield conservative values for the Ra-226 and diffusion coefficient parameters. However, further justification of the parameters values is not warranted because Atlas has addressed the issue of the "affected" soil sampling procedure resulting in unrepresentative parameter values by committing (March 1995) to test the "affected" soil after it is placed in the cell.

In the proposed testing program, Atlas commits to take samples at 15 locations from the upper and lower half of the "affected" soil layer in the disposal cell. Each sample will be analyzed for grain-size distribution, in-place density and moisture content, specific gravity, Ra-226 concentration, and emanation fraction. In addition, three samples of varying coarseness will be tested for diffusion coefficient. Staff suggests that the samples used for the diffusion coefficient analysis be representative of the layer being modeled, as the grain-size affect on the diffusion coefficient has already been documented in NUREG/CR-3533 (NRC 1984). Atlas stated that the test results will be reported to NRC prior to starting construction of the clay layer of the radon barrier.

The staff agrees with the general approach identified by the licensee in its proposed testing program for "affected" soil. Incorporation of the proposed testing program into the Reclamation Plan is considered a **CONFIRMATORY ITEM**.

6.2.3 Parameters for Radon Barrier Soils

Moab Wash Sandy Soil

Most of Atlas' parameter values for geotechnical properties for the uncontaminated Moab Wash sandy soils are the average test results of three splits of a composite sample. Staff agrees that the samples taken should be representative of the available borrow material and considers that the limited testing is acceptable for the geotechnical parameters.

The density and porosity values used in the model are within the expected range for sandy soil and are acceptable to staff. The long-term moisture content of 2.8 percent was calculated using the Rawls and Brakensiek equation (NRC 1989) and is conservative considering the nature of the material. The diffusion coefficient value was determined from tests on samples with moisture contents (percent dry weight) that were less than the long-term moisture value which is conservative and, therefore, acceptable to staff.

The Ra-226 parameter value for the sandy soil layer of the radon barrier is assumed to be zero or background in the Atlas model. Staff had previously expressed concern that significant concentrations of windblown contamination might remain in Moab Wash soil excavated for the sandy soil layer of the radon barrier. This concern is based first on Atlas' reliance on gamma surveys to distinguish tailings contamination and secondly on the definition of background Ra-226 in the Reclamation Plan. The gamma survey is a concern because gamma meter readings do not correlate well with soil Ra-226 concentrations in the range of concern (approximately background) for tailings cleanup in the Moab Wash borrow area. Moab Wash soil that will be used for the radon barrier must have background levels of Ra-226 in order to comply with Criterion 6 (5) which states that "...soils used for near surface cover must be essentially the same, as far as radioactivity is concerned, as that of surrounding surface soils." Therefore, a thorough gamma survey and a conservative gamma level would need to be employed to avoid leaving significant contamination in the Moab Wash borrow area and, as a result, potentially in the radon barrier.

The second concern regarding the potential for residual contamination in the cell cover is the definition of soil background Ra-226 in the construction specifications. The background Ra-226 value is defined as "the average value plus two standard deviations." Such a definition could result in significant amounts of Ra-226 remaining in the Moab Wash soil that will be placed in the cover, causing non-compliance with Criterion 6 (5).

Atlas responded to the first concern by indicating that the gamma radiation survey method was used to estimate the extent of contamination for design purposes and that it provides a conservative estimate. Staff considers that this response does not fully address the concern because without knowing how the survey will be implemented, it is not possible to judge the adequacy of the gamma survey method for defining acceptable radon barrier soils in the Moab Wash borrow area.

Atlas responded to the second concern for the sandy layer of the radon barrier by indicating that the Reclamation Plan Construction Specifications will be revised to indicate that the soil background Ra-226 value is the average value approved by NRC (March 1995). Atlas also submitted a proposed sampling and testing plan for establishing a soil background Ra-226 value (March 1995, Appendix F). Test results will be provided to NRC for approval, prior to using the Ra-226 value for cleanup verification. Staff considers this approach acceptable to address the second part of the issue of the Ra-226 value for the sandy layer of the radon barrier. However, until the gamma survey/sampling procedure for verification of tailings cleanup in the Moab Wash sandy soil borrow area is provided for NRC approval and the Reclamation Plan Specifications (Section 1.14 and 5.3.3) and page 40 of the text (April 1993) are revised to indicate that the background soil Ra-226 value is the average value approved by NRC, the Ra-226 parameter value for the sandy layer of the radon barrier is an **OPEN ISSUE**.

