FINAL
STANDARD REVIEW PLAN
for the Review and Remedial Action of Inactive Mill Tailings Sites under Title I of the Uranium Mill Tailings Radiation Control Act

Revision 1

U.S. Nuclear Regulatory Commission

Office of Nuclear Material Safety and Safeguards
Division of Low-Level Waste Management and Decommissioning

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STANDARD REVIEW PLAN (SRP) - INTRODUCTION

Uranium mill tailings are created in the extraction of source material from uranium-bearing ore. These mill tailings wastes, from both inactive and active mills pose a long-term hazard to the public health and safety. Congress enacted the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), to provide for the disposal, long-term stabilization, and control of these uranium mill tailings in a safe and environmentally sound manner.

In UMTRCA, Congress stated its finding that uranium mill tailings "... may pose a potential and significant radiation health hazard to the public, ... and ... that every reasonable effort should be made to provide for stabilization, disposal, and control in a safe and environmentally sound manner of such tailings in order to prevent or minimize radon diffusion into the environment and to prevent or minimize other environmental hazards from such tailings."

The Environmental Protection Agency (EPA) was directed to set "... standards of general application for the protection of the public health, safety, and the environment ..." for directing this process of stabilization, disposal, and control. UMTRCA authorized the Department of Energy (DOE) to conduct necessary remedial actions at 24 designated inactive uranium processing sites to achieve compliance with the standards established by EPA. It also requires NRC to concur in DOE's remedial actions at each site (in Section 108) and to issue licenses for these sites (in Section 104) that may encompass any "... monitoring, maintenance, or emergency measures necessary to protect public health and safety."

DOE, assisted by the Technical Assistance Contractor (TAC) and the Remedial Action Contractor (RAC), develops and issues a Remedial Action Plan (RAP) to document the proposed remedial action to be implemented at a particular site. The RAP describes the series of activities and presents the proposed design stabilizing the residual radioactive materials at the disposal site. The proposed design and sequence of activities in the RAP should assure long-term protection of the public and the environment.

In accordance with UMTRCA Section 108(a)(1), the NRC staff reviews and concurs with the RAP, and any subsequent modifications. By its concurrence in the remedial action selection, the NRC staff must conclude that the planned remedial actions will comply with EPA's applicable standards in 40 CFR 192, Subparts A, B, and C and provisions in 40 CFR 264 referenced in Part 192. The Technical Evaluation Report (TER) documents the technical and regulatory basis for the NRC staff's concurrence in DOE's proposed remedial action.

The RAP for a specific site remediation can encompass a number of separate documents that normally consist of the following:

1) Remedial Action Selection Report
2) Bidder's information - Attachment 1
3) Geology Report - Attachment 2
4) Groundwater Hydrology Report - Attachment 3
5) Supporting TAC calculations - Appendices to Attachment 3
6) Water Resources Protection Strategy Report - Attachment 4
7) RAC calculations (usually multiple volumes)

The Remedial Action Selection (RAS) report provides an overview of the remedial action plan. The other documents are detailed supporting documents to the RAS report. Attachment 1 contains information that will be provided to subcontractors (to the RAC) involved in carrying out the remedial action work. This information usually includes drawings and specifications on the cell construction and site cleanup. Attachment 2 is a detailed report on the regional and site-specific geology. Information contained in this report normally includes descriptions of the stratigraphy, but also includes discussions on geomorphology and seismology. The Groundwater Hydrology Report provides information on the hydrogeology of both the processing and disposal sites (if they are different), including information on the hydrostratigraphy, hydraulic properties, geochemistry, and water use. The supporting TAC documents contain calculations and data to support conclusions and results presented in the Groundwater Hydrology Report. The Water Resources Protection Strategy Report describes how DOE proposes to meet the EPA groundwater standards. RAC calculations are usually engineering calculations and supporting information on the disposal cell stability and the cover design.

When a RAP is received, NRC management will assign a project manager (PM) who will be responsible for compiling the NRC staff's response to DOE. The PM also makes sure that the project stays on schedule. A team of technical staff will be assigned by management to review specific aspects of the RAP in their respective technical discipline.

<u>Acceptance Review</u>

The staff will conduct an acceptance review of the preliminary final RAP to determine the completeness of the information submitted in the RAP. This review is a comparison of the submitted information to the areas of review discussed in SRP Sections 1.1, 2.1, 3.1, 4.1, and 5.1 (NRC, 1989B). The RAP will be considered acceptable, if the provided information is complete, reflects an adequate reconnaissance and physical examination of the regional and site conditions, and provides appropriate analyses and design information to demonstrate that the EPA standards are met.

This review can be completed quickly if the RAP contains sufficient information and provides adequate data to support the conclusions such that the staff can make an independent assessment of DOE's assumptions, analyses, and conclusions. The discussions presented in the RAP should lead the reviewer in a logical manner from premises through to the conclusions. The objective of each section of the RAP is to describe the technical features that affect the ability of the site and the disposal cell design to comply with the EPA standards. All information, data discussions, interpretations, and conclusions should be directed to this objective. If the staff determines that the RAP is unacceptable for full review, a letter will be prepared and transmitted by NRC management unacceptable for full review, a letter will be prepared and transmitted by NRC management to DOE explicitly stating the reasons for the rejection.

RAP Review

The staff review of DOE's preliminary final and final RAPs is covered in the following Standard Review Plans (SRP). Basic requirements for NRC's concurrence in DOE's proposed remedial action are established as follows:

1. There must be reasonable assurance of compliance with the EPA control requirements 40 CFR 192 for durability of stabilization and control of radon, and protection of groundwater resources in; and

2. There must be reasonable assurance of compliance with the EPA requirements in 40 CFR 192 for cleanup of the processing site.

NRC concurrence is granted, provided that the technical findings presented in the RAP support the conclusions that the proposed remedial action meets the above requirements and is therefore consistent with the applicable EPA standards. The NRC documents their findings and the basis for their concurrence in a TER. Each technical reviewer prepares a portion of the report for one or more of the technical areas listed below. These technical sections are organized by the Project Manager (PM) into the complete TER document.

This SRP consists of major chapters addressing each of the areas of review listed below. The primary purpose of the SRP is to help assure that NRC staff review of DOE's Uranium Mill Tailings Remedial Action (UMTRA) project documents are conducted in a thorough, focused, efficient, and consistent manner and that the staff's findings are properly documented. Secondly, the SRP provides DOE, the impacted states and Indian tribes, and other interested parties with an understanding of the NRC review process.

Each SRP chapter has been written to provide the review procedures and acceptance criteria for all of the technical areas pertinent to that chapter. The SRP cannot provide detailed lists of acceptance criteria and step-by-step procedures to be used in every technical review area due to the site-specific nature of these reviews. Additional detail is given in those areas that require additional clarification of the NRC staff position. Each chapter of the SRP is organized into five sections as follows:

Areas of Review

The scope of the technical review is described in this section. The section contains a brief description of specific technical information and analyses that must be reviewed by each technical reviewer. It also contains a discussion of any information needed (or review expected) from other technical reviewers to permit the primary reviewer to complete the review.

Acceptance Criteria

This section contains a general statement of the purpose for reviewing the specific technical area, and an identification of which standards apply to that review. The basis for

TABLE 1 - Review Areas

REVIEW AREA	PRIMARY REVIEW TOPICS
Geology and Seismology	Geologic adequacy of site with respect to EPA stability standards
Geotechnical Engineering	Adequacy of geotechnical engineering aspects of the site and design with respect to EPA stability standards
Surface Water Hydrology	Adequacy of erosion protection design with respect to EPA stability standards
Water Resources Protection	Adequacy of protection against future groundwater contamination and cleanup of existing contamination with respect to EPA standards for groundwater protection
Radon Attenuation	Adequacy of radon attenuation design with respect to EPA radon control standards
Site Cleanup	Adequacy of the program for cleanup of contaminated lands and structures with respect to the EPA cleanup standards

determining the acceptability of the site characterization or design within the scope of the technical review pertinent to each SRP chapter is also provided. In addition to the regulatory requirements of the EPA Standards, the technical basis may consist of general or specific guidance provided in NRC Regulatory Guides, Staff Technical Positions, and other documents.

Review Procedures

This section discusses how the review is accomplished. The section describes procedures that the reviewer goes through to demonstrate reasonable assurance that the applicable standards have been met.

Evaluation Findings

The general conclusions and findings that result from the review are discussed in this section. Specific conclusions and findings depend on the site specific circumstances. However, examples of specific findings are discussed in each technical review area. For each SRP chapter, these conclusions and findings are included in the corresponding TER

References

This section lists the technical and regulatory references typically used in the review process.

This SRP will be revised and updated periodically as the need arises to clarify the content, correct errors, and incorporate modifications approved by the Division of Low-Level Waste Management and Decommissioning.

A revision number and publication date are printed on each page of the SRP. Individual chapters will be revised as needed. Consequently, the revision numbers and dates may vary from chapter to chapter.

1.0 GEOLOGY AND SEISMOLOGY

1.1 Areas of Review

The RAP and/or its supporting documents must contain sufficient regional and site-specific geologic and seismologic information related to the proposed disposal site to support the proposed remedial action.

1.1.1 Geologic and Seismologic Characterization

Information on the location of the site with respect to regional and site specific geologic, geomorphic, stratigraphic, structural, seismic, and tectonic features will be reviewed by staff.

1.1.2 Geologic Stability

Information on the geologic aspects of the site stratigraphy presented in the RAP will be reviewed. The information includes discussion of the unconsolidated surficial deposits, and the formation, composition, sequence and correlation of the lithologic strata under the site and the region surrounding the site.

1.1.3 Bedrock Suitability

Information on the regional and site-specific structural geology and tectonics should be provided in the RAP. Data should be obtained by standard photogeologic analysis and field reconnaissance of the study area and from review of the pertinent literature.

1.1.4 Geomorphic Stability

The staff will review geomorphic investigations including an analysis of regional and local landforms to provide evidence of geomorphic processes that may influence the stability of the site, the ages of geomorphic surfaces, information on the regional and site specific geomorphology, and an evaluation of the potential for and evidence for (a) destructive geomorphic processes, such as mass wasting, excessive erosions rates, and stream encroachment, and (b) fault activity and crustal deformation.

1.1.5 Seismotectonic Stability

The staff will review information on the regional and site-specific seismicity provided in the RAP, including DOE's estimate of earthquake-induced ground accelerations that could occur at the site, assessment of the potential for ground rupture due to fault displacement at the site, and assessment of the potential for other types of tectonic hazards (e.g., volcanic activity) affecting the stability of the site.

1.2 Acceptance Criteria

1.2.1 Regulatory Requirements

The basic acceptance criteria pertinent to the geologic and seismic stability aspects of these reviews is provided in EPA's 40 CFR Part 192, Subpart A [EPA, 1987]. 40 CFR 192.02 states that:

"Control of residual radioactive materials and their listed constituents shall be designed to:

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

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

(1) Exceed an average release rate of 20 picocuries per square meter per second [over the entire surface of the disposal site and over at least a one year period], <u>or</u>

(2) Increase the annual average concentration of radon-222 in air at or above any location outside the disposal site by more than one-half picocurie per liter."

Control is defined in the regulation as "any remedial action intended to stabilize, inhibit future misuse of, or reduce emissions or effluents from residual radioactive materials."

It is the staff's position that the requirements and implementation guidelines of 40 CFR 192 (Subparts A - C and Supplementary Information sections) necessitate that consideration be given to geologic and seismologic parameters.

1.2.2 Regulatory Guidance

There are presently no NRC regulatory guides directly applicable to the geologic and seismologic aspects of the UMTRA program. However, there are staff technical positions and contractor reports that may provide generic guidance in this area. These reports are:

(a) Bernreuter, D.L., J.B. Savy, R.W. Mensing, and D.H. Chung, 1984, "Seismic Hazard Characterization of the Eastern United States: Methodology and Interim Results for Ten Sites," NUREG/CR-3756, Appendix C-A.

(b) Schumm, S.A., and R.J. Chorley, 1983, "Geomorphic Controls on the Management of Nuclear Waste," NUREG/CR-3276.

(c) Staff Technical Position (NRC, 1989b) - "Standard Format and Content for Documentation of Remedial Action Selection at Title I Uranium Mill Tailings Sites."

1.3 Review Procedures

1.3.1 Geologic and Seismologic Characterization

The staff will review the RAP to determine whether a thorough evaluation of the geologic and seismologic stability bases of the remedial action plan has been presented along with the basic data supporting all conclusions. The geological and seismological site characterization is considered acceptable if the information provided is adequate to determine that the design coupled with the site characteristics provides reasonable assurance of meeting the requirements of 40 CFR 192. Although geologic and seismologic site characterization provides data pertinent to the reviews under the other major chapters of this SRP (Geotechnical Engineering, Water Resources, Radon Attenuation and Site cleanup, and Erosion Protection), this chapter discusses only the needs for assessment of geologic and seismologic stability.

The site investigations must be adequate in scope and technique to provide the necessary data.

1.3.2 Geologic Stability

The presentation on geologic stability is acceptable if the demonstrated understanding of geologic processes provides reasonable assurance that compliance with 40 CFR 192 will not be jeopardized by these processes.

Regional stratigraphic information is discussed in sufficient detail to give clear perspective and orientation to the site-specific information presented. This regional information may be obtained from published reports, maps, private communications or other sources. The discussion of the regional stratigraphy is assessed to determine if it is adequately referenced, and illustrated by regional surface and subsurface geologic maps, stratigraphic columns, and cross sections.

A field investigation, exploration and sampling program should be performed to define the stratigraphy and properties of the surface and subsurface materials at the site, the uranium mill tailings as they exist at the site, and any borrow materials planned for the remedial action design. The investigation program is determined to be appropriately presented if it includes:

(a) Plot plan(s) showing the locations of all site explorations such as borings, trenches, seismic lines, piezometer and geologic profiles, with the configuration of the remediated pile and limits of the site superimposed thereon.

(b) Stratigraphic profiles and cross sections of the mill tailings pile and the site illustrating the detailed relationship of the proposed remedial action to the subsurface materials. The cross sections should incorporate the location of borings or other exploratory methods from which the information in the cross sections is derived (i.e., idealized cross sections not based on discrete site-specific data are not adequate for site characterization).

(c) Logs of core borings, geophysical investigations and/or test pits.

(d) Description of the exploration techniques used.

(e) Description of the origin, depth, thickness, physical characteristics (e.g., color, sorting, texture), mineralogy, and degree of consolidation of each lithologic unit noting zones of alteration or weathering profiles.

(f) Discussion of the relationship of the site stratigraphy to the regional stratigraphy.

The following questions are considered in reviewing the characterization of the geologic hazards to a site:

(a) Are the data presented derived from investigations that employed adequate, generally accepted procedures and methodologies? Were the data collected under an approved QA/QC program?

(b) Does the technical terminology used conform to standard reference works and to the definitions in the latest edition of the American Geological Institute's "Glossary of Geology?"

(c) Does the evaluation consider all pertinent available information?

(d) Are the data and procedures used clearly and comprehensively documented?

(e) Are adequate data and procedures employed to determine hazardous parameters?

(f) Are uncertainties and alternative interpretations considered?

(g) Is the reviewer led in a logical manner from the data and/or premises to the conclusions?

When insufficient or inadequate justification is provided to support interpretations and conclusions, the staff will request that additional investigations or sensitivity studies be provided. The staff also may perform an independent analysis of the data provided to assess whether reasonable and conservative alternative interpretations are indicated.

1.3.3 Bedrock Stability

The staff will review bedrock information in the RAP to determine whether investigative activities and technical information about the site have been adequately presented. The information is determined to be appropriately presented if it includes a(n):

(a) Determination of the structural geologic conditions at the site and the region surrounding the site, including its tectonic history;

(b) Identification and description of tectonic structures, particularly faults, at the site and the region surrounding the site, whether buried or exposed at the surface;

(c) Identification and description of the structural and tectonic province or provinces that influence the local seismicity;

(d) Identification and description of "surface faulting,"i.e. differential ground displacement at or near the surface caused by tectonism. It is distinct from non-tectonic types of ground disruptions such as landslides, fissures and craters. Fault investigations related to this issue should be directed at identifying capable faults in the immediate site area;

(e) Identification and description of regional and site-specific volcanic activity; and

(f) Identification and description of actual or potential surface or subsurface subsidence, tilting, uplift, or collapse associated with regional or local tectonic deformational zones.

The presentation on bedrock stability is acceptable if the demonstrated understanding of geologic processes provides reasonable assurance that compliance with 40 CFR 192 will not be jeopardized by these processes.

The generic review questions utilized in reviewing the characterization of site bedrock geology are the same as those presented in Section 1.3.2.

1.3.4 Geomorphic Stability

The staff review of geomorphic stability must conclude that the physiographic (geomorphic) province(s) in which the site is located has been appropriately identified and that the extent and distinguishing characteristics (e.g., elevation, relief) of the province has been adequately described. This description should expound on the nature and extent of the major active processes modifying the present-day topography of the province(s) and should be supplemented by pertinent large and small scale topographic maps (e.g., USGS 7.5-minute and 2-degree USGS quadrangle maps).

The review will determine whether: 1) Characterization studies include aerial photographs and topographic maps of the site and its vicinities; 2) Topographic base maps of adequate scale have been utilized to generate geomorphic-hazards maps that delineate areas where landscape changes associated with drainage networks, slopes, rivers, and piedmonts (as discussed in NUREG/CR-3276) may adversely affect site stability; 3) Areas subjected to subsidence of natural or man-made subsurface conditions have been identified, as well as areas where wind erosion may be a significant factor; 4) Delineation of these areas has taken into account the various factors influencing geomorphic processes such as relief, landform morphology, near-surface geology pedology, age of landforms, and resident biota; and 5) Each relevant geomorphic process identified is described, including rate of activity, frequency of occurrence, and specific controlling mechanisms or factors.

As a necessary input to the geomorphic hazard evaluations, past, current, and potential for future recovery of natural resources in the site region will be assessed. This assessment should consider, for example, the potential for mining related surface subsidence at a site where underground mining is known to have occurred (based on mine development records), or can be expected to occur (based on inferences from available geologic information). It is expected that such an assessment will be based on review of pre-existing historical, geologic, and economic resources information.

The presentation on geomorphic stability is acceptable if the demonstrated understanding of geomorphic processes provides reasonable assurance that compliance with 40 CFR 192 will not be jeopardized by these processes. The important conclusions to be drawn at an acceptable disposal site are: (1) The disposal site occurs on bedrock or a geomorphic surface sufficiently old that there is reasonable assurance the site is and will remain stable for the performance period of the remedial action, and (2) Geomorphic processes are occurring at rates and locations near the disposal site, such that they will not have a destructive effect upon the disposal site during the performance period. The generic review questions to be utilized in reviewing the characterization of geomorphic hazards are the same as those presented in Section 1.3.2.

1.3.5 Seismotectonic Stability

The staff review of seismotectonic stability must conclude whether the information and investigations in this section provide an adequate basis for selection of the Maximum Credible Earthquake (MCE) and determination of the resulting vibratory ground motion at the site. Data should be obtained by standard photogeologic analysis and field reconnaissance of the study area and from review of the pertinent literature. The staff will determine whether the investigative activities and technical information relating to the site include the following:

(a) Listing of all recorded earthquakes that have occurred in the tectonic province or provinces expected to influence the local seismicity. This listing should include the date of occurrence of the earthquake, its magnitude, and the location of the epicenter. Since earthquakes have been reported in terms of various parameters such as intensity at a given location, and effect on ground, structures and people at a specific location, some of these data may have to be estimated by use of appropriate empirical relationships.

(b) Where possible, association of epicenters or locations of highest intensity of historically reported earthquakes with tectonic structures. Epicenters or locations of highest intensity that cannot be reasonably identified with tectonic structures should be identified with tectonic provinces.

In conducting this review, the staff will consider that an acceptable method for selecting the MCE includes the following steps:

<u>Step 1 - Determination of the Maximum Tectonic Province Earthquake</u>

For those earthquakes not associated with known tectonic structures (i.e., "floating" earthquakes) the largest event that has occurred in each of the tectonic provinces expected to influence the seismicity of the site should be identified. For each of these earthquakes, the peak horizontal acceleration at the site should be determined by using an accepted attenuation relationship between earthquake magnitude and distance. Campbell (1981), Joyner and Boore (1981), Campbell (1982), and Nuttli (1983) in Bernreuter et al. (1984), are examples of acceptable relationships. In applying these relationships, 15 km should be used as the site-to-source distance for "floating" earthquakes in the tectonic province containing the site, or in proximate tectonic provinces less than 15 km from the site. For "floating" earthquakes in tectonic provinces more than 15 km from the site, the actual distance of closest approach of these provinces to the site should be used as the site-to-source distance. The acceleration value adopted should be the mean-value plus one-standard-deviation (i.e., 84th percentile value). Possible soil amplification effects should be taken into account.

Step 2 - Identification of Capable Faults

Faults within the site region should be assessed as a source of earthquakes capable of producing on-site acceleration in excess of the maximum event determined in Step 1. This assessment can be made based on the fault length versus magnitude relationships developed by Slemmons (1982) or Bonilla (1984). For faults whose ground motion exceeds the maximum peak horizontal acceleration determined in Step 1, a determination should be made as to whether they are capable faults. A fault is capable if it meets the definition in Appendix B as demonstrated by suitable methods, such as those outlined by Slemmons (1977).

Step 3 - Designation of the Maximum Credible Earthquake

From among the earthquakes associated with capable faults, as determined in Step (2) and earthquakes identified in Step (1), the event that yields the maximum peak horizontal acceleration at the site should be designated as the maximum credible earthquake (MCE).

The presentation on seismotectonic stability is acceptable if the demonstrated understanding of tectonic processes provides reasonable assurance that compliance with 40 CFR 192 will not be jeopardized by these processes. The generic review questions to be utilized in reviewing the characterization of tectonic hazards are the same as those presented in Section 1.3.2.

1.4 Evaluation Findings

If the evaluation by the staff, based upon a complete review of geologic and seismic stability aspects of the remedial action plan documents, confirms that the applicable standards and regulatory guidelines have been met, documentation of the findings will state: 1) that the stratigraphic, geomorphic, seismic and tectonic investigations adequately characterize the site and support all conclusions; 2) that the analyses necessary to provide reasonable assurance of long-term geologic stability are acceptable and contain adequate margins of safety, and 3) that, from a geologic point of view, the general remedial action design represents a feasible plan for meeting with reasonable assurance the long-term stability provision of the EPA standards established by 40 CFR, Part 192, Subpart A.

Staff reservations about any portion of the RAP will be stated in sufficient detail to make clear the precise nature of the staff concern.

1.5 References

Bonilla, M.G., R.K. Mark, and J.J. Lienkaemper, "Statistical Relations among Earthquake Magnitude, Surface Rupture Length, and Surface Fault Displacement," Bulletin of the Seismological Society of America, vol. 74, pp. 2379-2411, 1984.

Campbell, K.W., "Near-Source Attenuation of Peak Horizontal Acceleration," Bulletin of the Seismological Society of America, vol. 71, pp. 2039-2070, 1981.

Campbell, K.W., "A Preliminary Methodology for the Regional Zonation of Peak Ground Acceleration," Proc. 3rd International Earthquake Microzonation Conference, Seattle, Washington, pp. 365-376, 1982.

Code of Federal Regulations, Title 40, Protection of Environment, Part 192, "Health and Environmental Protection Standards for Uranium Mill Tailings," 1987.

Joyner, W.B. and D.M. Boore, "Peak Horizontal Acceleration and Velocity from Strong Motion Records Including Records from the 1979 Imperial Valley, California, Earthquake," Bulletin of the Seismological Society of America, vol. 71, pp. 2011-2038, 1981.

Shannon & Wilson, Inc and Agbabian-Jacobsen Associates, "Soil Behavior Under Earthquake Loading Conditions State-of-the-Art Evaluation of Characteristics for Seismic Responses Analyses," U.S. Atomic Energy Commission Contract W-7405-ENG-26, January 1972.

Slemmons, D.B., "State-of-the-Art for Assessing Earthquake Hazards in the United States: Report 6, Faults and Earthquake Magnitude, "Miscellaneous Paper S-73-1, U.S. Army Engineer Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi, 1977.

Slemmons, D.B., P. O' Malley, R.A. Whitney, D.H. Chung, and D.L.Bernreuter, "Assessment of Active Faults for Maximum Credible Earthquakes of the Southern California-Northern Baja Region," University of California, Lawrence Livermore National Laboratory publication no. UCID 19125, 48 p., 1982.

U.S. Nuclear Regulatory Commission, "Seismic Hazard Characterization of the Eastern United States: Methodology and Interim Results for Ten Sites," NUREG/CR-3756, Appendix C-A, 1984.

---"Geomorphic Controls on the Management of Nuclear Waste," NUREG/CR-3276, 1983.

---"Staff Technical Position - Standard Format and Content for Documentation of Remedial Action Selection at Title I Uranium Mill Tailings Sites", February, 1989b.

2.0 - GEOTECHNICAL STABILITY

2.1 Areas of Review

The RAP and/or its supporting documents must contain geotechnical information and design details related to the proposed disposal site and all materials associated with the remedial action design including soil and rock cover, foundation materials, contaminated materials, and other materials for any zones such as liners, filters, or capillary breaks. The major areas of information that should be presented in the RAP for review by the staff are briefly described as follows:

2.1.1 Characterization of Site Stratigraphy and Uranium Mill Tailings

Information presented in the RAP on the geotechnical aspects of the site stratigraphy and the geotechnical characteristics of the uranium mill tailings designated for stabilization will be reviewed.

Information on geotechnical characteristics of the site and the tailings pile will include: exploration data, test results, description of physical properties, and both static and dynamic engineering parameters of the materials in question, as well as discussion of groundwater conditions for all critical subsurface strata at the site, including information on the annual groundwater fluctuation.

2.1.2 Slope Stability

Exploration data, test results, slope characterization, and analyses related to the stability of all natural and man-made earth and rock slopes whose failure, under any of the conditions to which they could be exposed throughout the design period, could adversely affect the integrity of the remedial action plan will be reviewed.

2.1.3 Settlement

The results of testing and analyses conducted to estimate deformation and differential settlement of subsurface materials and uranium mill tailings under both static and seismic conditions, and the resulting effects on the soil cover will be reviewed.

2.1.4 Liquefaction Potential

An analysis of the liquefaction potential of subsurface and pile material will be reviewed. Consequences of liquefaction of subsurface soils and/or uranium mill tailings affecting the stability of cover materials and erosion protection layer will also be analyzed.

2.1.5 Soil Cover Engineering Parameters

Information provided related to soil cover material, including field exploration data, laboratory test results, and design details pertinent to the geotechnical stability aspects of cover design, i.e., cover thickness, compaction requirements, gradations, permeability, and dispersivity will be reviewed.

2.1.6 Construction Considerations

Information on the geotechnical aspects of the remedial action construction will be reviewed. These may include details such as: the sequence of construction activities, material placement procedures, and important quality control aspects of the construction.

2.1.7 Radon/Infiltration Barrier Hydraulic Conductivity

Testing, calculations, and justification of radon/infiltration barrier design hydraulic conductivity will be reviewed.

2.2 Acceptance Criteria

2.2.1 Regulatory Requirements

The basic acceptance criteria pertinent to the geotechnical stability aspects of these reviews is provided in EPA's 40 CFR Part 192, Subpart A (EPA, 1987). 40 CFR 192.02 states that:

"Control of residual radioactive materials and their listed constituents shall be designed to:

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

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

(1) Exceed an average release rate of 20 picocuries per square meter per second [over the entire surface of the disposal site and over at least a one year period], or

(2) Increase the annual average concentration of radon-222 in air at or above any location outside the disposal site by more than one-half picocurie per liter."

Control is defined in the regulation as "any remedial action intended to stabilize, inhibit future misuse of, or reduce emissions or effluents from residual radioactive materials."

It is the staff's position that the requirements and implementation guidelines of 40 CFR 192 (Subparts A and C and Supplementary Information sections) necessitate that due consideration be given to geotechnical parameters. NRC Staff Technical Positions have been developed for Standard Format and Content for Documentation of Remedial Action Selection at Title I Uranium Mill Tailings Sites (NRC, 1989b) and for Testing and Inspection Plans During Construction of DOE's Remedial Action at Inactive Uranium Mill Tailings Sites (NRC, 1989a).

2.2.2 Regulatory Guidance

There is one NRC regulatory guide directly applicable to the geotechnical aspects of the UMTRA program, and two that address geotechnical aspects of site investigations for nuclear power plants which may provide additional guidance on reviewing mill tailing impoundments. These reports are:

(a) Regulatory Guide 3.11 (NRC, 1977) - "Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills" - This guide describes some engineering practices and methods generally considered satisfactory for the design, construction, and inspection of earth and rockfill embankments used for retaining uranium mill tailings.

(b) Regulatory Guide 1.132 (NRC, 1979) - "Site Investigations for Foundations of Nuclear Power Plants" - This guide describes programs of geotechnical engineering site investigations that would normally meet the needs for evaluating the performance of earthworks under anticipated static and dynamic loading conditions. It provides general guidance and recommendations for developing site-specific investigation programs as well as specific guidance for conducting subsurface investigations, the spacing and depth of borings, and sampling.

(c) Regulatory Guide 1.138 (NRC 1978) - "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants" - This guide describes laboratory investigations and testing practices acceptable for determining soil and rock properties and characteristics needed for geotechnical engineering analysis and design.

2.3 Review Procedures

The following is a brief description (by review area) of the general procedures for review conducted by the staff in evaluating the geotechnical stability aspects of the RAP supporting a proposed UMTRA project. Publications that are typically used in this review are listed in Section 2.5.

2.3.1 Characterization of Site Stratigraphy and Uranium Mill Tailings

Using appropriate references listed in Section 2.5, and other sources, the staff will review the information presented and field investigations performed to characterize the site stratigraphy and the geotechnical properties of the tailings materials. The staff will determine whether all the necessary information has been provided pursuant to the guidelines of the Standard Format and Content (NRC, 1989b). The information on site stratigraphy and tailings materials will be acceptable if its scope and level of detail is commensurate with the influence such information has on the determination that the remedial action will comply with 40 CFR 192.

The following questions will be considered in the review:

(a) Is the regional stratigraphy defined in sufficient detail such that it provides a clear perspective and orientation to the site-specific subsurface information?

(b) Are the exploratory techniques used by the site investigator consistent with current practice? Do the samples represent the in-situ soil conditions?

(c) Do the investigations provide coverage of the site and borrow material areas in sufficient detail to define the specific subsurface conditions with a high degree of confidence?

(d) Have all soils that might be unstable because of their physical or chemical properties been identified and adequately evaluated?

(e) Are the investigations performed (including laboratory and field testing) sufficient to establish the engineering parameters of borrow materials, tailings, and underlying soil and rock materials at the site?

(f) Have the records of the historic fluctuations of ground water at the site as obtained from monitoring local wells and springs and/or by analysis of piezometer and permeability data from tests conducted at the site been presented in sufficient detail to effectively incorporate the information into geotechnical stability analyses? This aspect of the review is coordinated with the hydrogeologic characterization review performed under Chapter 4 of this SRP.

The borrow material exploration program will be reviewed for its adequacy to support a determination of the suitability of borrow material for a specific use. The procedure for restoration of the borrow area will be reviewed for its effect on the performance of the stabilized tailings pile, particularly its effect on the site drainage, ground water table, and overall long-term stability of the tailings.

In meeting the general regulatory positions of Regulatory Guides 1.132 and 1.138, the determination of engineering properties of underlying materials at the site, uranium mill tailings, and borrow materials will be considered acceptable by the reviewer if applicable methods are properly used in characterizing the materials. The test data obtained should be consistent with the needs of the proposed remedial action at the site. The test methods are described, for example, in geotechnical journals published by the American Society of Civil Engineers, applicable standards published by the American Society for Testing and Materials, Institution of Civil Engineers, and various research reports prepared by Universities. The parameters of the materials must be supported by field and laboratory test records.

The staff will determine that a detailed discussion of laboratory sample preparation has been provided when applicable. For critical laboratory tests, details such as how saturation of the sample was determined and maintained during testing, or how the pore pressures changed should be given.

The staff review should determine that the RAP appropriately presents a detailed and quantitative discussion of the criteria used to verify that the samples were properly taken and tested in sufficient number to define all the critical soil parameters for the site. For sites that are underlain by saturated soils or sensitive clays, it should be shown that all zones which could become unstable due to liquefaction or strain softening phenomena have been adequately sampled and tested. Dispersive characteristics of the soil should be investigated, if applicable. The test program and discussion should also show that the consolidation behavior of the soils, as well as their static and dynamic strength parameters, have been adequately defined. The reviewer should determine that the RAP appropriately explains how the developed data are used in the analyses, how the test data are enveloped for design, and why the design envelope is conservative, and that the RAP includes a table indicating the value or range of values of the parameters used in the analyses.

To determine whether sufficient investigations were performed, the staff will evaluate the effectiveness of the boring, sampling, and testing programs in defining the specific site conditions pertinent to all analyses and design necessary to demonstrate that the remedial action plan meets the stability standards. If it is the staff's judgment that the investigations or testing are inappropriate or insufficient, additional investigations may be requested. The final conclusion will be based in part on professional judgment, considering the complexity of the site subsurface conditions. As part of the review, the staff must ascertain that appropriate laboratory and field techniques and equipment are employed in determining the material parameters.

2.3.2 Slope Stability

Plot plans, cross-sections, and profiles of slopes of the tailings pile and all nearby slopes, the failure of which could adversely affect the stability of the remedial action plan, will be reviewed and compared with exploratory records and provisions of the RAP to ascertain that the most critical conditions have been addressed and that the characteristics of all slopes have been adequately defined. The soil and rock test results will be reviewed to determine if there is sufficient relevant test data to support the selection of the soil strength characteristics used in the slope analysis. The review will also consider whether appropriate soil and rock characteristics derived from the investigations have been completely and conservatively incorporated into the design. The discussion of characteristics of critical slopes at the site will be considered acceptable by the reviewer if it includes:

(a) Cross-sections and profiles of the slope in sufficient number and detail to represent all significant slope and foundation conditions.

(b) A summary and description of static and dynamic properties of the soil and rock comprising the slope and a discussion of procedures used to estimate, from the available field and laboratory data, conservative soil parameters and profiles to be used in the analysis.

(c) A summary and description of the ground water conditions within or beneath the slope.

The reviewer will consider the discussion of the stability analysis satisfactory if valid static and dynamic analyses have been presented to demonstrate that there is an adequate margin of safety. If the safety factors resulting from the analysis are not appropriate for the hazards posed by a slope failure, or if clearly unconservative soil properties were used, the staff will request additional data to verify the assumptions.

The criteria and methods of analysis will be reviewed to ascertain that appropriate techniques have been employed. The slope analyses will be reviewed to determine that an appropriately conservative approach has been used, and that all adverse conditions to which the slope might be subjected have been considered. A number of different methods of analysis are available in the literature. To be acceptable, the static analyses should include calculations with different assumptions and methods of analysis to assess the following:

(1) The uncertainties with regard to the shape of the slope, the boundaries and parameters of the several types of soils within the slope, the forces acting on the slope, and the pore pressures acting within the slope.

(2) Failure surfaces corresponding to the lowest factor of safety.

(3) The effect of the assumptions inherent in the method of analysis used.

No single method of analysis is entirely acceptable for all stability assessments; thus, no single method of analysis is recommended. Relevant manuals issued by public agencies (such as the U.S. Navy Department, U.S. Army Corps of Engineers, and U.S. Bureau of Reclamation) are often used in reviews to ascertain whether the analyses performed are reasonable (see list of references). If any of the important interaction effects cannot be included in a given analysis, such effects must be treated in some approximate but conservative fashion. The engineering judgement of the presenter will be given strong consideration in the staff's review of the analyses and in assessing the adequacy of the resulting safety factors. The dynamic stability of slopes will be reviewed considering the maximum credible earthquake and potential site amplification of ground motions.

To be acceptable, the dynamic analyses must account for the effect of dynamic stresses of the MCE on soil strength parameters. Similar to the static analyses, the various parameters such as geometry, soil strength, and hydrodynamic and pore pressure forces, should be varied to show that there is an adequate margin of safety. Pseudostatic analyses in lieu of the dynamic analysis are acceptable if the strength parameters used in the analyses are conservative, the materials are not subject to significant loss of strength and development of high pore pressures under dynamic loads, and the resulting minimum factor of safety suggests an adequate margin. The design seismic coefficient to be used in the pseudostatic analysis should be either 67 percent of the peak acceleration of the MCE at the foundation level of the tailings pile or 0.10, whichever is greater. If the design seismic coefficient is greater than 0.20, then the dynamic stability investigation may be augmented by other appropriate methods (i.e., deformation method, finite element method), depending on specific site conditions.

If the staff review indicates that questionable assumptions have been made or nonstandard or inappropriate method of analysis has been made, the staff may model the slope in a manner consistent with the data, and perform an independent analysis.