Klondike Flats Clay

Atlas' radiological and geotechnical parameter values for the clay (obtained in the Klondike Flats area) are the average results of testing performed on three samples. Atlas stated (March 1995) that the characteristics of the clay (Mancos Shale) were uniform throughout the formation and that DOE had used material from the same formation to construct the radon barrier at the Grand Junction Title I site. Atlas has not completed arrangements for a particular borrow source and relies on the construction specifications to support the radon barrier design in lieu of extensive borrow source characterization. The specifications describe prequalification procedures, as well as requirements for testing the source throughout construction.

Based on a review of the physical properties, NRC staff determined that the parameter values for the clay were acceptable except for the long-term moisture value, as discussed below. The tested material met the proposed construction specifications for the clay layer of the radon barrier.

Atlas derived a long-term moisture content value of 16.2 percent by averaging capillary moisture test results. As indicated in the discussion of the fine tailings, staff questioned the validity of applying results from this test procedure to this modeling application without comparison to the results of other methods of estimating the long-term moisture content or in situ measurements. Based on its own analysis, staff determined that a moisture value of 14.7 percent (value used in the Grand Junction model) was appropriate for the clay layer of the radon barrier if supported by borrow source characterization. The results of this analysis were communicated to Atlas and Atlas accepted this moisture value and adjusted the measured diffusion coefficient value for the clay in the proposed radon model (March 1995) to correspond to a revised moisture value of 14.7 percent.

Staff also notes that the diffusion coefficient value (0.00168 cm^2/s) Atlas used is significantly different (i.e., less conservative) from the value (0.0025 cm^2/s) derived by the Department of Energy after extensive testing of the Grand Junction clay at the same moisture content approved for the Atlas clay. The low diffusion coefficient of the radon barrier clay is critical to Atlas' demonstration, through its radon barrier modeling, that the long-term radon flux standard can be met. However, the staff's concern related to the diffusion coefficient has been addressed by Atlas' commitment to do further testing (including at least 3 diffusion coefficient tests) of the clay borrow area prior to construction of the clay layer.

Because Atlas has not chosen a final borrow source for the clay material, staff considers that the test values used for parameter values must be confirmed. Therefore, incorporation of the proposed testing program for the final clay borrow area into the Reclamation Plan is a **CONFIRMATORY ITEM**.

Staff further considers that the clay borrow proposed testing program should also include analysis and/or gamma surveys to demonstrate that the clay layer of the radon barrier will contain background levels of Ra-226, in order to comply with Criterion 6 (5). This is an **OPEN ISSUE**.

6.3 Calculational Methodology and Results

Atlas modeled the radon flux for the covered disposal cell utilizing the RADON computer code (NRC, 1989). For modeling and design purposes, Atlas divided the disposal cell into three areas: 1) the embankment (side slopes), which consists of coarse tailings; 2) coarse tailings in the peripheral portion of the impoundment (top slope); and 3) fine tailings within the central portion of the impoundment.

Area 1, the side slopes (approximately 45 acres), consists of coarse tailings designed with a 7-foot-thick sandy layer for the radon barrier. Areas 2 and 3 (approximately 62 and 29 acres, respectively) will consist of coarse tailings over ore and fine tailings, respectively, because the licensee proposes to decrease the slope of the existing embankment by moving coarse tailings to the top. This will result in a 7-foot-thick layer over the fine tailings. The fine tailings have a high Ra-226 concentration so the overlying thick layer of coarse tailings will reduce radon emanation from this source. The less contaminated "affected" soil, at least 16 inches thick, will then be placed on top of coarse tailings in areas 2 and 3.

In response to NRC staff comments, Atlas proposed a revised radon barrier design for the top slope (i.e., Areas 2 and 3) in March 1995 (see Figure 6.1), that was based on a revised radon model that relies on more conservative parameter values. In the revised design, the radon barrier minimum thickness (clay plus sandy layers) has been increased to 17 inches over the coarse tailings area, and to 21 inches over the fine tailings area. The clay layer will be a minimum of 8 inches thick over the coarse tailings area and 12 inches thick over the fine tailings area. The clean soil layer minimum thickness has been increased to 9 inches over the entire top slope. Because the side slopes do not contain fine tailings or the clay layer, Atlas did not change the model for that area.