2.3.3 Settlement

The settlement of the remediated tailings as a result of volume change of the soils and rock beneath the pile, and volume change of the tailings pile as a result of its self-weight and weight of cover materials are to be evaluated by appropriate methods. The discussions of settlement analyses will be considered acceptable if the settlement of subsurface materials and the tailings has been analyzed to include: rebound, settlement, and differential settlements (caused by zones of slimes, the varying material thicknesses, and the heterogeneous nature of the pile) under the loads of fill and of seismic loading. In general, the review procedure will include:

(a) Determining whether the soil and rock parameters used in the settlement analyses represent the in situ conditions at the site. The site investigation, sampling, and laboratory test programs must be adequate to support this determination. The stratigraphy used in the analysis, particularly the location of slimes zones within an embankment, will be reviewed.

(b) Determining whether the methods of settlement analyses are appropriate for the tailings embankment, and soil conditions at the site. Contributions to settlement by drainage of mill tailings and by consolidation/compression of slimes and/or sands are reviewed. Both instantaneous and time-dependent components of total and differential settlements will be verified. An analysis of the potential for development of cracks in the earth cover (radon barrier) as a result of differential settlements will be reviewed.

(c) Determining whether the total and differential settlement estimates represent conservative and tolerable behavior of the remediated pile.

2.3.4 Liquefaction Potential

Liquefaction potential will be reviewed by a study of the results of geotechnical investigations including boring logs, laboratory classification test data, and soil profiles to determine if any of the site soils or the tailings pile material could be susceptible to liquefaction. The results of in-situ tests such as the standard penetration test along with density and strength tests on undisturbed samples obtained in exploration borings will be examined. Ground water conditions will be reviewed. The analysis of the expected maximum ground acceleration and the potential for soil amplification will also be reviewed. Alternatively, post-earthquake stability methods based on residual strengths, and deformation analysis, may be utilized to examine liquefaction.

If it is determined that there may be liquefaction-susceptible soils beneath the site or in the tailings pile; the site exploration methods, laboratory test program, and analysis will be reviewed for adequacy and reasonableness. When the need for an in-depth analysis is indicated, an assessment of the potential adverse effects that complete or partial liquefaction could have on the stability of the embankment may be based on cyclic triaxial test data obtained from undisturbed soil samples taken from the critical zones in the site area. The liquefaction potential analysis will be reviewed in detail and compared to an independent study performed by the staff, if necessary.

2.3.5 Soil Cover Engineering Parameters

The staff will review the following geotechnical stability aspects of the earthen cover:

(a) Determine that an adequate quantity of the specified borrow material has been identified at the borrow source.

(b) Ascertain that placement density, specific gravity, moisture content, dispersivity and shrinkage properties used in the soil cover design have been determined by suitable laboratory testing such that long-term stability standards will be met. Note that permeability issues are discussed separately in Section 2.3.7.

(c) Verify that the particle size gradation of the earth cover, bedding layers, and the rock layer are compatible to assure their stability against particle migration during the design life.

(d) Determine that the cover has been designed to accommodate the effects of anticipated freeze-thaw cycles.

(e) Determine, if bentonite amendment to the radon barrier is proposed, that supporting discussions appropriately address laboratory testing and field procedures associated with amended materials.

(f) Determine if the cracking potential of the cover has been adequately addressed. Both cracking due to settlement and shrinkage should be evaluated. In the past, NRC has favorably reviewed cracking potential calculations performed as described by Lee and Chen (subsidence) and Spangler and Handy (shrinkage). Other reasonable solutions will also be considered.

Review of the radon attenuation aspects of the cover design is addressed in the SRP Chapter 5, Radon Attenuation.

2.3.6 Construction Considerations

The geotechnical aspects of the planned construction operations will be reviewed to identify any related design flaws or deviations from standard engineering practice for earthworks. The review will ascertain if all the tailings and contaminated materials at the site can be placed within the configuration of the proposed stabilized pile. The construction sequence will be reviewed to verify the feasibility of achieving the intended final configuration of the tailings, particularly when tailings are to be relocated to new areas of the remediated pile. Material placement procedures, including procedures intended to achieve the desired moisture content (drying, if needed) and placement density and permeability are reviewed. If mixing of the fine tailings (slimes) with sand tailings is proposed, the specifications to control the mixture and determination of engineering properties of this mixture will be reviewed.

Aspects of proposed quality control will be reviewed to verify that adequate provisions have been included to ensure that the construction will be in accordance with the RAP. In particular, details of the testing and inspection program, including type and frequency of tests proposed, will be reviewed and compared to NRC guidance on testing and inspection (NRC, 1989a).

2.3.7 Hydraulic Conductivity

The geotechnical design aspects of the cover will be reviewed to ensure that the radon/infiltration barrier component of the layered cover has a minimal hydraulic conductivity, to limit radon emissions from, and water infiltration into, stabilized mill tailings. The review will verify if the hydraulic conductivity has been minimized by compacting fine-grained soil for a sufficient depth above the stabilized tailings. Natural borrow soils having insufficient silt and clay content to effectively reduce the barrier's hydraulic conductivity can be amended with bentonite for improved effectiveness.

In response to the Environmental Protection Agency groundwater standards, designers of radon/infiltration barriers for mill tailings sites are proposing increasingly limited design hydraulic conductivity (k) values. It is not unusual for laboratory permeability test values to yield results of 10^{-8} to 10^{-10} cm/sec. Such tests are performed on compacted soil samples considered by the design engineer to represent the soil to be used for the radon/infiltration barrier.

Several recent technical papers (Goode, et. al., 1986; Rogowski, 1990; Panno, et. al., 1991; and Benson and Daniel, 1990) have raised serious questions on the exclusive use of laboratory testing for demonstrating hydraulic conductivity values in those cases where a radon barrier k-value less than 10^{-7} cm/sec is specified. Based on a review of these technical papers, field testing is necessary since construction operations and soil material variability can create preferred pathways, joints, seams, holes, and flaws that effectively increase a barrier's hydraulic conductivity. According to Daniel (1990), the hydraulic conductivity may be underestimated by "an order of magnitude or more".

The review staff shall verify that a rational basis for the design hydraulic conductivity (k) value for the radon/infiltration barrier has been provided in the RAP. For any situation in which $k < 10^{-7}$ cm/sec is specified, the staff shall verify that either: (1) a test fill program will be undertaken to verify the constructibility; or (2) the RAP narrative and accompanying analyses have adequately demonstrated why the recent technical papers are not relevant for the site specific low k value. If the RAP demonstrates why field testing is not required, the reviewer shall provide the rational basis in the TER for not requiring field testing at a specific site. If field testing is required, staff should ensure that the test fill specifications require that the hydraulic conductivity value be verified by in-place testing with double-ring infiltrometers or other approved methods. The test fill construction plan and verification program will be reviewed for adequacy by staff.

For all cases where $k < 10^{-7}$ cm/sec and the test fill program requirement has been defined, specifications and related documents (RAIP, etc.) shall include a strict quality control program. An acceptable QC program should provide a mechanism(s) to ensure that as-built construction duplicates the test fill construction techniques on the cell barrier. The objective of the QC program will be to provide assurance that uniform and high-quality construction of the cell barrier has been achieved.

2.4 Evaluation Findings

If the evaluation by the staff, based upon complete review of geotechnical stability aspects of the remedial action plan documents, confirms that the applicable standards and regulatory guidelines have been met, documentation of the findings will state: 1) that the investigations performed at the site are adequate to justify the soil and rock properties characterizing the substrata, tailings and borrow materials; 2) that the analyses necessary to provide reasonable assurance of long-term geotechnical stability are acceptable and contain adequate margins of safety, and 3) that the general remedial action design represents a feasible plan for meeting with reasonable assurance the long-term stability provision of the EPA standards established by 40 CFR, Part 192, Subpart A. Staff reservations about any portion of the RAP will be stated in sufficient detail to make clear the precise nature of the staff concern.

2.5 References

Benson, C.H. and Daniel, D.E. (1990), Influence of Clods on Hydraulic Conductivity of Compacted Clay"

Code of Federal Regulations, Title 40, Protection of Environment, Part 192,"Health and Environmental Protection Standards for Uranium Mill Tailings," 1987.

Daniel, David E., "Compacted Clay and Geosynthetic Clay Linings"

Daniel, D.E. and Benson, C.H., "Water Content-Density Criteria for Compacted Soil Liner", 1990.

Fermulk, N. and Haug, M., (1990), Evaluation of In-Situ Permeability Testing Methods" Geotechnique, The Institution of Civil Engineers, London.

Goode, D., Young, M., Weber, M., Forstrom, J., (1986), "Information on Permeability Testing of Soil Covers and Liners"

Journal of the Geotechnical Engineering Division, Proceedings of the American Society of Civil Engineers.

Lee, K.L., and Shen, C.K., "Horizontal Movements Related to Subsidence," Journal of Soil Mechanics and Foundation Division, Volume 95, No. SM-1, ASCE, New York, January, 1969.

Panno, S.V., Herzog, B.L., Cartwright, K., Rehfeldt, K.R., Krapac, I.G., and Hensel, B.R. (1991), Field-Scale Investigation of Infiltration Into a Compacted Soil Liner"

Rogowski, A.S., (1990), "Relationship of Laboratory- and Field-Determined Hydraulic

Conductivity in Compacted Clay Liner"

Shannon & Wilson, Inc. and Agbabian-Jacobsen Associates, "Soil Behavior Under Earthquake Loading Conditions State-of-the-Art Evaluation of Characteristics for Seismic Responses Analyses," U.S. Atomic Energy Commission Contract W-7405-eng-26, January 1972.

Spangler, M.G., and Handy, R.L., Soil Engineering, Harper and Row, Publishers, New York, 1982.

Stagg, K. and O. Zienkiewicz, "Rock Mechanics in Engineering Practice," John Wiley & Sons, 1968.

Terzaghi, K. and R. B. Peck, "Soil Mechanics in Engineering Practice," 2nd ed., John Wiley & Sons, 1967.

U.S. Army Corp of Engineers, "Soil Sampling," Engineering Manual EM1110-2-1907, March 1972.

---"Instrumentation of Earth and Rockfill Dams, Engineering Manual EM1110-2-1908,Part 1 and 2," August and November, 1971.

--- "Laboratory Soil Testing," Engineering Manual EM 1110-2-1906, November 1970.

---"Engineering and Design Stability of Earth and Rock Fill Dams," Manual N. EM 1110-2-1902, Office of the Chief of Engineers, Dept. of the Army, 1970.

U.S. Bureau of Reclamation, "Earth Manual," First Edition, U.S. Dept. of Interior, 1968.

U.S. Department of the Navy, "Soil Mechanics," NAVFAC DM 7.1, May, 1982

---"Foundations and Earth Structures," NAVFAC DM 7.2, May, 1982

---"Soil Dynamics, Deep Stabilization, and Special Geotechnical Construction," NAVFAC DM 7.3, May 1982.

U.S. Nuclear Regulatory Commission, Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants," Revision 1, March 1979.

---Regulatory Guide 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants," April 1978.

---Regulatory Guide 3.11, "Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills," Revision 2, December 1977.

---"Rock Riprap Design Methods and Their Applicability to Long-Term Protection of Uranium Mill Tailings Impoundments," NUREG-2684, August 1982.

---"Consolidation of Tailings," NUREG-3204, October 1983a.

---"Guidance for Disposal of Uranium Mill Tailings: Long-Term Stabilization of Earthen Cover Materials," NUREG-3199, October 1983b.

---"Design Considerations for Long-Term Stabilization of Uranium Mill Tailings Impoundments," NUREG-3397, October 1983c.

---"Geomorphic Controls on the Management of Nuclear Waste," NUREG/CR-3276, 1983d.

---"Geotechnical Quality Control: Low-Level Radioactive Waste and Uranium Mill Tailings Disposal Facilities," NUREG-3356, 1983e.

---"Staff Technical Position on Testing and Inspection Plans During Construction of DOE's Remedial Action at Inactive Uranium Mill Tailings Sites", January, 1989a.

---"Staff Technical Position - Standard Format and Content for Documentation of Remedial Action Selection at Title 1 Uranium Mill Tailings Sites", February, 1989b.

3.0 SURFACE WATER HYDROLOGY/EROSION PROTECTION

3.1 Areas of Review

The NRC staff will review hydrologic information, analyses, and design details presented in the RAP and/or its supporting documents to assure the plan provides long-term erosion protection in accordance with the EPA standards for stability (40 CFR, Part 192, Subpart A). The major areas of review in the long-term erosion protection aspects of the design are briefly described in the following sections.

3.1.1 Hydrologic Description of Site

The staff will review the following hydrologic site characterization information:

(1) identification of the relationships of the site to surface water features in the site area, and

(2) identification of mechanisms, such as flood and dam failures, that may require special design features to be implemented.

This review requires identification of the hydrologic characteristics of streams, lakes (e.g., location, size, shape, drainage area, etc.), and existing or proposed water control structures that may adversely affect the long-term stability of the site design.

3.1.2 Flooding Determinations

The staff will review the assessment of the flooding potential for each site, including a determination of the precipitation potential, the precipitation losses, the runoff response characteristics of the watershed, the accumulation of flood runoff through river channels and reservoirs, the magnitude of the probable maximum flood (PMF) or project design flood (if a flood less than the PMF is used) at the site, and the critical water levels, shear stresses, and velocity conditions at the site. The staff also will review: (1) the analyses and justification for the use of a flood less than the PMF, (2) the probable maximum precipitation (PMP) potential, and resulting runoff, for site drainage and for drainage areas adjacent to the site, and (3) the modeling of physical rainfall and runoff processes to estimate possible flood conditions at the site.

The assessment of flooding also will include a review of possible geomorphic changes that could affect the potential for flooding and erosion at the site. As applicable, the staff will review the following: (1) identification of types of geomorphic instability; (2) changes to, and impacts associated with, flooding and flood velocities due to geomorphic changes; and (3) mitigative procedures to reduce or control geomorphic instability.

The assessment of flooding also will include a review of potential dam failures, if upstream reservoirs exist. Peak water levels, flood routing procedures, and velocities will be reviewed in the determination of potential hazards due to failure of upstream water control structures from either seismic or hydrologic causes. If an existing analysis concludes that seismic or hydrologic events will not cause failures of upstream dams and produce the governing flood at the site, the analysis will be reviewed to assure that information which supports such a conclusion (e.g., record of contact with dam designers) is included. If an analysis is provided that concludes that a dam failure flood due to a PMF or a seismically-induced flood is the design basis flood, the computations will be reviewed to assure that appropriate and/or conservative model input parameters have been used.

3.1.3 Water Surface Profiles, Channel Velocities, and Shear Stresses

Depending on the type of computational models used, the staff will review the model, including the determination of flooding depths, channel velocities, and/or shear stresses used to determine riprap sizes needed for erosion protection. The staff will review the various detailed computations for each model and will review the acceptability of the input parameters to the model.

3.1.4 Erosion Protection Design

Design details and analyses pertinent to the following aspects of erosion protection will be reviewed, as applicable:

(1) Erosion protection against the effects of flooding from nearby large streams.

(2) Erosion protection for drainage and diversion channels.

(3) Erosion protection for the top and side slopes of the pile.

(4) Erosion protection for the apron/toe area of the side slope.

(5) Durability of the erosion protection.

(6) Construction considerations, including specifications, quality assurance programs, quality control programs, and inspection programs.

3.1.5 Design of Unprotected Soil Covers and Vegetated Soil Covers

If an unprotected soil cover or a vegetated soil cover is proposed, the following design details, calculations, and analyses will be reviewed:

(1) Determination of allowable shear stresses and permissible velocities for the cover.

(2) Determination of allowable shear stresses and permissible velocities for the cover in a degraded state, including the effects of fires, droughts, vegetation succession, and other impacts to the ability of the cover to function without maintenance.

(3) Information on types of vegetation proposed and its ability to survive natural phenomena.

(4) Information, analyses, and calculations of all input parameters to models used.

3.2 Acceptance Criteria

3.2.1 Regulatory Requirements

The basic acceptance criteria pertinent to the erosion protection aspects of these reviews is provided in EPA's 40 CFR Part 192, Subpart A. 40 CFR 192.02 states that:

"Control of residual radioactive materials and their listed constituents shall be designed to:

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

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

(1) exceed an average release rate of 20 picocuries per square meter per second, or

(2) increase the annual average concentration of radon-222 in air at or above any location outside the disposal site by more than one-half picocurie per liter."

Control is defined in the regulation as "any remedial action intended to stabilize, inhibit future misuse of, or reduce emissions or effluents from residual radioactive materials."

3.2.2 Regulatory Guidance

NRC regulatory guides have not been developed which are directly applicable to the surface water hydrology aspects of the UMTRA program. However, there are staff technical positions that may provide generic guidance in this area. These reports are:

(a) Final Staff Technical Position (FSTP) (NRC, 1990) - "Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites."

(b) Staff Technical Position (NRC, 1989b) - "Standard Format and Content for Documentation of Remedial Action Selection at Title I Uranium Mill Tailings Sites."

The Final Staff Technical Position, in particular, discusses acceptable methods for designing erosion protection to provide reasonable assurance of effective long-term control and thus meet the EPA standard. The FSTP also provides discussions and technical bases for use of specific criteria to meet the 1000-year longevity requirement, without the use of active maintenance.

3.3 Review Procedures

3.3.1 Hydrologic Description of Site

The information normally presented is not amenable to independent verification, except through cross-checks with available publications related to hydrologic characteristics of the site region and through observation during site visits. The review procedure consists of evaluating the completeness of the information and data, by sequential comparison with information available from references. Based on the description of the hydrosphere (e.g., geographic location and regional hydrologic features), potential site flood mechanisms are identified.

The staff also will analyze geomorphic considerations, as described in SRP Section 1. Based on these analyses, the staff will estimate the potential for geomorphic changes to occur and to have a significant effect on the ability of the site and its protective features to prevent flood intrusion and erosion of the tailings over a long period of time. If geomorphic problems are identified, the staff will give particular attention to several areas of the design, depending on site conditions and potential for geomorphic changes to occur. These areas include: (1) the apron and toe of the disposal cell; (2) intersection of natural gullies with erosion protection features, such as a diversion channel, and (3) diversion channel outlets. A detailed discussion of the erosion protection design for these and other features is given in SRP Section 3.3.4, below.

Acceptance of the information presented is based on a qualitative evaluation of the completeness and quality of information, data, and maps. The description of structures, facilities, and erosion protection designs should be sufficiently complete to allow independent evaluation of the impact of flooding and intense rainfall. Site topographic maps should be of good quality and of sufficient scale to allow independent analysis of pre- and post-construction drainage patterns.