The radon flux model for each area, considering parameter values and proposed construction, is somewhat conservative in that the radon attenuation resulting from the 6-inch filter layer on the sideslopes was not included. Also, Atlas noted that portions of the clean dike fill material (originally placed to retain the tailings) and the interim cover will remain in place, but other portions will be mixed with the "affected" soil layer and upper layer of tailings during excavation and regrading. The ultimate disposition of these clean materials cannot be easily quantified at this point but will provide additional radon attenuation capacity not accounted for in the model.

The Atlas radon flux models/calculations assume that the Ra-226 content of the clay and sandy layers of the radon barrier is zero. This is appropriate because the footnote to Criterion 6 (1) indicates that the flux standard applies only to emissions from byproduct materials. However, the footnote states that the radon emissions from covering materials should be estimated as part of developing a closure plan. This requirement reemphasizes the need for Atlas to address the staff concern regarding the Ra-226 level of the radon barrier materials (see Issues 2 and 3).

Atlas' modeling results indicate that the long-term radon flux should be 19.1, 19.8, and 18.5 pCi/m^2s for the side slopes, fine tailings, and coarse tailings

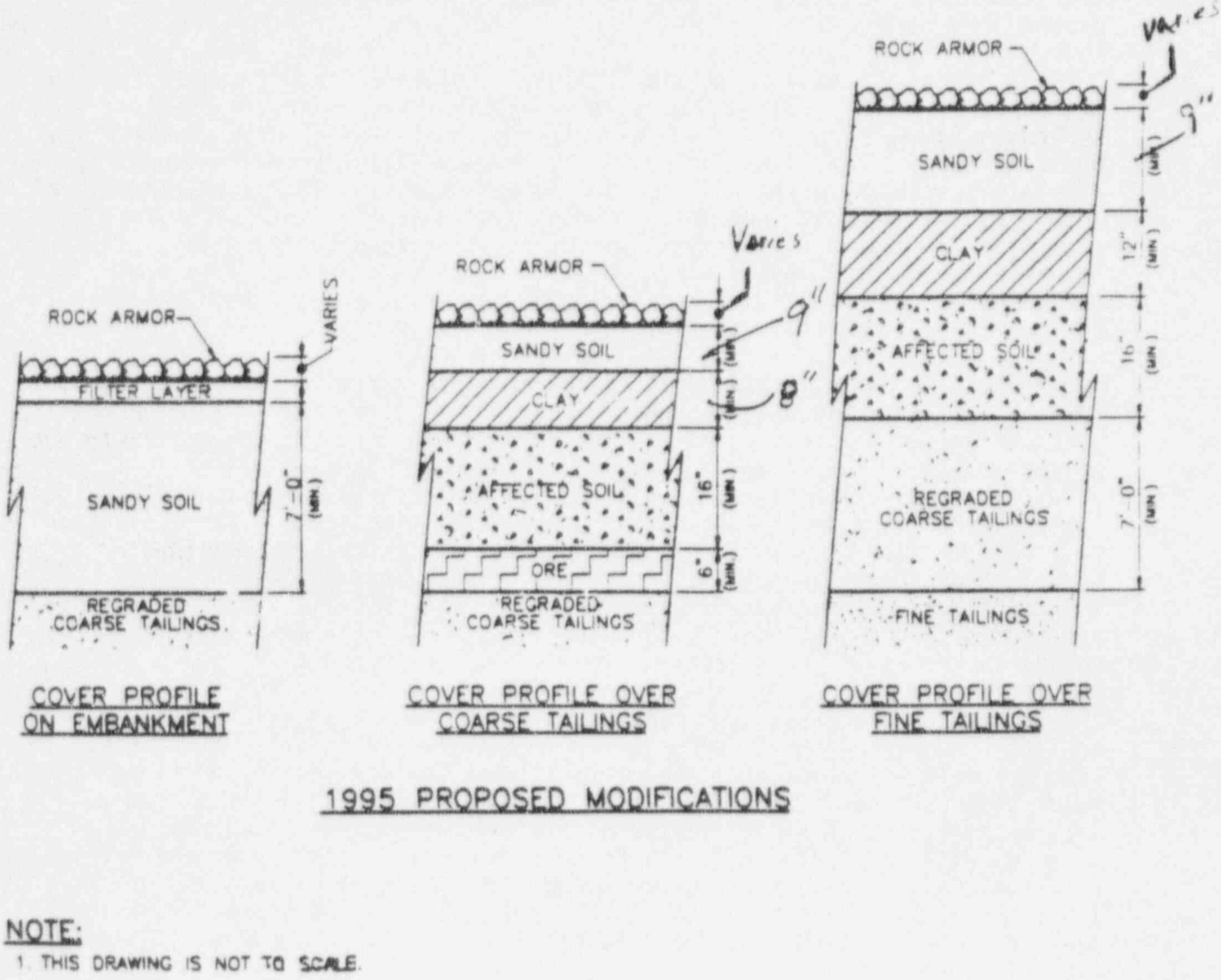

Figure 6-1: Reclaimed impoundment soil cover profiles, taken from drawing No. 88-067-A112, March 21, 1995 Atlas submittal