3.3.2 Flooding Determinations

The staff will estimate the flood levels, velocities, shear stresses, and magnitudes, as described below. Staff estimates may be made independently from basic data, by detailed review and checking of the RAP analyses, or by comparison with estimates made by others that have been reviewed in detail. The evaluation of the adequacy of the estimates is a matter of engineering judgment, and is based on the confidence in the estimate, the degree of conservatism in each parameter used in the estimate, and the relative sensitivity of each parameter as it affects the flood level or flood velocity.

The evaluation of flooding is, for review purposes, separated into two parts: (1) flooding on large adjacent streams, as applicable, and (2) flooding on local drainage channels and protective features. The acceptability of using the PMF as the design flood event is presented in the FSTP. The review procedure for evaluating a PMP/PMF event is outlined in the FSTP. For large drainage areas, PMF estimates approved by the Chief of Engineers, Corps of Engineers, and contained in published or unpublished reports of that agency, or generalized estimates may be used instead of independent staff-developed estimates. The staff will utilize flood estimates developed by Crippen and Bue (1977) and by the

U. S. Bureau of Reclamation (1986) to determine historic regional floods. If the historic maximum floods exceed the proposed PMF estimates, the staff will perform a detailed evaluation to determine the reasons for the discrepancies; the staff will compare basin lag times, rainfall distributions, soil types, and infiltration loss rates to determine if there is a logical basis for the PMF values being less than historic floods. Without such estimates, the staff will generally use Corps of Engineers' runoff, impoundment, and river routing models to independently estimate PMF discharge and water levels at the site. If a computer model such as HEC-1 is used, the staff will review the adequacy of the various input parameters to the model, including but not limited to the following: drainage area, lag times and times of concentration, design rainfall, incremental rainfall amounts, temporal distribution of incremental rainfall, and runoff/infiltration relationships. When detailed independent estimates are necessary, the applicant will be requested to provide all necessary basic data not already included in the supporting documents.

Information pertinent to computation of the design flood should be submitted in sufficient detail to enable the staff to perform an independent flood estimate. Acceptance of the analysis is based on: acceptability of model input parameters; general agreement of the staff's and the RAP estimates of flood levels and peak discharges; and the adequacy of the computational methods used for such estimates.

For dam failures, the staff will review the analyses provided in the RAP or will independently estimate the peak flows at the site. The acceptable "worst conditions" that should be postulated in the analysis of upstream dam failures are: (1) an approximate 25-year flood on a normal operating reservoir pool level coincident with the dam-site equivalent of the earthquake for which the remedial action project is designed; (2) a flood of about one-half the severity of a PMF on a normal reservoir pool level coincident with the dam-site equivalent of one-half of the earthquake for which the remedial action project is designed; and (3) a PMF (or design flood) on a normal reservoir pool. Conditions (1) and (2) are applied when the dam is not designed with adequate seismic resistance; condition (3) is applied when the dam is not designed to safely store or pass the design flood. Often, it may be much easier to perform simplified flood analyses assuming a dam failure, rather than detailed analyses of the seismic resistance of a dam. In such cases, the staff will review those simplified flood analyses by the procedures outlined in Section 3.3.4, below.

In those cases where it is documented that it is clearly impractical to design erosion protection features for an occurrence of the PMF, the staff will evaluate the information provided in the RAP as follows:

(1) The staff will review several proposed designs (of varying slopes, configurations, alignments, drainage areas, etc.) to (a) determine the difficulties in providing a reasonable design at a given site, (b) determine that reasonable designs have been identified, and (c) determine that the designs are impractical.

(2) The staff will review erosion protection requirements associated with each of the

above designs.

(3) The staff will review the costs (including transportation) associated with each design.

(4) The staff will review the analyses and logic that justify the reduction in flood criteria.

(5) The staff will review the flood design bases and design of protective features with respect to the ability of the design to satisfy the EPA minimum stability requirement of 200 years.

(6) The staff will review the ability of readily-available erosion protection materials to satisfy design requirements.

Additional information regarding justification of a stability period of less than 1000 years can be found in the FSTP. In general, a proposed design based on less than a PMF event must provide reasonable assurance of meeting the EPA stability requirement of 200 years. The ability of the design to resist such flood events is independently checked and evaluated by the staff to assure that minimum EPA standards are met.

In the detailed review of flooding, the staff will carefully consider several factors that are important in determining a local PMP/PMF event. These factors include:

(1) Determination of Design Rainfall Event. The staff will consult appropriate Hydrometeorological Reports and determine that correct values of the one-hour and six-hour PMP events, as applicable, have been determined.

(2) Infiltration Losses. The staff will check calculations to verify that conservative values of infiltration have been selected.

(3) Times of Concentration. The staff will verify that appropriate methods (depending on the slope, configuration, etc.) have been selected. The staff will independently verify that the methods selected compare reasonably well with various velocity-based methods of design.

(4) Rainfall Distributions. The staff will verify that the rainfall distributions (particularly the 2½-minute, 5-minute, and 15-minute distributions) compare well with the distributions suggested in the FSTP.

For dam failures, the acceptability and conservatism of the RAP estimate of flood potential and water levels are reviewed. In general, depending on the potential for flooding, the staff will verify that the RAP dam failure analyses are either realistic or conservative by determining locations and sizes of upstream dams assuming an instantaneous failure (complete removal) of the dam embankment and computing the peak outflow rate.

If this simplified analysis indicates a potential flooding problem, the analysis may be repeated using more refined techniques, and additional information and data may be requested. Detailed failure models, such as those of the Corps of Engineers and National

Weather Service are utilized to identify the outflows, failure modes, and resultant water levels at the site.

If a flood less than a PMF can cause dam failure and is proposed as the design basis flood, the review procedures outlined above are employed to determine the impracticality of designing for a PMF and to determine the acceptability of the flood used.

3.3.3 Water Surface Profiles, Channel Velocities, and Shear Stresses

Using the guidance presented in the FSTP, the staff will verify that localized flood depths, velocities, and shear stresses used in models for rock size determination (such as the Safety Factors Method or the Stephenson Method) are acceptable. For offsite flooding effects, the staff will verify that computational models (such as HEC-2) have been correctly and appropriately used and that the output from the model has been correctly interpreted. The staff will verify that acceptable models and input parameters have been used in all of the various portions of the flood analyses and that the resulting flood forces have been acceptably accommodated. Information regarding acceptable models may be found in the FSTP.

3.3.4 Erosion Protection Design

The staff will check the RAP analyses or perform independent review analyses of floods, flood velocities, and rock durability according to the guidelines provided in the FSTP. If the design assumptions and calculations are reasonable, accurate, and/or compare favorably with independent staff estimates, the designs are found acceptable.

Depending on the designs proposed, the staff will review erosion protection designs for the following areas: (1) top slope; (2) side slope; (3) apron/toe; (4) diversion channel; and (5) diversion channel outlet. Specific review procedures and acceptance criteria for each of these areas are discussed below, including areas of particular concern and importance.

3.3.4.1 Top Slope

Because the use of the Safety Factors Method (Simons and Senturk, 1977) provides an acceptable computation method for design of erosion on relatively flat slopes, the staff will review input parameters to the model according to the recommendations given in the FSTP and referenced technical procedures. The staff will assess the design flow rate, the depth of flow, angle of repose, specific gravity, and other parameters.

3.3.4.2 Side Slope

The staff will review parameters to acceptable models, such as the Stephenson Method (Stephenson, 1979), similar to those listed in Section 3.3.4.1, above.

3.3.4.3 Apron/Toe

The review of the design of the apron and toe is accomplished by verifying that several design features in this area have been properly designed.

For the lower end of the side slope where it meets the toe, the staff will verify that proper consideration has been given to the potential occurrence of increased shear forces resulting from turbulence and energy dissipation produced by hydraulic jumps when the flow transitions from supercritical to subcritical. The staff will verify that appropriate design criteria (such as that used by the Corps of Engineers in their Hydraulic Design Criteria manual) have been used to increase the rock size to account for the increased velocities or shear forces.

For the main area of the toe, the staff will assure that appropriate methods have been used to design the riprap, depending on the magnitude of the slope of the toe.

For the downstream end of the toe, the staff will verify that acceptable assumptions have been made regarding the assumed collapse of the rock into scoured areas to prevent gully intrusion into the pile. Flow concentrations, collapsed slopes, and computational models used by the applicant will be evaluated.

For the natural ground area at the downstream end of the toe, the staff will verify that appropriate methods have been used to compute scour depths and that natural erosion will not adversely affect long-term stability.

3.3.4.4 Diversion Channels

Using the criteria and guidance presented in the FSTP, the staff will evaluate the design of diversion channels in several critical areas.

For the main channel area, the staff will verify that appropriate models and input parameters have been used to design the erosion protection. The staff will assure that flow rates, flow depths, and shear stresses have been correctly computed.

For the channel side slopes, the staff will verify that the side slopes are capable of resisting flow velocities and shear stresses from flows that occur directly down the side slope. This occurs often when diversion channels are constructed perpendicular to natural gullies (which discharge into the diversion channel). The shear forces in these locations often greatly exceed the forces produced by flows along the channel, particularly when the natural ground slopes in the area are greater than the slope of the diversion channel.

For the outlet of the diversion channel, the staff will evaluate the design of erosion protection to assure that erosion in the discharge area (normally a natural gully, swale, or channel) has been adequately addressed. Designs similar to apron/toe designs will be evaluated to determine their resistance to erosion.

For the entire length of the diversion channel, the staff will evaluate the effects of sediment accumulations on flow velocities, ditch capacity, and need for increased rock size or capacity.

3.3.4.5 Rock Durability

The staff will review the results of durability testing of proposed rock sources to assure that durable rock will be provided. The FSTP provides a detailed method for evaluating rock quality.

3.3.4.6 Construction Considerations

The staff will review the plans, specifications, inspection programs, and QA/QC programs to assure that adequate measures are being taken to construct the design features according to accepted engineering practices. The staff will compare the information provided with typical programs used in the construction industry.

3.3.5 Design of Unprotected Soil Covers and Vegetated Soil Covers

If a soil cover is proposed, the staff will evaluate the design using the general criteria outlined in the FSTP. Particular attention will be given to the input parameters to various models.

(a) The staff will verify that the design flow rate includes an appropriate flow concentration factor that reflects consideration of settlement, soil removal by sheet flow and wind, degradation of the vegetation cover, intrusion of trees, blockage of flows by fallen trees, etc.

(b) The staff will assure that estimates of Manning's "n" value correspond to the vegetation cover proposed and do not underestimate or overestimate the value to determine allowable shear stresses and permissible velocities, respectively.

(c) The staff will verify that appropriate values of allowable shear stresses and permissible velocities have been used and conservatively reflect potential changes that could occur to the cover over a long period of time as a result of fires, droughts, diseases, vegetation succession, or general cover degradation.

(d) The staff will check analyses and/or independently calculate allowable slopes using several different methods and ranges of input parameters. Using a range of flow concentration factors, shear stresses, permissible velocities, "n" values, and models, the staff will check the sensitivity of the analyses and will verify that reasonable and appropriate values of input parameters have been selected.

If a sacrificial soil cover is proposed for use for the minimum 200-year period, the staff will check the calculations and justification for reduction of the stability period using procedures given in the FSTP.

3.4 Evaluation Findings

If the evaluation by the staff, based upon complete review of hydraulic engineering aspects of the remedial action plan, confirms that the EPA standards and regulatory guidelines have been met, documentation of the review will state that:

(1) the flood analyses and investigations adequately characterize the flood potential at the site,

(2) the analyses of hydraulic designs are appropriately documented and employ an acceptable level of conservatism, and

(3) the general remedial action plan with respect to surface water hydrology and erosion considerations represents a feasible plan for assuring the long-term stability provisions of the EPA standards established by 40 CFR 192, Subpart A.

Staff reservations and unresolved technical issues, based on the review of the surface water hydrology and erosion protection aspects of the proposed remedial action, will be stated in sufficient detail to clearly define the nature of the concerns.

3.5 References

American Nuclear Society, American National Standard for Determining Design Basis Flooding at Power Reactor Sites, ANSI/ANS-2.8, 1981.

Chow, V. T., Open Channel Hydraulics, McGraw-Hill Book Co., New York, 1959.

Code of Federal Regulations, Title 40, Protection of Environment, Part 192,"Health and Environmental Protection Standards for Uranium Mill Tailings," 1983.

Crippen, J.R. and Bue, C.D., "Maximum Floodflows in the Conterminous United States," USGS Water Supply Paper #1887, 1977.

Fread, D.L., "DAMBRK: The NWS Dam-Break Flood Forecasting Model,"National Weather Service, Silver Spring, MD, continuously updated.

Henderson, F.M., Open Channel Flow, MacMillan Co., New York, 1971.

Interagency Advisory Committee on Water Data, Hydrology Subcommittee Working Group on PMF Risk Assessment, "Draft Report on the Feasibility of Assigning a Probability to the Probable Maximum Flood," June 1985.

Nelson, J.D. et al., "Design Considerations for Long-Term Stabilization of Uranium Mill Tailings Impoundments", NUREG/CR-3397, ORNL-5979, October 1983.

Simons, D.B. and Senturk, F., Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado, 1977.

Stephenson, D., Rockfill Hydraulic Engineering Developments in Geotechnical Engineering No. 27, Elsevier Scientific Publishing Company, 1979.

Temple, D.M., et al., "Stability Design of Grass-Lined Open Channels," U.S. Department of Agriculture, Agricultural Handbook Number 667, 1987.

U. S. Army Corp of Engineers, "Flood Hydrograph Package," HEC-1, Hydrologic Engineering Center, continuously updated.

---"Water Surface Profiles," HEC-2, Hydrologic Engineering Center, Davis, California, continuously updated.

---"Reservoir System Operation for Flood Control," HEC-5, HydrologicEngineering Center, Davis, California.

---"Stone Protection," CE 1308, January 1948.

---"Standard Project Flood Determinations", EM 1110-2-1411, 26 March 1952 (rev. March 1965).

---"Flood Hydrograph Analysis and Computations," EM 1110-2-1405, August 1959.

---"Backwater Curves in River Channels," EM 1110-2-1409, December 1959.

---"Routing of Floods through River Channels," EM 1110-2-1408, March 1960.

---"Hydraulic Design Criteria," continuously updated and revised.

---"Hydraulic Design of Spillways," EM 1110-2-1603, March 1965.

---"Interior Drainage of Leveed Urban Areas: Hydrology," EM 1110-2-1410, May 1965.

---"Policies and Procedures Pertaining to Determination of Spillway Capacities and Freeboard Allowances for Dams," EC 1110-2-27, February 1968.

---"Hydraulic Design of Flood Control Channels," EM 1110-1601, July 1970.

---"Additional Guidance for Riprap Channel Protection,"ETL 1110-2-120, May 1971.

---"Runoff from Snowmelt," EM 1110-2-1406, 5 January 1980.

U. S. Bureau of Reclamation, Design of Small Dams, Second Edition, U.S. Department of the Interior, 1973.

---"Comparison of Estimated Maximum Flood Peaks with Historic Floods," 1986.

U.S. Nuclear Regulatory Commission, Final Staff Technical Position (FSTP) "Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites," 1990.

---Regulatory Guide 1.59, "Design Basis Floods for Nuclear Power Plants."

---"Staff Technical Position - Standard Format and Content for Documentation of Remedial Action Selection at Title 1 Uranium Mill Tailings Sites", February, 1989b.

U.S. Weather Bureau, Hydrometeorological Reports (now U.S. Weather Service, NOAA), Hydrometeorological Branch: Nos. 43, 49, 55.

4.0 WATER RESOURCES PROTECTION

4.1 Areas of Review

The NRC staff has developed a systematic approach for reviewing Remedial Action Plans (RAPs) developed by the U.S. Department of Energy (DOE) for the UMTRCA Title I Uranium Mill Tailings sites. This chapter presents a standard approach for reviewing, evaluating, and documenting the technical and regulatory findings for issues pertaining to Water Resources Protection. The ultimate objective of the review is to determine if the proposed remedial action(s) meets the U.S. Environmental Protection Agency (EPA) regulatory standards and is technically achievable. The primary review areas for the Water Resources Protection issues are:

(1) Site characterization of features that affect surface-water and ground-water movement,

(2) Conceptual design of the proposed remedial action,

(3) Disposal Standards (40 CFR 192, Subpart A; and best engineering practices),

(4) Ground-Water Cleanup (40 CFR 192, Subpart B; and best available technologies), and

(5) Supplemental Standards (40 CFR 192, Subpart C).

Additional discussion of these review areas is provided in SRP Section 4.3.

4.1.1 Site Characterization

The staff will review regional and site-specific hydrogeologic information related to both the former processing site and the proposed disposal site. The hydrogeologic information should include both surface-water and ground-water systems, along with any interrelations among those systems. The processing and disposal sites should be adequately characterized for determining the needed level of remedial action and for evaluating the impact the proposed remedial action may have on the water resources.

The site characterization review will also include an examination of the assessments that evaluate the existing and potential impacts of water contamination. These assessments should provide both quantitative and qualitative estimates of the impact to humans and the environment from any existing and potential groundwater contamination.

4.1.2 Conceptual Design

A detailed description of the proposed remedial action, including a conceptual design of the disposal facility, is an integral part of the water resources review. This aspect of the review provides the basis for evaluating whether the proposed remediation will meet the ground-water protection standards established by EPA. The conceptual design narrative should describe the principal design features that will be relied upon to demonstrate compliance with the ground-water protection standards (NRC, 1989).

4.1.3 Disposal Standards

The proposed disposal design must assure compliance with the ground-water protection standards. Compliance is demonstrated through engineering assessments of the anticipated performance of the critical design features and provisions to demonstrate the post-closure performance of the design through ground-water monitoring. Credible failure scenarios and conceptual corrective action plans must also be identified, along with a commitment to a detailed Long-Term Surveillance Plan.

4.1.4 Ground-Water Cleanup

A clear statement of intent concerning the restoration of ground water contaminated by milling operations must be presented in the RAP. The implementation of ground-water cleanup may be deferred to a later project phase, as long as the delay does not impact human health or the environment in the vicinity of the processing site. Detailed implementation plans and hydrogeologic characterizations are performed as part of the deferred activities.

4.1.5 Supplemental Standards

Supplemental ground-water protection standards may be used if the processing or disposal sites meet the regulatory criteria for applying supplemental standards as defined in 40 CFR 192.21. These standards may be used *in lieu* of the standards in Subparts A and B, and may be either numerical or narrative performance objectives. The criterion that allows the use of supplemental standards must be identified and the specific standard must be clearly stated in the RAP.

4.2 Acceptance Criteria

4.2.1 Regulatory Requirements

The acceptance criteria that are pertinent to the Water Resources Protection aspects are contained in EPA's regulations under 40 CFR 192, Subparts A, B, and C. The original standards were promulgated with an effective date of March 7, 1983 (48 FR 602; January 5, 1983).