areas, respectively. Therefore, based on this modeling, the average radon flux would meet the standard of 20 pCi/m^2s. Atlas has indicated they will perform additional flux modeling if the test values for the "affected" soil, coarse tailings, or clay are significantly different than values used in the current radon flux model. If the new modeling results indicate that the long-term radon flux will not meet the standard, Atlas has committed to adjust the radon barrier thickness to ensure that the average radon emission from the disposal site will be limited to 20 pCi/m^2s, as required by Criterion 6 (1) of 10 CFR Part 40, Appendix A.

6.4 Durability of the Radon Barrier

As discussed in previous sections, disruption of the radon barrier by wind or rain will be prevented by the erosion protection layer, and there is a low likelihood of major cracking of the cover due to differential settlement of the tailings because final cover placement will not begin until 90 percent of primary consolidation (settlement) of the tailings has occurred (Atlas Technical Specifications Section 9.3.1, June 1992). In addition, the clay layer of the barrier will be protected from significant cracking due to desiccation by the material placed above it and by the moisture-retaining properties of the clay. Staff considers that the proposed clay layer thickness of at least 8 inches can be achieved in construction and that adequate limits on drying and cracking of the layer will be maintained by the design.

Another aspect of the evaluation of the long-term integrity of the radon barrier is estimating the likelihood of intrusion by burrowing animals or deep-rooted plants. Atlas indicated that biointrusion of the radon barrier will be restricted by the unfavorable environment of the rock layer in the final cover. Although it is recognized that some volunteer plant growth will occur, the licensee concluded that it will most likely be shallow-rooted grasses whose roots should not penetrate the 12 inches of cover materials above the clay layer. Animals indigenous to the area are not expected to select the reclaimed disposal area over native terrain for habitation. The rock cover will not be conducive to digging or to establishing vegetation to create an acceptable habitat. In addition, the tall slopes (about 100 vertical feet) surrounding the disposal area will be armored with rock which should discourage passage onto the upper portion of the disposal area. Based on the staff's experience with other sites, the reclaimed facility does not appear to provide a desirable habitat. Therefore, the staff agrees that the cover is unlikely to be significantly disrupted by burrowing animals or deep-rooted plants.

Frost penetration of the barrier and the potential for resulting disruption within the barrier layer was also examined. Atlas addressed the effect of freeze/thaw cycles on the radon barrier, and concluded that the clay will not be susceptible to frost heave, as the coarse tailings below it will not support capillary action. Therefore, the ability to transport excess water to the frost line does not exist, and the susceptibility of the cover system to frost heave can be considered low. Also, Atlas performed an analysis of potential frost penetration using the Modified Berggren equation method, as proposed by the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory (COE 1968). Using historical weather data in the equation, it was shown that potential damaging frost penetration of the radon barrier was unlikely, thus the proposed design need not be modified for additional protection. Staff agrees that the data supports the licensee's conclusion that significant freeze-thaw damage is unlikely to occur to the clay layer of the radon barrier as described in the proposed design (see Section 3.3.4 for further discussion).

The licensee's conclusions as to the ability of the proposed borrow materials to perform adequately in the cover system are acceptable to staff, subject to review of the results of the proposed material testing program. Adequate design conservatism should ensure long-term radon barrier integrity, assuming that long-term stability of the disposal cell is achieved (see Sections 2, 3, and 4).

6.5 Measured Radon Flux

Criterion 6 (2) of Appendix A requires licensees to measure the average radon flux as soon as reasonably achievable after placement of the radon barrier to demonstrate that the radon flux criterion has been achieved. The flux limit is the same as that for the modeled (design) long-term radon flux. The measured flux on newly constructed radon barrier should easily meet the flux criterion because the materials contain, relative to later years, more moisture and fewer cracks. If the radon flux model or the barrier construction were seriously flawed, this would be reflected in the average measured radon flux value submitted to NRC. If the measured flux does not meet the criterion, staff could require corrective action such as additional radon barrier material.

6.6 Conclusions

Staff can not conclude that the proposed barrier design (March 1995) is acceptable until the issues identified above are resolved. Inadequacies in the sampling program, uncertainties in the method for differentiating contaminated ("affected") soil versus uncontaminated radon barrier borrow soil in the Moab Wash, and uncertainties in the clay borrow source require that more information be provided to confirm the design. The staff can not conclude that the long-term radon flux standard and other cover requirements of Criterion 6 will be achieved until the following open issues are resolved:

1. Provide a sampling plan for Ra-226 analysis of the upper 3 to 4 feet of coarse tailings and the technical basis for modeling the coarse tailings on the sideslopes as being homogenous (i.e., a single layer) for Ra-226 concentration.

2. Provide the gamma survey and sampling procedures for verification of tailings cleanup in the Moab Wash sandy soil borrow area for NRC approval. Also provide revised Reclamation Plan Specifications (Section 1.14 and 5.3.3) and page 40 of the text to indicate that the background soil Ra-226 value is the average value approved by NRC to demonstrate that the radon barrier will comply with Criterion 6 (5).

3. Include in the testing program for the clay borrow material, analysis and/or gamma surveys to determine Ra-226 value, to demonstrate that the

radon barrier will comply with Criterion 6 (5).

In addition, the following confirmatory items must be satisfactorily resolved by the licensee:

1. Provide revised Reclamation Plan pages pertaining to the method of composite sampling for ore and tailings to accurately describe the sampling program.

2. Incorporate in the Reclamation Plan, the proposed testing program for "affected" soil to substantiate the radon flux model/calculation parameter values.

3. Incorporate in the Reclamation Plan, the final clay borrow area proposed testing program to substantiate the radon flux model parameter values for the clay material.

7.0 APPENDIX A ASSESSMENT

Appendix A to 10 CFR 40 establishes technical, financial, ownership, and long-term site surveillance criteria relating to the siting, operation, decontamination, decommissioning, and reclamation of uranium milling facilities. Each site-specific licensing decision is to be based on the criteria in the appendix, taking into account the public health and safety and the environment. Decisions based on the criteria in the appendix must take into account the risk to the public health and safety and the environment with due consideration to the economic costs involved. Decisions as to the ability of the design to meet "reasonably achievable" criteria must take into consideration the state of technology as well as the economics of improvements in relation to the resulting benefits.

The following Appendix A criteria were considered for the proposed licensing decision to amend Source Material License SUA-917 in accordance with the reclamation plan submittals. Criterion 2, 8, and 11 are not applicable for review and approval of a reclamation plan and were therefore not considered.

Criterion 1

Criterion 1 addresses the general goal of siting and designing facilities to provide for the permanent isolation of tailings and associated contaminates by minimizing disturbance and dispersion by natural forces without the need for ongoing maintenance. The following site features must be considered when evaluating a proposed site:

1. Remoteness from populated areas:

   The Moab Mill is located on the west bank of the Colorado River, 3 road miles northwest of the City of Moab, in Grand County, Utah. There is a private residence adjacent to the restricted area to the northeast. The 1990 census reports a population of 4050 for the city of Moab. This shows a decrease in population from the 1980 census which reported a population of 5333 for Moab. The population of Grand County has also decreased from a population of 8200 in 1980 to 6800 according to the Utah Department of Employment Security. Review of data from the licensee indicates that the population within a 10 km radius of the mill has been declining since 1970. (See Draft Environmental Impact Statement, October 1995.)

   Adjacent lands and waters are used for a variety of activities. State Highway 279 and U.S. Highway 191, both adjacent to the site, are major transportation routes for industry and tourism. Outdoor recreational use of the area is heavy, Arches National Park is located about 2 miles northwest of the site.

   Population projections for these areas are difficult to make. There may be significant population increases in the immediate future due to the development of outdoor recreational facilities and the proximity of National and State parks. It is doubtful, however, that there will be any increase in the immediate proximity of the disposal area. The

Nature Conservatory has purchased the wet-lands between the City of Moab and the Colorado River, prohibiting development in this area. Any development to the east of the disposal area, on the west bank of the Colorado River, would be in the flood plain for Moab Wash and the Colorado River. The licensee will be required to include the entire reconfigured Moab Wash in the final fenced restricted area which will help ensure that there are no future developments in the immediate vicinity of the disposal area.