In 1985, the standards dealing with ground-water requirements were remanded by court action. EPA published proposed new standards on September 24, 1987; but to date the standards have not been finalized. Section 108 of UMTRCA requires that DOE comply with the ground-water protection standards proposed by EPA, until such time as the standards are promulgated in final form. Consequently, the remedial action programs are progressing with the published 1987 standards as regulatory guidance. The Commission believes that sites where remedial action has been essentially completed prior to EPA's promulgation of final ground-water standards will not be impacted by the final ground-water standards. Although additional effort may be appropriate to assess and remediate any existing contaminated ground-water at the processing sites, the existing disposal site designs should be sufficient to provide long-term protection against future ground-water contamination. Appendix D contains the 1987 ground-water protection standards (EPA, 1987). The EPA standards are divided into three components:

Subpart A — Subpart A contains standards to control further contamination at the disposal sites. The ground-water protection standards have provisions to:

(1) Identify a list of hazardous constituents;

(2) Determine concentration limits for the identified hazardous constituents; and

(3) Determine the compliance point(s) where concentration limits must be met.

In addition to the constituents designated in §261, Appendix VIII of the Resource Conservation and Recovery Act (RCRA); EPA requires that molybdenum, combined radium—226 and —228, combined uranium—234 and —238, and nitrate (as N) be characterized at all sites. EPA also designated Maximum Concentration Limits (MCLs) and activity limits for these constituents, along with net gross alpha activity.

Not all of the constituents listed in Appendix VIII have MCLs. The complete list of constituents which currently have MCLs (Parts 192, 261, and 264) are provided in Table 2. None of the 14 organic compounds listed in Table 2, with the exception of 1,2-Dichloroethane, have been identified in uranium mill tailings.

The standards further incorporate provisions for ground-water monitoring to evaluate post-disposal performance of the disposal facility and for the use of alternate concentration limits (ACLs). Additionally, §192.02(a)(4) requires that the facility closure is performed in such a manner that future maintenance is minimized.

Subpart B — Subpart B contains cleanup standards for the processing site, including ACLs, and passive ground-water restoration. Specific guidance on ACLs for Title I sites has not yet been established by NRC. However, guidance on ACL application at Title II facilities is available (NRC Staff Technical Position, 1988b). Under the Subpart B standards, the use of ACLs require EPA's approval after NRC determines that the ACLs are as low as reasonably achievable, considering practicable corrective actions. Subpart B also provides for passive restoration allowing ground-water cleanup through natural flushing for an extended period of up to 100 years, if the ground water will not be used as a drinking water source within the remedial period.

Subpart C — Subpart C contains criteria for applying supplemental standards that may be used in place of the requirements of Subparts A and B, under specific circumstances. §192.21 lists eight conditions (eligibility requirements) that allow the use of supplemental standards.

Supplemental standards may be applied if any one of these conditions pertains to the site. The supplemental standards are qualitative in nature. Consequently, achieving

TABLE 2 - Maximum Concentration Limits (MCLs)

HAZARDOUS CONSTITUENT	MCL (mg/L)
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium	0.05
Lead	0.05
Mercury	0.002
Selenium	0.01
Silver	0.05
Endrin (1,2,3,4,10,10—hexachloro—6,7—epoxy—1,4,4a,5,6,7,8,8a—octahydro—1,4—endo, endo—5,8—dimethanonaphthalene)	0.0002
Lindane (1,2,3,4,5,6—hexachlorocyclohexane, gamma isomer)	0.004
Methoxychlor (1,1,1—trichloro—2,2'—bis(p—methoxyphenylethane))	0.1
Toxaphene ($C_{10}H_{10}Cl_6$, Technical chlorinated camphene, 67 to 69 percent chlorine)	0.005
2,4—D (2,4—Dichlorophenoxyacetic acid)	0.1
2,4,5—TP Silvex (2,4,5—Trichlorophenoxypropionic acid)	0.01
Benzene (Cyclohexatriene)	0.005
Vinyl chloride (Ethene, chloro-)	0.002
Tetrachloromethane (Carbon tetrachloride)	0.005
1,2—Dichloromethane (Ethylene dichloride)	0.005
Trichloroethene (Trichloroethylene)	0.005
1,1—Dichloroethylene (Ethene, 1,1—dichloro-)	0.007
1,1,1—Trichloroethane (Methyl chloroform)	0.20
p—Dichlorobenzene (Benzene, 1,4—dichloro-)	0.075
Nitrate (as N)	10
Molybdenum	0.1
Combined Radium—226 and —228	5 pCi/L
Combined Uranium—234 and —238	30 pCi/L
Gross Alpha Particle Activity (excluding radon and uranium)	15 pCi/L

specific numerical values are not necessary to meet the standards, as long as the performed actions come as close to meeting the otherwise applicable standards (Subparts A and B) as is reasonable under the circumstances. The proposed actions and the supplemental performance standards must be identified and justified by DOE in the RAP.

4.2.2 Regulatory Guidance

There are no regulatory guides directly applicable to the Water Resources Protection aspects of the Title I program.

4.3 Review Procedures

The NRC staff review of Water Resources Protection assessments is performed for the purpose of providing a technically-defensible, independent verification that the selected remedial actions will meet the EPA ground-water protection standards. The NRC staff review is not meant to duplicate DOE's assessment effort. In performing these reviews, the NRC staff focuses on independently verifying the conclusions and selections made by DOE. The NRC staff verification might include independent literature surveys, data assessments, or calculations. The staff reviewers identify items of concern and convey the issues through written comments or requests for additional information. The staff primarily focuses on the following areas:

4.3.1 Site Characterization

An adequate characterization includes facility, vicinity, and hydrogeologic information. The reviewer should ensure that these components are described in terms of both the surface-water and ground-water systems at the processing and disposal sites.

4.3.1.1 Facility Characterization

An adequate facility characterization is needed to evaluate the existing and potential contamination at the processing site. This characterization provides information on human activities that may have impacted the mill site. General descriptions of the facility might be presented in the executive summary or introductory sections of the RAP. The reviewer should ensure that the general descriptions provide adequate detail for evaluation of the water resources protection assessments. A facility characterization is acceptable if it includes:

(1) The description of the uranium recovery process(es) and the duration of use,

(2) A description of reagents and the relative quantities used in the milling process, and

(3) A description of waste management practices, such as; types of wastes generated, waste discharge locations, retaining structures for wastes, relative waste quantities, and chronology of waste management practices.

The reviewer will also determine whether the level of detail provided in the facility characterization is proportional to the amount of information required for an adequate contaminant-source characterization. The expected impacts of the described operational practices on the hydrogeologic system, and background water quality should also be considered during the facility characterization review.

4.3.1.2 Vicinity Characterization

At some sites, human activities unrelated to the milling operation and natural processes may have altered the hydrogeologic system. Such activities may influence the selection of remedial actions. Human activities include: ground-water use, crop irrigation, mine dewatering, ore storage, municipal-waste landfills, oil and gas development, and exploratory drilling. Natural processes include: geothermal springs, natural concentration of soluble salts by evaporation, and ground-water/surface-water interactions.

The reviewer will determine whether these factors have been appropriately considered in the remedial action selection. An acceptable vicinity characterization adequately identifies and evaluates the magnitude of the effects of vicinity activities and processes on the selection of remedial actions.

4.3.1.3 Hydrogeologic Characterization

The hydrogeologic characterization is the primary site characterization component that is used to evaluate whether the proposed remedial actions will comply with the EPA ground-water protection standards. The hydrogeologic characterization relies on comparisons of the base-line conditions to the milling operation influences. The characterization also encompasses the anticipated impacts that any existing contamination may have on present and future human and environmental populations. The primary elements of the hydrogeologic characterization include:

(1) Identification of hydrogeologic units,

(2) Identification and assessment of the hydraulic and transport properties,

(3) Description and measurement of the geochemical conditions and the contamination extent, and

(4) Assessment of the current and future water uses.

The reviewer should be sensitive to the overall quality and defensibility of DOE's field investigations. There may be instances where DOE will use data or take measurements from other projects, which were not conducted by DOE, and may not have the same level of quality control as the UMTRA Project investigations. The reviewer should identify any data presented in the RAP that were not developed by DOE and what design or characterization conclusions are influenced by those data. The reviewer should confirm that DOE has provided written assurance that any 'non-DOE data' used in the RAP are at least of an equivalent quality-level as data that DOE would have developed. Examples of the data types that may be included in this category are:

- Existing monitoring well data from previous investigations,
- Historical analytical data, or
- Aquifer property measurements, both field and laboratory derived.

There may be other types of data presented in the RAP that were not developed by DOE during the course of the UMTRA Project. The reviewer should identify these data as apart of the RAP review.

4.3.1.3.1 Identification of Hydrogeologic Units

The reviewer should verify that adequate hydrogeologic information is provided for review (NRC, 1989). This information includes; the geometry, lateral extent, and thickness of all potentially affected aquifers and confining units at the processing and disposal sites. This information will normally be provided as hydrostratigraphic cross-sections and outcrop maps. The reviewer should ensure that the data quality and quantity are adequate to support a technically-defensible interpretation.

The reviewer should also verify that DOE has provided sufficient descriptions of the unsaturated units that may convey hazardous constituents to the water-bearing units. Adequate information should be provided to support a representative conceptual model for contaminant transport pathways. This would include identifying potential preferential flow pathways that are both natural and man-made.

The identification of hydrogeologic units is important in determining where (i.e., the uppermost aquifer) regulatory compliance will be met. As an example, the NRC staff has had questions in several reviews (Belfield/Bowman and Rifle sites) as to whether specific units were identified as aquitards or aquifers. This specific concern had a direct bearing on the depth that post closure compliance monitoring would be performed, and whether the monitoring would be appropriate for verifying cell performance.

Adequate characterization information should also be provided for the processing site, if the RAP proposes to relocate the tailings from the processing site to a new disposal site. Characterization at the processing site, in these cases, is used to evaluate any proposal to defer the ground-water restoration to a later project phase. The level of characterization necessary to support the deferral of ground-water restoration is likely to be less rigorous than the characterization needed to develop and implement a restoration program. The characterization should be sufficient to support the conclusion that human and environmental populations will not be substantially impacted if the ground-water restoration is delayed to a later project phase.

The NRC reviewer should not assume that the hydrostratigraphic description provided in the Geology report of the RAP corresponds closely with the description in the Ground-Water Hydrology report. Since these reports are often prepared by different staff within the DOE's Technical Assistance Contractor (TAC), and emphasize different characterization concerns; there are often differences between the two reports that may become important when identifying potential preferential flow zones.

As appropriate, the reviewer should determine that the following information has been included in the identification of the hydrogeologic units:

- Maps of sufficient detail that show the dimensions and locations of hydrogeologic systems that could have been impacted by milling operations;

- Descriptions and measurements of any interactions among the various components of the hydrogeologic system, such as, surface-water and ground-water relationships;

- Climatic characteristics, including precipitation, potential evapotranspiration, and temperature;

- Geologic characteristics, including local and regional structures, fractures and joints, lithologic and stratigraphic distributions, and solution porosity (refer to Chapter 1.0 — Geology and Seismology); and

- Surface-water characteristics including location, flow rates, drainage areas, seasonal variations, hydrographic modifications, and current water allocations (refer to Chapter 3.0 — Surface Water Hydrology and Erosion Protection).

The review of the properties that affect ground-water flow and contaminant transport are performed under separate review categories, as described below.

4.3.1.3.2 Hydraulic and Transport Properties

The reviewer should verify that DOE has adequately described the hydraulic and transport properties of potentially affected hydrogeologic units at both the processing and disposal sites (NRC, 1989). Hydrogeologic parameters that should be provided in the RAP include: hydraulic conductivities (K_h and K_v), gradient, effective porosity, solution porosity, storage coefficient, and dispersivity. The reviewer must determine which of these parameters exerts the greatest influence on compliance with the standards. The reviewer should confirm that the critical parameters have been measured at the site during DOE's characterization efforts. The exception to this is the effective porosity, which can be conservatively estimated, based on lithology and measured grain-size distributions. Normally, an effective porosity of 10 percent is assumed conservative (represents the largest flow velocity), unless measured grain size and compaction information support a different value.

The reviewer should examine the methods, procedures and calculations that DOE used to obtain these parameters. For example, the hydrologist should review DOE's aquifer testing field procedures and calculations to confirm that the proper field and data-analysis techniques were used to develop the hydraulic conductivity measurements. If DOE proposes to use mean hydraulic parameters in their analyses, the reviewer should consider that many hydrogeologic parameters, including hydraulic conductivity, typically exhibit a log-normal distribution. Consequently, the geometric mean may be more representative of the overall conditions within a unit than the arithmetic mean.

The reviewer should also verify that literature values selected for effective porosity conform to the measured porosities of the various geologic materials. As a coarse check, the measured total porosity (inverse of the geotechnical void ratio) will generally be greater than effective porosity, because the dead-end pores do not contribute to fluid flow. Also, the specific yield measured during pumping tests of unconfined aquifers will be roughly equivalent to the effective porosity of the aquifer medium.

The storage coefficient is usually not a critical parameter unless transient analyses are performed. Generally, most of DOE's analyses assume steady-state ground-water flow conditions given the long time periods represented by the analyses. Dispersivities are also not generally critical, unless a contaminant transport analysis is used to demonstrate compliance. Dispersivity is difficult to quantify at the field scale, consequently literature values are often used. The reviewer should evaluate the literature dispersivity values, and verify that they represent conservative estimates.

Discussions of the various hydrogeologic parameters, including ranges for various geologic materials, can be found in Todd (1980); Bear (1979); Freeze and Cherry (1979); Lohman (1972); and Walton (1970).

An acceptable ground-water flow characterization should consider the aquifer properties and geologic features that affect the rate and direction of ground-water advection. The characterization of transport mechanisms should include contaminant dispersion properties and aquifer attenuation factors.

4.3.1.3.3 Geochemical Conditions and Contamination Extent

Details on the geochemical conditions that could affect the attenuation of hazardous constituents is an essential part of the submitted information (NRC, 1989). In general, this information will not be needed at a separate processing site until DOE proposes to address the Subpart B standards.

The reviewer must ensure that information on the geochemical conditions at the disposal site is provided, to support the conclusion that the standards will be met. The primary geochemical information includes:

- The chemical composition of the tailings leachate,
- The chemical and mineralogical composition of the subsurface materials, and
- The background ground-water quality.

The chemical composition of the leachate is readily measured from tailings pore-water samples. The chemical and mineralogical composition of the underlying lithologies are characterized by measurements of pH, buffering capacity, redox potential, adsorptive capacity, cation exchange capacity, and identification of the clay mineralogy. The general chemical characteristics of fluids within the lithologies can be described by measurements of pH, temperature, specific conductivity, redox potential, and buffering capacity.

Tailings leachate will generally be oxidized and either highly acidic or highly alkaline, depending on the milling process. Geochemical precipitation will cause some radionuclides, heavy metals, and some major ions to become relatively immobile. DOE generally takes credit for attenuation as an additional level of conservatism when the ground-water protection standards are met through some other mechanism. The attenuation capability for these cases is usually supported by laboratory analyses of organic content and bulk clay mineralogy, field measurements of redox and pH, and valences of the hazardous constituents.

Batch column-equilibria measurements, using representative leachate and soil samples, also must be performed in cases where the geochemical attenuation is the primary mechanism for achieving compliance with the standards. The reviewer should determine that DOE has demonstrated that adequate attenuation material is available at the disposal site to meet the design-life criteria of the disposal cell. DOE also should provide an assessment of the likelihood of permeability reduction in the attenuating medium, due to the additional mineral precipitation, and any adverse impacts on other design components of the disposal cell. Additionally, DOE should address the likelihood of hazardous constituents disorbing from the attenuation media under changes in redox conditions.

The extent of existing ground-water contamination must be determined at the processing site, even if DOE proposes to defer ground-water cleanup. An adequate characterization of the background ground-water quality is fundamental to the assessment of the existing ground-water contamination. Background water quality is defined as the chemical quality of water that would be expected at a site if contamination had not occurred from the uranium milling operation. Ambient contamination from uranium ore bodies, mining operations, or other human activities are considered as part of the background water quality.

DOE usually provides a statistical comparison between the on-site, down-gradient ground-water quality; and background ground-water quality to determine the contamination extent. The statistical methodology normally employed is an EPA methodology (EPA, 1989b). The reviewer must confirm that DOE has demonstrated that public health and the environment will not be substantially affected by deferring the ground-water cleanup. The effort expended to determine the background water quality should be proportional with the anticipated impacts any potential contamination may have on human health and the environment. The reviewer should determine that the background water-quality determination includes the following types of information, as applicable:

- Maps of sufficient detail and legibility showing the background monitoring locations;
- Descriptions of background monitoring devices including wells, springs, community water supplies, suction samplers, or other sampling devices;
- The distribution of wastes and contaminated materials at and near the site;
- Description of historical changes in hydraulic heads, flow directions, and flow rates relevant to the monitoring locations;

- Laboratory water-quality data for hazardous constituents major ions and indicator parameters;

- Assessments of any observed variations in background water quality;

- Identification of any off-site sources of water contamination; and

- Quality control/quality assurance procedures associated with the background water quality measurements; such as sampling protocols, laboratory analytical methods, field measurements, sample handling procedures, and quality assurance documentation.

An acceptable characterization of the contamination extent should include the spatial distributions of contaminants in ground water and surface water that exceed background or MCL concentrations of the hazardous constituents or indicator parameters. The contaminant distribution described in the characterization should be based on an adequate number of sampling locations and sampling episodes to technically support DOE's interpretation. The reviewer should determine that the characterization includes:

- The distribution and characteristics of on-site wastes; such as wind-blown contaminated materials, tailings piles, raffinate ponds, evaporation ponds, ore storage areas, and rubbish heaps;

- Identification of constituents that are measured at concentrations above the background levels and are reasonably expected to occur at the processing site;

- Constituent concentrations and indicator parameter values, including: pH, Specific Conductance, major ions, minor ions, trace metals, nitrate, uranium—234 and —238, radium—226 and —228, and thorium-230;

- A comparison, statistical or graphical, of the contaminated water quality to the background water quality;

- Maps and cross-sections showing the distribution of constituent concentrations in the ground water; and

- Quality assurance validation of the collected analytical data by replicate analyses, and ionic charge balances to within 5 percent of the total dissolved solids concentration.

Determining the contamination extent is required when DOE proposes on-site disposal, and also when DOE proposes to defer ground-water cleanup. DOE must clearly demonstrate that the on-site disposal will not interfere with future cleanup activities. The reviewer should consider the following technical elements when verifying whether DOE has adequately characterized existing ground-water contamination:

(1) Adequacy of the number of wells to represent background, on-site, and down-gradient conditions;

(2) Suitability of the background well locations;

(3) Appropriateness of screened intervals and completion depths for wells; and

(4) Appropriateness of the constituents (hazardous and indicator) included in the analyses.