2. Hydrologic and other natural conditions as they contribute to continued immobilization and isolation of contaminants from ground-water sources:

The reclaimed disposal area will be capped with a cover system which will minimize infiltration. The review of ground-water conditions at the site to assure compliance with 10 CFR 40, Appendix A, is currently being done under other licensing actions. The licensee is currently implementing a corrective action program (CAP) to return ground-water quality to established standards. The CAP was submitted on March 31, 1989, and was fully operational prior to July 1, 1990. The CAP is being revised as a result of information collected since it was initiated.

3. Potential for minimizing erosion, disturbance, and dispersion by natural forces over the long-term:

The potential for wind and water erosion will be minimized by several design features. The tailings will be re-contoured and covered by an erosion protection cover. A drainage system will be constructed to divert precipitation away from the tailings. The tailings cover and diversion channels will be protected from flooding and erosion by engineered rock riprap. The cover and channels have been designed in accordance with the guidance suggested by the staff (NRC, 1990). The staff considers that erosion protection which meets that guidance will provide adequate protection against erosion and dispersion by natural forces over the long term.

4. The tailings will be disposed of in a manner that will not require active maintenance to preserve conditions at the site:

The staff considers that the erosion protection will not require active maintenance over the 1000-year design life, for the following reasons: 1) the riprap has been designed to protect the tailings from rainfall and flooding events which have very low probabilities of occurrence over a 1000-year period, resulting in no damage to the layers from those rare events; 2) the rock proposed for the riprap layers will be durable and is not expected to deteriorate significantly over the 1000-year design life; and 3) during construction the rock layers will be placed in accordance with appropriate engineering and testing practices, minimizing the potential for damage, dispersion, and segregation of the rock.

The staff is unable to conclude that the site will not require active maintenance to mitigate the effects of geologic, including seismic, disturbances. Open issues identified in Sections 2 and 3 must be resolved before the staff can make this determination.

Criterion 3

Criterion 3 sets below-grade disposal as the prime option for tailings disposal.

Relocation of the tailings to another site so that all the contaminated material could be placed below grade is technically feasible; however, if the other criteria are met, the benefits over stabilizing the tailings in place would be negligible. (See Draft Environmental Impact Statement, January 1996.) If the existing site is determined to be adequate and it is feasible to design the disposal cell to meet the closure criteria (i.e., the open issues identified in Section 1 are resolved), the cost of disposing the contaminated materials below grade by relocating the disposal area would be much greater than the benefit realized, making relocation economically impracticable.

If below-grade disposal is not practicable, the disposal plan must provide reasonably equivalent isolation of the tailings from natural erosional forces. This is addressed in Criteria 4, 6, and 12.

Criterion 4

Criterion 4 sets specific technical criteria for disposal of tailings.

Criterion 4(a) requires that upstream rainfall catchment areas be minimized to decrease erosion potential and the size of the floods which could erode or wash out sections of the tailings disposal area.

The site is located in an area which is flooded by offsite floods from Moab Wash and the Colorado River. However, as discussed in the Section 4, the site is protected from direct onsite precipitation and flooding by engineered riprap layers for the top and side slopes; the tailings disposal cell will need this protection regardless of where it is located. The riprap for the side slopes and drainage ditches is large enough to resist flooding from the minimal flow velocities of floods occurring from a PMF on the Colorado River. A large rock apron has been designed to provide protection against the potential migration of Moab Wash and the Colorado River. The staff therefore concludes that the erosion potential at the site has been acceptably minimized, since any flooding at the site will be mitigated by the erosion protection, and the forces associated with offsite floods are minimal.

Criterion 4(b) states that topographic features should provide good wind protection.

The Atlas facility is located in an area that provides good wind protection due to the local topography. Cliffs on the western side of the facility rise abruptly for 1000 feet. To the north and east of the site are 500- to 600-ft high barren sandstone formations. The staff considers that the site will be adequately protected from wind erosion by placement of an engineered riprap layer that protects the tailings from surface water erosion. Studies performed for the NRC have shown that an engineered riprap layer designed to protect against water erosion will be capable of providing adequate protection against wind erosion.

Criterion 4(c) states that cover slopes must be relatively flat after stabilization to minimize erosion potential and to provide conservative factors of safety assuring long-term stability. In general, slopes should not be steeper that 5H:1V.

The side and relatively flat top slopes of the covers will be protected from erosion by engineered riprap layers designed to provide long-term stability (see Section 4.3). In order to reduce the length of the slopes and, therefore, to minimize intrusion onto the Colorado River floodplain, the side slopes will be 10H:3V. The erosion potential of the covers will be minimized by the design of the rock to be sufficiently large to resist flooding and erosion, based on the slope selected. The staff concludes that the slopes, with their corresponding rock designs, will be sufficiently stable to meet the erosion aspects of this criterion. However, the staff is unable to conclude that the slopes will provide long-term stability until open issues identified in Sections 2 and 3 are resolved.

Criterion 4(d) requires a full self-sustaining vegetative cover be established or a rock cover employed to reduce erosion to negligible levels. The rock cover design must include consideration of such factors as the shape, size, composition, and gradation of the rock particles; rock cover thickness and zoning of particle size; and steepness of underlying slopes. The rock must be good quality.

Due to the arid nature of the site, the licensee made no attempt to substantiate self-sustaining vegetation over a 1000-year period. The contaminated tailings will be protected from flooding and erosion by an engineered rock riprap layer. The riprap has been designed in accordance with the guidance suggested by the NRC staff (NRC, 1990). As discussed in Section 4, the staff considers that erosion protection which meets that guidance will provide adequate protection against erosion and dispersion by natural forces over the long term. Adequate protection is provided by: (1) selection of proper rainfall and flooding events; (2) selection of appropriate parameters for determining flood discharges; (3) computation of flood discharges using appropriate and/or conservative methods; (4) computation of appropriate flood levels and flood forces associated with the design discharge; (5) use of appropriate methods for determining erosion protection needed to resist the forces produced by the design discharge; (6) selection of a rock type for the riprap layer that will be durable and capable of providing the necessary erosion protection for a long period of time; and (7) placement of a riprap layer in accordance with accepted engineering practice and in accordance with appropriate testing and quality assurance controls.

As discussed in Section 4, the staff can not conclude that the proposed rock cover provides the necessary protection until the open issues that are identified in that section are resolved.

Criterion 4(e) requires that the impoundment not be located near a capable fault that could cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand.

Staff evaluations of the structural stability of the disposal cell considered the effects of earthquakes. As discussed in Sections 2 and 3, the staff is unable to conclude that the impoundment could withstand the acceleration from an assumed maximum credible earthquake on the northeast trending fault without more information from the licensee. Additionally, the issue of whether the Moab fault is capable has not been resolved.

On the basis of independent reviews and analyses, the staff can not conclude that all the requirements of Criterion 4 will be met by the licensees's proposed reclamation plan.

Criteria 5, 7, and 13

Criteria 5, 7, and 13 concern ground-water protection. As previously discussed, ground water is being addressed under separate licensing actions. However, ground-water protection standards at the site will be in accordance with these criteria.

Criterion 6

Criterion 6 sets forth performance criteria for the disposal of tailings.

Criterion 6(1) requires that waste disposal areas be closed in accordance with a design which provides reasonable assurance that average releases of radon-222 and radon-220 to the atmosphere will be limited to 20 picocuries per square meter per second (pCi/m^2s). The design is to be effective for 1000 years to the extent reasonably achievable and, in any case, for at least 200 years.

The evaluation of the radon barrier utilized the RADON computer code (NRC, 1989b) and acceptable parameters, except as noted, to estimate radon emanation from the contaminated materials. The design is supported by adequate construction specifications, settlement monitoring, and quality control programs. However, the staff can not conclude that the cover design will limit radon releases to atmosphere to 20 pCi/m^2s, until the open issues identified in Section 6 are resolved.

The design basis events for erosion protection features protecting the radon barrier are the PMP and the PMF events. Both of these events are considered to be the most severe that are reasonably possible and thus provide reasonable assurance of not being exceeded during the 1000-year design life. The erosion protection features should assure that excessive erosion does not occur during the design life. However, the staff can not conclude that the erosion protection features will be effective for the 1000 year design life until the open issues identified in Section 4 are resolved.

The design basis event for seismic stability is the maximum credible earthquake on either the Moab fault, if it is determined to be a capable fault, or the northeast trending fault. These events are considered the most severe seismic events reasonably possible that could affect the site. It is extremely unlikely that either will be exceeded during the 1000 year design life. However, the staff can not conclude that the tailings cell will withstand the maximum credible earthquake until the open issues identified in Sections 2 and 3 are resolved. Additionally, until open issues identified in Section 2 related to geologic stability have been resolved, the staff can not conclude that the tailings cell design will remain effective for the required duration.

Criteria 6(2) and 6(3) require the licensee to verify by testing, as soon as reasonably achievable after placement of the final radon barrier, or portions of the final radon barrier, the effectiveness of the radon barrier in limiting radon releases. Criterion 6(4) requires the licensee to report the results of the verification within 90 days of completion and to maintain the pertinent data and calculations.