When ground-water cleanup is deferred, the complete determination of the vertical and lateral ground-water contamination extent is not the main concern of the review; unless human health or environmental populations could be affected by the contamination. It is expected that the existing plume will continue to migrate until cleanup is initiated. The reviewer should also verify that DOE has made provisions to continue monitoring the plume until restoration has been initiated.

4.3.1.3.4 Water Use

The reviewer should verify that information on existing and projected water uses near the processing and disposal sites has been provided (NRC, 1989). The information should include a description of the hydrologic zones or locations where the water is being extracted, a description of the use, and water quality information. Generally, this information is provided for the area within a 1.6-3.2 kilometer (km) (1-2 mile (mi)) radius of the site.

The reviewer must assure that DOE has demonstrated that the surrounding water users will not be adversely affected by deferral of ground-water cleanup. In some cases, DOE indicates that the site is hydraulically isolated from nearby water users. In these cases, it is only necessary that DOE adequately demonstrate that the site is isolated and that there are no water users within the boundaries of the isolated area.

Human water consumption is not the only water use considered in the review. Any use that may bring someone into contact with the contaminated water must be considered when evaluating health hazards. For example, contaminated ground water containing radon, which is only used in the rest rooms of a building, could still pose a substantial health hazard.

Many of the Title I processing sites are located near rivers, since the uranium milling process typically requires a large amount of water. There commonly is a hydraulic relationship between the surface water and the shallow ground-water systems at those sites located within the river floodplain. Over some portion of the year, the river will serve as a discharge location for the shallow ground-water system. Typically DOE provides water-quality data up-stream and down-stream of the site to quantify any water-quality impacts.

The reviewer should assess whether the information demonstrates that contaminants entering the river will be diluted to below the appropriate concentration limits, even during low flow conditions. DOE must provide information in the RAP that quantifies the impacts to down-stream users, including recreational uses.

4.3.2 Conceptual Design Features

The reviewer should confirm that DOE has described the principal design features of the proposed remedial action that are relied upon to demonstrate compliance with the water resources protection aspects of the standards (NRC, 1989).

DOE will likely propose one of the following disposal options for the remedial action at a mill site:

(1) Tailings and contaminated materials are stabilized in place at the processing site (SIP);

(2) Tailings and contaminated materials are stabilized on site (SOS), but moved to a different location on the processing site property; or

(3) Tailings and contaminated materials are relocated to a different property and stabilized.

The selection of the disposal method that will meet the EPA standards (DOE, 1989a) is based upon technical and cost considerations. Figure 1 shows a schematic cross-section of the typical disposal cell design that DOE might use.

As Figure 1 shows, DOE typically employs a multi-component cover design, which consists exclusively of natural materials. The cover is the most important design element for demonstrating compliance with the ground-water protection standards. Cover designs will vary from site to site; however, the following components will have the greatest impact for Water Resources Protection:

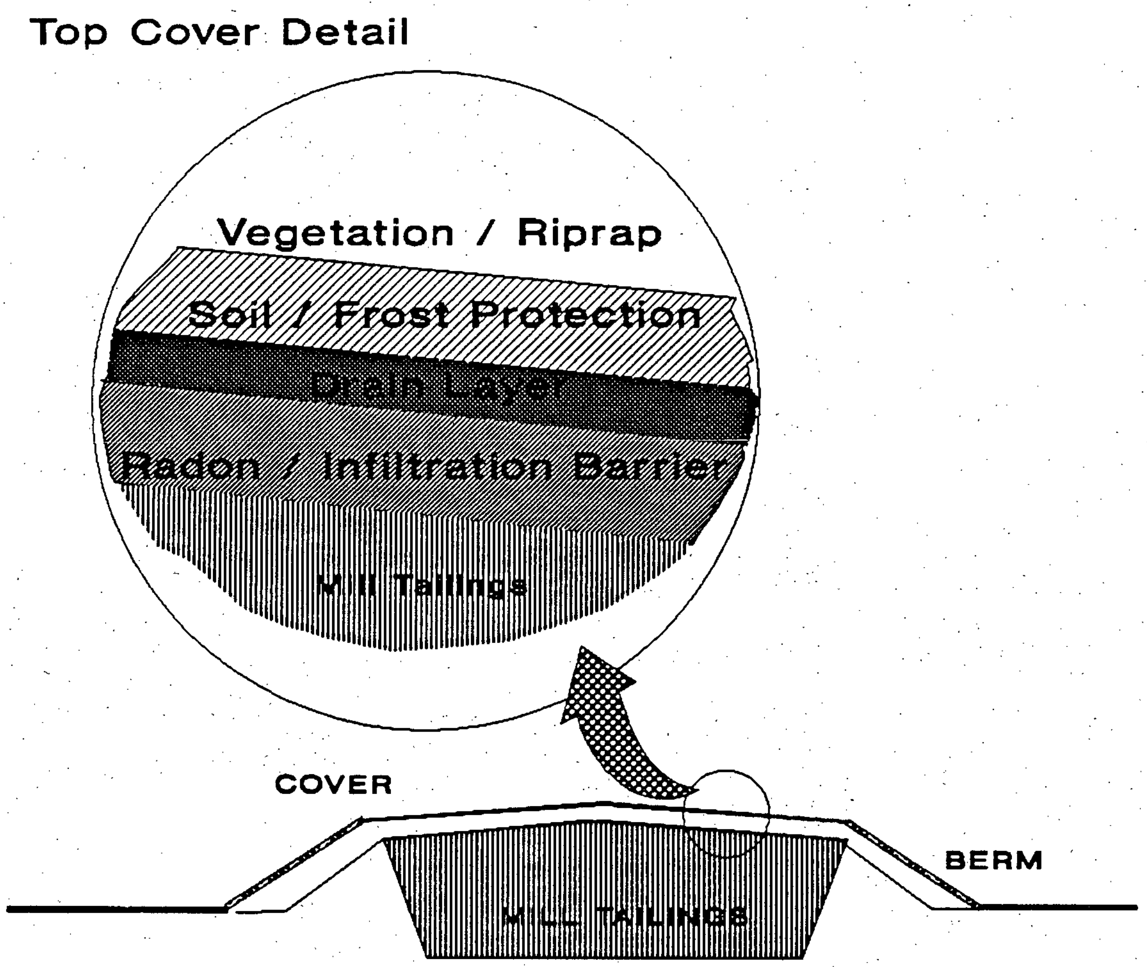
- The radon/infiltration barrier;
- The drain layer(s); and
- Vegetation (if applicable).

The amount of water that will come in contact with the contaminated materials will be the main factor that determines the amount of leachate generation; and, consequently, whether the ground-water standards will be met. Some determination of the leachate-generation potential is needed, since it is reasonable to expect that some meteoric water will enter the tailings. The radon/infiltration barrier is the most important cover component for demonstrating compliance with the ground-water protection standards, because it is designed to limit the amount of water that enters the tailings.

The radon/infiltration barrier is usually constructed from compacted clays. There may be some instances where a sodium bentonite additive is used to further reduce the hydraulic conductivity of the barrier. Synthetic liners have not been used, because their long-term reliability has not been demonstrated (Caldwell et. al., 1988).

Both the drain layer and vegetation will usually keep water away from the radon barrier. These components usually provide an added level of confidence that the standards

FIGURE 1 - Schematic of a Typical UMTRA Cover



will be met. Consequently, a separate compliance demonstration for these individual components is not generally performed. These components are primarily designed to perform a function other than limiting infiltration.

The drain layer normally consists of coarse sand with a large horizontal hydraulic conductivity. This layer is normally placed above the radon barrier to provide lateral drainage off the barrier. Ideally, this layer will aid in keeping the barrier from becoming fully saturated. The drain layer is also used to protect the radon barrier from freeze/thaw stresses. The cover vegetation (note: DOE does not commonly include vegetation on the side-slopes), helps to remove moisture by evapotranspiration. A vegetation cover is not proposed for all sites, due to climate considerations. When a vegetation layer is proposed, the primary function is for erosion protection, and limiting infiltration is an added benefit. Additional discussions on the cell cover components are presented in Chapter 2.0 GEOTECHNICAL STABILITY, and Chapter 3.0 SURFACE WATER HYDROLOGY AND EROSION PROTECTION.

The reviewer will generally not be concerned about the design features of the drainage layers and vegetation, since these components are typically not relied on to demonstrate compliance with the standards. DOE typically employs one of the following approaches to demonstrate that the radon barrier will contribute to the cell's compliance with the ground-water standards:

- An engineering analysis to show that fluid flux through the cover, equal to the design *saturated* hydraulic conductivity, will allow compliance with the standards;

- An engineering analysis to show that fluid flux through the cover, using the unsaturated hydraulic conductivity of the cover, will allow compliance with the standards; or

- A demonstration that shows that the standards can be achieved without limiting infiltration through the cover.

DOE commonly uses a simple volumetric mixing calculation as described in Hem (1985) to demonstrate that the standards will be met when a fluid flux equals the saturated hydraulic conductivity of the barrier. The results of this calculation should show that concentration limits will be met at the point of compliance. The assumption is made that the infiltration barrier has become fully saturated; therefore, only gravity drainage is occurring and the hydraulic gradient is one. Such an assumption is more conservative than assuming partial saturation, since the saturated hydraulic conductivity exceeds the unsaturated hydraulic conductivity.

The larger fluid flux used in this approach makes the compliance demonstration more difficult. As a consequence, DOE will usually include the lowest possible saturated hydraulic conductivity in the design of the radon barrier. The NRC staff has raised concerns on whether a saturated hydraulic conductivity of less than 1×10^{-7} cm/s can be constructed and adequately verified by field-scale measurements. The technical literature suggests that laboratory measurements of saturated hydraulic conductivity may not be representative of the field conditions. The Water Resources and Geotechnical reviewers should jointly evaluate whether DOE has provided adequate information to demonstrate compliance. Bennett and Horz (1991) provides a good discussion on laboratory- versus field-measured hydraulic conductivity values for covers. Additional discussions on the cover hydraulic conductivity are presented in Section 2.3.5.

DOE may also use an assumed fluid flux that is based on the unsaturated hydraulic conductivity of the barrier. Because the unsaturated conductivity is less than the saturated conductivity, the compliance demonstration may be easier to make. In this situation, DOE must demonstrate that the barrier will remain unsaturated throughout the design life of the cell. This demonstration is often difficult, considering the design life of the cell. DOE has previously attempted to use the results from a study for the Shiprock site, which indicated that the cover remains fairly unsaturated (DOE, 1989b), as a demonstration that the cover will remain unsaturated at other sites. The NRC staff has rejected this argument, because of some identified problems with the Shiprock test (Jones, 1989). The reviewer will have to rely on professional judgement to verify that DOE's demonstration, provided in the RAP, will adequately confirm that the cover will remain unsaturated.

The reviewer must ensure that DOE provides a clear and defensible compliance demonstration, if the proposed design does not rely on limiting infiltration in order to meet the standards. In these instances, the demonstration is usually based on:

- Climatic considerations,
- Hydraulic isolation of the uppermost aquifer,
- Geochemical properties in the underlying materials, or
- Meeting the criteria of §192.21 and proposing a supplemental standard for compliance.

4.3.3 Disposal Standards

The reviewer will verify, based on DOE's demonstrations, that the proposed design complies with EPA's ground-water protection standards in 40 CFR Part 192, Subparts A and C. DOE's demonstrations should include: (1) the ground-water protection standards, (2) a performance assessment, (3) a closure performance demonstration, and (4) a performance monitoring and corrective action program (NRC, 1989).

4.3.3.1 Ground-Water Protection Standards

The reviewer must confirm that DOE has proposed a ground-water protection standard for the disposal site (NRC, 1989). This standard must include: (1) a list of hazardous constituents, (2) a corresponding list of constituent concentration limits, and (3) a point of compliance.

4.3.3.1.1 Hazardous Constituents

The EPA has proposed a list of 375 hazardous constituents which must be considered by DOE. Additionally; molybdenum, nitrate, radium, net gross alpha and uranium must be also considered by DOE when developing a list of hazardous constituents.

The NRC uses the following criteria to determine the adequacy of the hazardous constituents list:

(1) The constituents are reasonably expected to be in or derived from the tailings;

(2) The constituents are listed in Appendix VIII of 40 CFR §261; with the addition of molybdenum, net gross alpha, nitrate, radium, and uranium (Table A, 40 CFR §192); and

(3) The constituents were detected in the tailings or ground water at the processing site.

Some understanding of the milling process used at the particular site is required to determine whether the constituents are reasonably expected in the tailings. A typical milling process involved crushing and grinding the uranium ore, dissolving it in either an acid or base solution, then concentrating and purifying the uranium with either an ion exchange or a solvent extraction (Merritt, 1971). The constituents are mobilized by leaching the crushed ore with either an acid or base. Sulfuric acid or sodium carbonate are typically used. Acid-extraction was used at most mills, because it is generally more effective than alkaline leach except for ores with a high carbonate content.

The leaching, concentrating, and purifying processes make the largest contribution to the hazardous constituents found in the tailings and ground water. The reviewer should verify that adequate information on the process is provided in the RAP. Table 3 provides a list of the common constituents associated with uranium tailings (NRC, 1987). This list is based upon a chemical survey performed by NRC staff at 17 Title II sites. This list is not all inclusive, since the milling process used may have contributed additional hazardous constituents.

DOE normally performs an initial scan of either pore fluids from the tailings or ground water from several existing wells to determine potential hazardous constituents for a particular site. Additional sampling is conducted to determine which specific organic compounds are present. The expected presence of organic compounds can be determined, based on the knowledge of the chemicals used during the milling process. Even if there is no record of organic compounds used in the process, screening tests should be performed to confirm the absence of organic compounds in the tailings and ground water.

DOE has developed a standard constituent list for inorganic screening of tailings-fluid or ground-water samples. Table 4 lists these constituents (DOE, 1989a). Each of the Table 4 constituents are included in the list of potential hazardous constituents, if they are identified above the detection limit. A comparison of Table 4 to Appendix VIII indicates that not all of the constituents in Table 4 are considered hazardous. Consequently, only those constituents (or elements of hazardous compounds) that exceed the method

TABLE 3 - Common Chemical Mill Constituents

INORGANIC CONSTITUENTS

Arsenic
Barium
Beryllium
Cadmium
Chromium
Cyanide
Lead
Mercury
Molybdenum
Net Gross Alpha
Nickel
Radium—226 and —228
Selenium
Silver
Thorium—230
Uranium

ORGANIC CONSTITUENTS

Carbon disulfide
Chloroform
Diethyl phthalate
2—Butanone
1,2—Dichloroethane
Naphthalene

TABLE 4 - Constituents/Detection Limits for Water Analyses[a]

CONSTITUENT	DETECTION LIMIT	CONSTITUENT	DETECTION LIMIT
Major Anions	(mg/L)	Copper	0.02
Bicarbonate	1.0	Cyanide	0.01
Carbonate	1.0	Iron	0.03
Chloride	1.0	Lead	0.01
Sulfate	0.1	Manganese	0.01
Fluoride	0.1	Mercury	0.0002
Nitrate	1.0	Molybdenum	0.01
Nitrite	0.1	Nickel	0.04
Nitrate and Nitrite	1.0	Selenium	0.005
Phosphate (as P)	0.1	Silver	0.01
Major Cations	(mg/L)	Sulfide (as H_2S)	0.1
Ammonium	0.1	Strontium	0.1
Calcium	0.01	Thallium	0.01
Magnesium	0.001	Tin	0.005
Potassium	0.01	Uranium	0.003
Sodium	0.002	Vanadium	0.01
Silica	2.0	Zinc	0.005
Minor and Trace[b]	(mg/L)	Tot. Dissolved Solids	10.0
Aluminum	0.1	**Organic Hazardous[c]**	(mg/L)
Antimony	0.003	Tot. Organic Carbon	1.0
Arsenic	0.01	**Radionuclides**	(pCi/L)
Barium	0.1	Gross alpha[d]	1.0
Beryllium	0.01	Gross beta[d]	0.5
Boron	0.01	Lead—210	1.5
Bromide	0.01	Polonium—210	1.0
Cadmium	0.001	Radium—226	1.0
Chromium	0.01	Radium—228	1.0
Cobalt	0.05	Thorium—230	1.0

[a] Field parameters including temperature, total alkalinity, pH, and specific conductance will be measured. Dissolved oxygen, Eh, and redox couples may be measured at specific work sites for further characterization.

[b] Elemental concentrations will be analyzed to satisfy the requirements of 40 CFR 192.

[c] Appendix IX of 40 CFR 264 will be analyzed to satisfy the requirements of organic analyses required in Appendix I of 40 CFR 192.

[d] These analyses must be determined on samples with less than 500 mg/L total dissolved solids.

Note: Detection limits above are those specified to laboratories subcontracted to perform analyses for the UMTRA Project. These levels are considered reasonably achievable, and consistent with Project goals and regulatory requirements.

detection limit, *and* are listed in Appendix VIII (40 CFR §261) or Table A (40 CFR §192); should be included in DOE's hazardous constituent list.

The elements of a hazardous compound should also be listed, if the combination of those elements detected in the tailings pore fluid would produce a hazardous compound under the right geochemical conditions in the subsurface. For example, if strontium and sulfide ions have been detected in the tailings pore fluid, and the geochemical conditions in the uppermost aquifer favor the precipitation of strontium sulfide (listed in Appendix VIII); then strontium and sulfide should be included as a hazardous constituent. However, if aluminum ions are detected and no corresponding anions would produce a hazardous compound under the subsurface geochemical conditions; then aluminum should not be listed as a hazardous constituent.

DOE commonly uses suction lysimeters to obtain pore fluid samples from the tailings. A lack of moisture within the tailings may preclude the collection of pore-water samples in this manner. In these cases, DOE will collect ground-water samples and infer the concentrations within the pore fluid. The reviewer should be aware that the projected concentration within the pore fluid should be higher than the measured ground-water concentration, because of the dilution. The identification of a hazardous constituent in the ground water should provide a fairly accurate representation of the more mobile compounds in the tailings.

4.3.3.1.2 Concentration Limits

A concentration limit must be specified for each of the hazardous constituents identified by DOE. The concentration limit must be either the Maximum Concentration Limit (MCL) as identified in Table 4.1, the background concentration, or an Alternate Concentration Limit (ACL). The reviewer should verify that DOE has provided a justification for its selection.

DOE typically proposes either the background level or the MCL's, whichever is greater. Many of the hazardous constituents, including some of the commonly detected constituents listed in Table 4.2, do not have an established MCL. Therefore, background levels or ACL's must be used in establishing the concentration limit.

The reviewer should ensure that the background concentrations accurately represent the ambient conditions that are unaffected by the milling operation. Ground-water samples collected from wells used to select a disposal site, where the processing and disposal sites are separate, are good representations of background levels since contaminants have not yet been placed on the site. However, the background levels must be clearly representative of non-milling conditions for sites where SIP or SOS disposal is proposed. Background samples should be collected from wells that are clearly unaffected by the contamination source, preferably hydraulically up-gradient of the milling site. A rigorous justification should be provided in the RAP if the wells used to establish background are not hydraulically up-gradient from the contamination source.

DOE will commonly use the statistical maximum concentration of the constituent as the proposed concentration limit. This is done to account for natural variations in water quality. The reviewer should verify the correct statistical method was used to establish the statistical maximum. DOE may propose the maximum measured concentration or the method detection limit as the concentration limit, if a statistical maximum cannot be determined.

4.3.3.1.3 Point of Compliance

The reviewer should confirm that the point of compliance (POC) for the disposal site has been proposed in the RAP (NRC, 1989). The POC is the location where the ground water can be monitored to determine compliance with the proposed concentration limits. The POC is defined as a vertical surface within the uppermost aquifer at the hydraulically down-gradient limit of the waste management area.

The NRC has generally interpreted the down-gradient limit of the waste management area to be the edge of the cover side slopes. It is not recommended that DOE be required to compromise the cover integrity in order to install monitoring wells at the actual edge of the reclaimed tailings.

DOE will generally propose to install a line of wells along the down-gradient edge of the cell to monitor the POC. The reviewer should verify that:

- The proposed monitoring well locations are hydraulically down-gradient from the cell,

- The proposed well spacings will adequately monitor the dominant flow pathways in the uppermost aquifer, and

- Screened intervals in the wells located in the uppermost aquifer will be able to detect potential contaminant releases.

Construction details for new POC monitoring wells are usually provided in the Long-Term Surveillance Plan (LTSP).

4.3.3.2 Performance Assessment

The reviewer should verify that DOE's assessment of disposal cell performance complies with the ground-water protection standards for disposal, listed in 40 CFR §192, Subparts A and C (NRC, 1989). This assessment should demonstrate that the identified hazardous constituents will not exceed the proposed concentration limits at the POC during the design life of the disposal cell.

DOE has employed a wide range of methods to assess the performance of the disposal unit. These methods range from qualitative narratives with supplemental standards to quantitative analyses using contaminant transport models. Regardless of the method, the reviewer should confirm that the information presented in the RAP is of adequate quality and quantity to support a defensible assessment. The characterization detail will be dependent on the type analysis used to demonstrate compliance.

The reviewer should not assume that simple, quantitative analyses are necessarily conservative. The reviewer should not attempt to duplicate DOE's analyses, especially for complicated transport models. The reviewer's resources can be more prudently applied by evaluating:

- The validity of the assumptions used to develop the conceptual model that represents the hydrogeologic system, and the limitations imposed by those assumptions;
- The technical-appropriateness of the analysis methods used under the constraints of the conceptual model; and
- The adequacy (quality and quantity) of the data used.

Duplication of analyses may be appropriate, if the reviewer is concerned whether DOE's analysis is technically defensible.

4.3.3.3 Closure Performance Demonstration

The reviewer should verify that the anticipated closure performance will comply with the standard in §192.02(a)(4), which references the RCRA closure performance standard in §264.111 (NRC, 1989). The demonstration should show that:

(1) The need for long-term maintenance of the disposal site has been minimized; and

(2) The disposal unit controls, minimizes, or eliminates releases of hazardous constituents to the ground water; to the extent necessary to comply with the ground-water protection standards.

Generally, DOE's compliance demonstration in the performance assessment will also adequately demonstrate that the disposal unit will control, minimize, and eliminate releases of hazardous constituents and comply with the ground-water standards. The use of adequate amounts of stable, natural materials in all components of the cover will generally demonstrate that long-term maintenance of the facility will be minimal.

The water resources protection reviewer should be aware that there are some aspects of the engineering design that may have been proposed to comply with one review area, but may compromise compliance in another area. One example is the concern of moisture retention, redistribution, and accumulation that may result from the bottom of the cell having a hydraulic conductivity that is lower than the designed infiltration flux of the cover. This situation is often referred to as a *'bath tub'* effect. Although the designed radon barrier may meet the radon emission requirements, and the low hydraulic conductivity of the subgrade will comply with the provisions of eliminating releases of hazardous constituents; the potential water accumulation may cause a saturated condition in the disposal cell that could impact the long-term geotechnical stability of the contaminated materials.

As another example involving a *'bath tub'* effect, water added to the tailings for achieving the compaction specification and for dust suppression may redistribute by unsaturated-flow mechanisms and accumulate at the base of the disposal cell, causing the potential for short-term geotechnical instability. The reviewer should convey any concerns that may impact other technical areas to the appropriate NRC staff reviewers.

4.3.3.4 Ground-Water Monitoring and Corrective Action Plan

The reviewer should verify that a conceptual ground-water monitoring and corrective action program are described in the RAP (NRC, 1989). The EPA regulations (40 CFR Part 192.02(b)-(c)) require that DOE establish a post-disposal monitoring program to ensure that the ground-water protection standards are met, and a plan of corrective action in the event that contaminants are detected after closure has been completed. Any corrective action would have to be implemented within 18 months of a determination that ground-water concentration limits are, or will be exceeded.

DOE is only required to provide a general conception of the monitoring and correction action programs in the RAP, since the detailed aspects will be provided in the LTSP, which also requires the NRC concurrence. The reviewer should ensure that most of the realistic failure scenarios are identified and addressed by conceptual corrective action plans; and confirm that DOE states their intent to provide the detailed ground-water monitoring plans in the LTSP.

4.3.4 Ground-Water Cleanup

Restoration of contaminated ground water at the processing site can be postponed (deferred) if:

(1) The disposal activities proposed in the RAP will not interfere with future cleanup activities;

(2) The disposal activities can proceed independently of ground-water cleanup; and

(3) Public health and safety will not be affected by delaying ground-water restoration.

DOE has adopted a policy of deferring ground-water cleanup to a later phase of the UMTRA Project. Conceptual designs and descriptions of the restoration programs will be developed in a later project phase. The NRC has agreed with delaying restoration, as long as human-health and the environment will not be substantially affected, as verified by ground-water monitoring. The reviewer should confirm that the surrounding water users will not be adversely affected by delaying restoration (subsection 4.3.1.3.4 of this chapter).

If DOE chooses to initiate a ground-water cleanup, the reviewer must verify that the proposed ground-water cleanup actions will comply with EPA's ground-water protection standards. DOE's plan must demonstrate that:

(1) Ground-water cleanup standards will be achieved,

(2) Restoration is achievable, and

(3) Restoration is verified through a monitoring program (NRC, 1989).

The NRC review procedures for ground-water-cleanup compliance demonstration will be similar to those followed for compliance demonstration of the disposal standards. However, in general, a more detailed hydrogeologic characterization will be needed for the processing site than was previously performed for the disposal demonstration.

4.3.5 Supplemental Standards

Subpart C (40 CFR 192) of the ground-water protection standards allow for the use of supplemental standards *in lieu* of background levels, MCL's, or ACL's for the compliance demonstration. The standards may be either numerical or a narrative performance objective; however, DOE must clearly state the selected supplemental standard in the RAP. Compliance with the supplemental standards should be demonstrated through performance analyses or monitoring (NRC, 1989).

Supplemental standards may be applied if site-specific conditions satisfy one of the criteria in §192.21. The proposed remedial action must demonstrate compliance with the selected supplemental standard. Additionally, the proposed remedial action must come as close as possible to meeting the otherwise applicable standards in Subparts A and B. When the §192.21(f) or (g) criterion is applied, the proposed remedial action for ground-water restoration must also assure protection of human health and the environment. The reviewer should ensure that:

(1) The applicability criterion is appropriate for the site and supported by the hydrogeologic characterization,

(2) The supplemental standards have been clearly stated in the RAP document,

(3) The proposed remedial action will meet the selected supplemental standard,

(4) The remedial actions come as close as possible to meeting the otherwise applicable standards and protecting public health and the environment (if applicable).

4.4 Evaluation Findings

The reviewer may conclude that the RAP provides reasonable assurance of compliance with the EPA ground-water protection standards, if the proposed remedial actions satisfy the criteria described in this chapter. The reviewer must document the independent verifications that support the reasonable assurance conclusion in a Technical Evaluation Report (TER). The TER will identify the technical aspects of the review, any deviations from the review criteria or procedures, and justifications for those deviations. The reviewer can recommend NRC concurrence with the RAP, based on the reasonable assurance conclusion. If a reasonable assurance conclusion cannot be reached; the reviewer must:

- Describe and document any identified inadequacy,
- Provide a detailed description of the technical or regulatory basis for the inadequacy, and
- Identify, where possible, a technically-sound alternative approach that might resolve the inadequacy.

The specific inadequacies are identified as Open Issues in the Water Resources Protection text of the TER. All Open Issues (including the basis and approach for resolution) are listed in the 'Conclusions' section at the end of the TER. The reviewer documents the following conclusions in the TER before recommending complete concurrence with a RAP:

(1) Processing and disposal sites have been adequately characterized, including characterization of the uranium processing facility, vicinity activities and processes, background water quality, rate and direction of contaminated water flow, and extent of existing water contamination;

(2) Human health and environmental impacts potentially caused by water contamination have been adequately identified and characterized;

(3) The need for remedial actions for water resources has been adequately identified and assessed; and

(4) Potential implementation of remedial actions for water resources has been adequately evaluated, and the remedial actions selected for implementation have been adequately described in the Remedial Action Plan document.

When the open issues have been resolved, the Water Resources Protection portion of the TER is concluded with a statement that, "The proposed remedial actions comply, with reasonable assurance, with the EPA standards in 40 CFR Part 192.

4.5 References

Bear, J., Hydraulics of Groundwater, New York, New York: McGraw Hill International Book Company, 567 p., 1979.

Caldwell, J.A., Rager, R., and Larson, N.B., "The Impact of Proposed EPA Ground water Standards on UMTRA Project Disposal Cell Design," DOE Remedial Action Program Annual Meeting October 18-20, 1988.

Canter, L.W., and Knox, R.C., Ground Water Pollution Control, Chelsea, Michigan: Lewis Publishers, Inc., 526 p., 1985.

Freeze, R.A. and Cherry, J.A., Groundwater, Prentice-Hall: New Jersey, 1979.

Hem, J.D., "Study and Interpretation of the Chemical Characteristics of Natural Water," 3rd ed., USGS-Water Supply Paper 2254, 1985.

Jones, T.L., "Trip Report Albuquerque, New Mexico March 6-9, 1989," personal communication.

Korte, N., and Ealey, D., "Procedures for Field Chemical Analysis of Water Samples, Grand Junction, Colorado," Bendix Field Engineering Corporation, GJ/TM-07, 48 p., 1983.

Korte, N., and Kearl, P., "Procedures for the Collection and Preservation of Groundwater and Surface Water Samples and for the Installation of Monitoring Wells, Grand Junction, Colorado," Bendix Field Engineering Corporation, GJ/TC-08, 58 p., 1984.

Krauskopf, K.B., Introduction to Geochemistry, New York, New York: McGraw Hill Book Company, 617 p., 1979.

Lohman, S.W., Ground-Water Hydraulics, U.S. Geological Survey, Professional Paper 708, 70 p., 1972.

Merritt, R.C., "The Extractive Metallurgy of Uranium," Colorado School of Mines Research Institute, 1971.

Morrison, R.D., Ground Water Monitoring Technology, Prairie Sac, Wisconsin: Timco Manufacturing, Inc., 111 p., 1983.

National Research Council, Drinking Water and Health, Volume 1, Washington, District of Columbia: National Academy Press, 939 p., 1977.

National Research Council, Drinking Water and Health, Volume 5, Washington, District of Columbia: National Academy Press. 157 p., 1983.

Rogoshewksi, P., Bryson, H., and Wagner, K., Remedial Action Technology for Waste Disposal Sites, Park Ridge, New Jersey: Noyes Data Corporation, 496 p., 1983.

Scalf, M.R., McNabb, J.F., Dunlap, W.J., Cosby, R.L., and Fryberger, J., Manual of Ground-Water Sampling Procedures, Worthington, Ohio: National Water Well Association, 93 p., 1981.

Stallman, R.W., "Aquifer Test Design, Observation, and Data Analysis," U.S. Geological Survey, Techniques of Water Resources Investigations, Book 3, Chapter BI, 26 p., 1976.

Stumm, W., and Morgan, J.J., Aquatic Chemistry, New York, New York: John Wiley and Sons, Inc., 780 p., 1981.

Todd, D.K., The Water Encyclopedia, Port Washington, New York: Water Information

Center, 1970.

---, Groundwater Hydrology, New York, New York: John Wiley and Sons, Inc., 535 p., 1980.

TRW, "Environmental Study on Uranium Mill", American Mining Congress: Washington, D.C., 1979.

U.S. Bureau of Reclamation, Ground Water Manual, U.S. Department of Interior, 480 p., 1977.

U.S. Department of Energy (DOE), "Technical Approach Document - Revision II," UMTRA - DOE/AL 050425.0002, 1989a.

---, "Moisture Contents and Unsaturated Conditions in UMTRA Project Radon Barriers," January 1989b.

U.S. Department of Interior (DOI), National Handbook of Recommended Methods for Water-Data Acquisition, 1985 (updated).

U.S. Environmental Protection Agency (EPA), "National Academy of Sciences, Water Quality Criteria," EPA R3/73-033, 594 p., 1972.

---, "Final Environmental Impact Statement for Remedial Action Standards for Inactive Uranium Processing Sites (40 CFR 192)," EPA 520/4-82-013-1 and 2, 1982.

---, "Final Environmental Impact Statement for Standards for the Control of Byproduct Materials from Uranium Ore Processing (40 CFR 192)," EPA 520/1-83-008-1 and 2, 1983.

---, "Test Methods for Evaluating Solid Waste," SW-846, 1984 (updated).

---, "Proposed guidelines for exposure assessment," Federal Register, v. 49, n. 227, pp. 46304 - 46312, 1984.

---, "Draft Alternate Concentration Limit Guidance based on § 264 Criteria: Information Required in ACL Demonstration," 1985.

---, "Standards for Remedial Actions at Inactive Uranium Processing Sites; Proposed Rule," Federal Register, Vol. 52, No. 185, 36000 - 36008, September 24, 1987.

---, "Ground-Water Protection Standards for Inactive Uranium Tailings Sites (40 CFR 192) - Background Information for Final Rule," EPA 520/1-88-023, March 1989.

---, "Statistical Analysis of Ground-Water Monitoring Data at RCRA (Resource Conservation and Recovery Act) - Facilities, Interim Final Guidance," EPA/530/SW-89/026, February 1989.

U.S. Geological Survey (USGS), "Summary Appraisals of the Nation's Ground-Water Resources," Professional Paper 813.

U.S. Nuclear Regulatory Commission (NRC), "Descriptions of United States Uranium Resource Areas," NUREG/CR-0597, 1979.

---, "Final Generic Environmental Impact Statement on Uranium Milling," NUREG-0706, 1980.

---, "Parameters and Variables Appearing in Repository Siting Models," NUREG/CR-3066, 244 p., 1982.

---, "Radiological Assessment," NUREG-3332, 1983.

---, "Sampling of Uranium Mill Tailings Impoundments for Hazardous Constituents," R. Dale Smith Memorandum to the Division of Waste Management, February 9, 1987.

---, "Draft Technical Position on Alternate Concentration Limits for Uranium Mills, Standard Format and Content Guide and Standard Review Plan for Alternate Concentration Limit Applications," June 1988.

---, "Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities," NUREG-0586, August 1988.

---, "Uranium Recovery and Reclamation Program - A Summary of the History, and Status of the U.S. Uranium Milling and Reclamation Industry," November 18, 1988.

---, "Standard Format and Content for Documentation of Remedial Action Selection at Title I Uranium Mill Tailings Sites," Division of Low-Level Waste Management and Decommissioning, Office of NMSS, February 24, 1989.

---, "Recommendations to the NRC for Soil Cover Systems Over Uranium Mill Tailings and Low-Level Radioactive Wastes - Laboratory and Field Tests for Soil Covers," NUREG/CR-5432, Vol. 2, January 1991.

Walton, W.C., Groundwater Resource Evaluation, New York, New York: McGraw Hill Book Company, 664 p., 1970.

Weber, M.F., personal communication to Malcolm R. Knapp, October 12, 1983.

5.0 RADON ATTENUATION AND SITE CLEANUP

5.1 Areas of Review

Remedial actions at UMTRA Project sites are required to meet appropriate standards for: (1) the release of radon from tailings disposal cells after reclamation, and (2) the cleanup of land and buildings at the processing sites. This chapter of the SRP establishes the performance and documentation of NRC's review of the proposed designs for the attenuation of radon by use of soil covers and for the processing site cleanup.

The two main areas of review for radon attenuation are the geotechnical and radiological properties of the contaminated and cover materials and the computer code or other model used for calculating the estimated radon flux from the completed embankment. The specific areas of review for the site cleanup are site characterization, standards for cleanup, and verification procedures.

5.1.1 Radon Attenuation

The RAP and/or its supporting documents contain geotechnical and radiological information supporting the selection of the properties of the tailings and radon barrier materials, that affect the radon barrier design. The bases and procedures for determining parameter values of the tailings and radon barrier materials will be reviewed. Information regarding the site investigations and the testing and sampling programs will be reviewed to substantiate the representativeness and validity of the parameter values.

Procedures for materials placement during remedial activities, as presented in the RAP construction specifications, will be reviewed to confirm that they are consistent with the radon barrier design.

The calculational methodology for estimating radon flux or required barrier thickness will be reviewed. Data on the parameter values used in the analysis will be reviewed for appropriateness and statistical validity.

If the radon air concentration approach is selected to demonstrate compliance with the EPA standard, the staff will review:

(a) Description of the model (numerical or analytical) used to approximate the average air concentration of radon,

(b) Description of the assumptions made and the selected model input parameter values that are specific to conditions at the site including:

(i) Meteorological conditions: stability, wind direction frequency, wind speed, effective dispersion factors used and justification that selected values of these parameters represent the long-term conditions.

(ii) Radon source strength and justification for the selected value.

(iii) Factors of safety to account for reasonable assurance in meeting the 0.5 pCi/l off-site criterion in the long-term.

(c) References for the methodology used to estimate the concentration.