The licensee will be required to verify the effectiveness of the radon barrier by using the procedures described in 40 CFR part 61, appendix B, Method 115, or another method, if approved by NRC, and to report the results to NRC.

Criterion 6(5) precludes the use of materials containing elevated levels of radium in near surface cover materials.

Until the licensee resolves the open issue identified in Section 6 related to verification of radium content in soils for the cover, the staff can not conclude that material containing elevated levels of radium will not be used in the cover.

Criterion 6(6) imposes the long-term design requirements of Criterion 6 to all portions of the disposal site that contain a concentration of radium in land, averaged over areas of 100 square meters, which exceed the background level by 5 picocuries per gram (pCi/g) averaged over the first 15 centimeters below the surface and 15 pCi/g averaged over each 15 centimeter layer more than 15 centimeters below the surface.

The cleanup of contaminated areas is required by License Conditions Nos. 21 and 39 of Source Material License SUA-917. The cleanup will result in no areas outside the disposal cell exceeding the limit.

Criterion 6(7) requires that the licensee control, minimize, or eliminate post-closure escape of nonradiological hazardous constituents.

The radon barrier design includes a low permeability clay layer which will also serve to limit infiltration into the disposal cell. As a result, seepage of nonradiological hazardous constituents from the disposal cell will be minimized to the extent necessary to prevent threats to human health and the environment.

Criterion 6A

Criterion 6A requires the final radon barrier to be completed as expeditiously as practicable considering technological feasibility and that completion dates for the radon barrier and interim milestones be established in the license.

Milestones for the completion of the radon barrier are identified in License Condition No. 55 of Source Material License SUA-917.

Criteria 9 and 10

Criteria 9 and 10 require that a financial surety arrangement be established to assure that sufficient funds are available to carry out the decontamination and decommissioning of the facility and the reclamation of the disposal area, and to cover the payment of the charge for long-term surveillance and control by the long-term custodian of the site.

The licensee's currently approved surety instrument, a performance bond issued by the Acstar Insurance Company of New Britain, Connecticut in favor of the NRC, is in the amount of $6,500,000 for the purpose of complying with Criteria 9 and 10. The licensee also maintains a Standby Trust arrangement for the benefit of NRC, with Norwest Bank of Colorado N.A.

Within 3 months of approval of the reclamation plan for the disposal area, Atlas is required to submit a revised cost estimate. If estimated costs in the newly approved plan exceed the amount covered in the existing financial surety, the licensee is required to have a new surety instrument in place within 3 months of NRC approval of the new cost estimate. (License Condition No. 42 of Source Material License SUA-917.)

Criterion 12

Criterion 12 requires that the final disposition of tailings or wastes at milling sites should be such that ongoing active maintenance is not necessary to preserve isolation.

As discussed in Section 4, the staff considers that the erosion protection should not require active maintenance over the 1000-year design life, for the following reasons: (1) the riprap has been designed to protect the tailings from rainfall and flooding events which have low probabilities of occurrence over a 1000-year period, resulting in no damage to the layers from those rare events; (2) the rock proposed for the riprap layers is designed to be durable and is not expected to deteriorate significantly over the 1000-year design life; and (3) during construction, the rock layers will be placed in accordance with appropriate engineering and testing practices, minimizing the potential for damage, dispersion, and segregation of the rock. However, the staff can not conclude that the erosion protection features will be effective for the 1000 year design life without active maintenance until the open issues identified in Section 4 are resolved.

As discussed in Sections 2 and 3, the staff also considers that the site should not require active maintenance to mitigate the effects of geologic, including seismic, disturbances. However, the staff can not conclude that the design will not require active maintenance to mitigate geologic disturbances during the 1000 year design life until the open issues identified in Sections 2 and 3 are resolved.

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11. ABSTRACT *(200 words or less)*

This Draft Technical Evaluation Report (DTER) summarizes the U.S. Nuclear Regulatory Commission staff's review of Atlas Corporation's proposed reclamation plan for its uranium mill tailings pile near Moab, Utah. The proposed reclamation would allow Atlas to (1) reclaim the tailings pile for permanent disposal and long-term custodial care by a government agency in its current location on the Moab site, (2) prepare the site for closure, and (3) relinquish responsibility of the site after having its NRC license terminated. The NRC staff review has identified open issues in geology, seismology, geotechnical engineering, erosion protection, water resources protection and radon attenuation. The NRC will not approve the proposed reclamation plan until Atlas adequately resolves these open issues.

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