5.1.2 Processing Site Cleanup

The remedial action at UMTRA Project sites must meet cleanup standards for radioactive material. The staff will review data defining the extent (area, volume, and concentration) of contamination, the cleanup standards to be used at the processing site, the method(s) to be used to verify that the standards have been met, and the adequacy of the quality control program related to site cleanup.

5.2 Acceptance Criteria

5.2.1 Radon Attenuation

5.2.1.1 Regulatory Requirements

The purpose of the radon barrier design review is to assure that the disposal of uranium mill tailings will conform to the radon flux attenuation standards promulgated by the EPA. The basic acceptance criterion pertinent to the radiological aspects of the radon barrier reviews is provided in EPA's 40 CFR 192, Subpart A. Part 192.02 requires demonstration of reasonable assurance that the release of radon-222 to the atmosphere will not:

(a) Exceed an average release rate of 20 $pCi/m^2/s$ when averaged over the disposal area and over at least a one-year period, or,

(b) Increase the annual average concentration of radon-222 in air at or above any location outside the disposal site by more than 0.5 pCi/l.

5.2.1.2 Regulatory Guidance

There is one NRC regulatory guide and a NUREG document directly applicable to radon attenuation aspects for the UMTRA program. In addition, there is a staff technical position that may provide generic guidance. These reports are:

(a) Regulatory Guide 3.64 (NRC, 1989a) - "Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers." This guide describes methods that are acceptable to the staff for calculating radon fluxes through covers and for calculating the resulting minimum cover thickness. The guide also suggests methods for obtaining the various parameter values used in calculating the radon flux and cover thickness and offers suggested default values for certain parameters. Appendix B discusses the RADON program and gives a sample problem output.

(b) NUREG/CR-3533 (NRC, 1984) - "Radon Attenuation Handbook for Uranium Mill Tailings Cover Design." This handbook describes the design of earthen covers and their ability to control radon releases from uranium mill tailings. Equations based on diffusion theory for estimating radon releases from bare and covered uranium mill tailings are presented with the RAECOM computer code.

(c) Staff Technical Position (NRC, 1989b) - "Standard Format and Content for Documentation of Remedial Action Selection at Title I Uranium Mill Tailings Sites."

5.2.2 Processing Site Cleanup

5.2.2.1 Regulatory Requirements

The basic acceptance criteria pertinent to the radiological aspects of the processing site remedial action are provided in EPA's 40 CFR 192, Subpart B. Part 192.12 requires that:

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

(1) 5 pCi/g, averaged over the first 15 cm of soil below the surface and

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

(b) In any occupied or habitable building-

(1) The objective shall be an annual average radon decay product concentration, including background, not to exceed 0.02 WL; in any case shall not exceed 0.03 WL.

(2) The level of gamma radiation shall not exceed the background level by more than 20 microroentgens per hour.

Part 192.21 lists criteria for application of supplemental standards in lieu of the standards in Subparts A or B if the remedial action would cause any of these circumstances to exist applicable to soil and building cleanup:

(a) Pose a clear and present risk of injury to workers or to members of the public, notwithstanding reasonable measures to avoid or reduce risk.

(b) Produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near the site, now or in the future.

(c) Remedial cost at a vicinity property is unreasonably high relative to long-term benefits, and the residual radioactive materials do not pose a clear present or future hazard.

(d) The cost for cleanup of a building is clearly unreasonably high relative to the benefits.

(e) There is no known remedial action.

(f) Restoration of groundwater quality is technically impracticable from an engineering perspective.

(g) The ground water is Class III.

(h) Radionuclides other than radium-226 and its decay products are present in sufficient quantity and concentration to constitute a significant radiation hazard from residual radioactive materials.

Part 192.22 lists the supplemental standards as:

(a) When one or more criteria of Part 192.21 (a)-(e) exist, select and perform remedial actions that come as close to meeting the otherwise applicable standard as is reasonable under the circumstances.

(b) When Part 192.21 (h) applies, reduce other residual radioactivity to levels that are as low as is reasonably achievable.

(c) General determinations may be made that apply to all locations with specified characteristics. When action is proposed under this section for a specific location, DOE shall inform owners and occupants and solicit their comments.

5.2.2.2 Regulatory Guidance

Regulatory Guide 1.86, (AEC, 1974) "Termination of Operating Licenses for Nuclear Reactors," and the Branch Position Paper WM-7601, (NRC, 1984) "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct or Source Materials," are used for cleanup guidelines for surface contamination.

5.3 Review Procedures

5.3.1 Radon Attenuation

The radon barrier design, as presented in the RAP, is reviewed along with the basic data supporting the design. Methodology used to calculate the exit radon flux through the tailings/cover system or the ambient air concentration of radon-222 at the site boundary is also reviewed.

5.3.1.1 Evaluation of Parameters

The selection of values for tailings and cover material properties will be considered acceptable if the estimates of all values of the material parameters that are used in the calculational methodology lead to a reasonably conservative estimate of the radon flux.

The scope and technique of site investigations must be such that the field investigation and testing program provide the necessary data to support all conclusions. Whenever site-specific measured parameter values are utilized, they should be accompanied by supporting information describing the test method, its precision and accuracy, and its applicability for representing a long-term, large area average. The boring, sampling, and testing programs will be reviewed to assure that appropriate analytical methods have been employed and that sufficient and representative data have been collected for determining material property values of both the cover and contaminated materials. When sufficient test data are not available, conservative values may be chosen for use in the analyses if their use is justified.

The reviewer will assess whether parameter values are consistent with anticipated construction specifications and represent long-term conditions. The long-term attenuating capability of these materials needs to be justified. Short-term determinations of parameter values should not be considered because of the long-term specifications of the standards. The reviewer will also ascertain that the basis for obtaining parameter values and how the values are used in the analyses is addressed. The reviewer will determine whether moisture-dependent parameter value's determinations considered the long-term moisture content of the materials at the disposal site (e.g., emanation coefficient). The reviewer will confirm that the parameter values are used in a conservative and consistent fashion throughout the calculations.

The staff members assigned the health physics and geotechnical review duties will confer on the radon attenuation design and analysis, but each will have their areas of review emphasis. The geotechnical information on physical characteristics of the contaminated and cover materials as discussed in Chapter 2.0 of this SRP and the radiological information on contaminated materials will be reviewed. Also, the properties of the other layers of the cover will be considered in the context of how they will influence the integrity and long-term moisture content of the radon barrier. The review will extend to vicinity property material for those sites that have large volumes of off-site material that will be placed in the disposal cell.

Specific parameter considerations are as follows:

Long-term Moisture - The methodology used in the estimation of the long-term moisture content of the tailings material and the radon barrier material will be reviewed. The staff will determine whether adequate documentation of the basis for empirical relationships used in the analysis has been provided. The methodology to determine the moisture content will be reviewed to verify that consideration has been given to meteorological and hydrological conditions at the disposal site, bulk density, type of material, and the influence of overlying material layers. The staff will conduct independent calculations using methods described below. Estimated values of the long-term moisture content will be compared to present in-situ values to assure that the long-term value does not exceed the present field value derived from samples taken at a depth of 120 to 500cm (but not close to water table). Also, this borrow site value should be correlated to the conditions at the disposal site.

Soil moisture values used in the design will be considered acceptable if they represent the long-term moisture contents that conservatively bound the lower moisture retention capacities of the materials. The values should represent the lowest moisture contents that the soils can be expected to experience for any one year period during the long-term design life of the project.

Values of moisture contents for the tailings material will be considered acceptable if they represent reasonably conservative estimates of the equilibrium moisture after the tailings have been stabilized.

The reviewer will consider the following methods acceptable for predicting the long-term soil moisture, given the limitations stated above;

(a) Laboratory procedures ASTM D-3152 (fine-textured soils) and ASTM D-2325 (coarse- and medium-textured soils) conducted at 15-bar suction corresponding to the moisture content at which permanent wilting of plants occurs (Baver, 1956).

(b) The empirical relationship (Rawls and Brakensiek, 1982) established that predicts water retention values of a soil on a volume basis:

$$c = 0.026 + 0.005x + 0.0158y$$

where:

c = predicted 15-bar soil water retention value (cms/cms)
x = percent clay in the soil
y = percent organic matter in the soil

The 15-bar water retention value will be considered an acceptable estimate of the long-term moisture content of cover material when estimated by this method. The reviewer should be aware that this volumetric moisture content must be converted to a weight percentage for some applications.

This method takes into consideration the particle size distribution of the soil. Clay particle sizes are defined here as those finer than 0.002 mm in diameter.

Organic content measurement is generally determined by reaction with hydrogen peroxide or by exposure to elevated temperature. Other tests, if adequately justified, may be acceptable.

<u>Density, Specific Gravity, and Porosity</u> - Dry densities of the cover soils and tailings material determined from Standard Proctor Test data (ASTM D-698) or Modified Proctor Test data (ASTM D-1577) will be considered acceptable. The staff will accept compacting the cover materials to a minimum of 95% of the maximum dry density as determined by ASTM D-698 or to a minimum of 90% of the maximum dry density as determined by ASTM D-1577. When the tailings materials are moved from one location to another, they should be compacted to a minimum of 90% of the maximum dry density as determined by ASTM D-698. Field densities that will be achieved when the materials are compacted according to these specifications should be used in the methodology. Alternatively, if the pile is to be stabilized-in-place, the in-situ bulk densities should be used in the analyses.

The staff assumes reference specific gravities of 2.65 for the tailings and cover materials unless specific alternative values and a documented basis are provided in the analysis. An acceptable method for estimating the porosity of the material based on the bulk density and specific gravity is given in Regulatory Guide 3.64.

Material Thickness - The estimate of the tailings thickness will be considered acceptable if determined from estimates of total tailings production and the areal extent of the pile or by using representative values from boring logs of sufficient number. A value of 500 cm represents an equivalent infinitely thick tailings source, (NRC, 1989) and since this is a more conservative approach, it may be used without more specific analyses of thinner tailings sources. However, if material with low radium-226 content will be placed as a separate layer, that layer thickness estimate should not use the equivalent infinitely thick source value.

The estimated soil cover thickness in the remedial action design will be considered acceptable if the thickness reduces the calculated long-term radon flux to levels that meet the EPA standard.

Radon Diffusion Coefficient, D - The radon diffusion coefficient, "D," of the cover soil is of central importance for determining the cover thickness necessary to achieve a given radon flux reduction. The D-value is most accurately determined from direct measurements as described in NRC, 1984 (Section 3). The soil should be tested at the design compaction density in a range of moisture contents that bounds the lower moisture retention capacity of the soil.

Documentation of experimental precision and accuracy for measurement of the diffusion coefficient for candidate cover soils and tailings material should be provided. In evaluating the measurements, the long-term variability of this parameter should be factored into the estimation.

Models based upon physical characteristics of the soil or upon empirical correlations based on previously measured values of D may be acceptable for estimating the diffusion coefficient when measured values are unavailable. A correlation that is acceptable for the expected range of soil densities is one proposed by NRC (1984, Section 4) which employs the moisture saturation ratio. The estimation of the diffusion coefficients for the materials will be considered acceptable if it represents the long-term in-situ properties of the materials.

Radium Content - Values of the radium activity within the tailings (pCi/g) can be measured directly from tailings samples and other large-volume sources of contaminated material by the radon equilibrium method or by direct gamma spectroscopy (contractor procedures, RAC-015 have been approved by NRC staff).

Since the disposal cell performance standard deals only with radon generated by the contaminated tailings material, it is acceptable to neglect the radium activity in the cover soils provided the cover soils are obtained from background materials not associated with ore formations or other radium-enriched materials.

Emanation Coefficient, E - The value of the emanation coefficient, "E," will be considered acceptable, if shown to be representative of the tailings material and if supported by field and/or laboratory test records. Since the value of the coefficient is moisture-dependent, the value of the long-term moisture content must be considered when determining radon emanation. The emanation coefficient may be obtained by either the equilibration method or the prediction method as discussed in Austin and Droullard, 1978. If a measured value of the emanation coefficient is not provided in the analysis, use of a reasonably conservative reference value of 0.35 is considered acceptable by the staff.

Ambient Radon - The computer code requires input of the radon concentration above the top layer. A measured background value can be used, but a value of zero is conservative and is recommended.

The computer code also requires the input of other fundamental parameters. These include the radon decay constant, with an accepted value of 2.1×10^{-6}/s, and the equilibrium distribution coefficient, with an accepted value of 0.26. The precision also must be designated. The precision number that should be entered is the level of computational error that is acceptable and a value of 0.001 is recommended.

5.3.1.2 Evaluation of Radon Attenuation Model

The accepted basis for calculating radon flux and minimum cover thickness is one-dimensional, steady-state gas diffusion theory. NRC (1984) presents an analytical method and the computer code RAECOM for determining the surface radon flux from covered tailings, or alternatively, the cover thickness required to satisfy a specified radon flux criterion. The staff considers this analytical method and the RAECOM code acceptable for determining the necessary cover thickness to reduce radon flux to acceptable limits. The staff will use the comparable RADON code (NRC, 1989a) to validate the analysis. The main difference between the two codes is that RADON does not have the optimization for cost-benefit.

The staff will consider whether the average measured parameter values are conservative. NRC staff has accepted use of the average values plus or minus (whichever is more conservative) the standard error of the mean, but prefer the use of values that represent the 95% confidence level for the critical parameters of long-term moisture and radon diffusion coefficient.

Other methods that estimate the average surface radon release from the covered tailings disposal site or which estimate the annual average concentration of radon in air at or above any location outside the disposal site may be acceptable, if it can be shown that these methods produce reliable estimates of radon flux.

5.3.2 Processing Site Cleanup

5.3.2.1 Radiological Site Characterization

The reviewer will ascertain that the background level of radium in soil in the general area of the site is determined using representative soil samples from nearby uncontaminated areas. The value is used to derive the cleanup standard. The areal extent and depth of radium-226 contamination above the standards in the soil on the site, as well as in the tailings pile, must be determined from representative and adequate sampling. Also, the reviewer will determine that appropriate analysis of thorium-230 (also thorium-232 if presence suspected) has been performed.

The level of contamination in buildings will be reviewed. Structures and materials on the site must be designated for disposal in the tailings embankment, for decontamination, or in the case of hazardous or toxic substances, for disposal/treatment in an appropriate facility. Contaminated asbestos, properly packaged, has been allowed to be placed with the tailings if precautions in its handling and placement are followed.

The staff will determine whether conclusions in the RAP are adequately substantiated by the characterization data or otherwise justified in an acceptable manner.

5.3.2.2 Standards Used for Cleanup

The reviewer will verify that DOE has committed to clean up and place within the disposal cell all materials on the processing site that are in excess of the EPA Radium-226 standards (40 CFR 192 Subpart B). There should also be a commitment to clean to appropriate standards any surface alpha or beta-gamma contamination of equipment and structures to be released for unrestricted use.

If the application of supplemental standards is proposed for an area, the reviewer will determine if adequate data are provided to determine that one or more of the criteria of 40 CFR 192.21 appropriately applies to the area in question.

When suspected naturally occurring ore is to remain on the site, the reviewer will determine if appropriate procedures are presented for its identification, such as use of uranium-238/radium-226 ratios, or visual criteria. Staff has previously defined naturally occurring ore as material that has not been disturbed by mining processes. DOE is not responsible for the remediation of material identified as naturally occurring ore.

If elevated levels of uranium are expected to remain after the radium-226 criteria has been met, the reviewer will determine whether appropriate criteria for cleanup are presented in the RAP. An acceptable cleanup standard for total uranium is 10 pCi/g in the top 15 cm of soil and 30 pCi/g in subsequent 15 cm layers. This standard is based on the amount of uranium that would decay to radium levels meeting the EPA standard.

If areas that already meet the radium criteria still have elevated thorium levels, the RAP should contain criteria such that remediation will continue until the amount of radium (residual and from thorium decay) that would be present in 1000 years meets the cleanup standard. An acceptable alternate criteria for a deeply-buried thorium deposit would be to determine that the amount of radon that could exit into a 100 square meter structure built over that deposit would meet the EPA radon progeny standard for habitable structures.

5.3.2.3 Verification

The procedures used to verify that the cleanup has been accomplished according to the standards will be examined to assure that the resulting data will provide reasonable assurance that all applicable standards will be met. Any detailed information on verification procedures presented elsewhere, should be appropriately referenced and have been previously acceptable to NRC.

Staff will determine that the RAP indicates that a percentage of verification samples will be analyzed for thorium and that a statistical basis for choosing the percentage of thorium samples is provided. For sites with known elevated levels of thorium, at least 10% of the samples analyzed for thorium content is acceptable.

If a new verification procedure is proposed, for example when cobbly soil is encountered, the reviewer will determine that the proposed new method will provide reasonable assurance that the EPA standards have been met.

If alpha and beta-gamma contamination on the surfaces of structures and equipment is to be remediated, adequate testing should be planned to substantiate that release for unrestricted use standards have been met.

If habitable buildings are to remain on site, the reviewer will insure that the RAP indicates that the radon daughter concentration will be measured after remedial action and evaluated against the EPA standard for radon progeny and that interior gamma levels will also be demonstrated to meet the EPA standard.

5.4 Evaluation Findings

The staff's review of radon attenuation and site cleanup should verify that sufficient information has been provided in the RAP and supplemental documents such that the following findings can be made:

5.4.1 Radon Attenuation

If the staff evaluation of the radon barrier analysis in the RAP confirms that the standards and regulatory guidelines have been met with reasonable assurance, documentation of the review will state that:

(a) the investigations performed and assumptions made justify the choice of parameter values used to determine required cover thickness and the resultant radon flux and/or ambient air concentration of Radon-222;

(b) the statistical and computer code analyses are acceptable and contain adequate levels of assurance; and

(c) the remedial action design represents a feasible plan for assuring long-term performance with respect to radon flux attenuation.

Staff reservations about any portion of the analysis or design will be stated in sufficient detail to make clear the precise nature of the staff's concern.

5.4.2 Processing Site Cleanup

If the staff evaluation of the processing site cleanup design confirms that applicable standards will be met, the staff will document that the RAP has met the following objectives:

(a) Radiological characterization has been conducted at the processing site to acceptably identify the subsurface boundary of the tailings pile as well as the depth and area of the mill yard, ore storage, and windblown or other contaminated areas. The results of this characterization have been used to plan the excavation control monitoring and the final verification of the land and buildings.

(b) DOE has committed to the cleanup of the processing site in accordance with the EPA standard in 40 CFR 192 Subpart B, or supplemental standards, and cleanup of any surface contamination in excess of the recommended standards.

(c) The procedures identified in the RAP for the final radiological verification are consistent with generic procedures (RAC-015) that have previously been reviewed and approved by the staff.

NRC staff can then state that they are prepared to concur with the site cleanup aspects of the proposed remedial action. However, if the objectives have not been met satisfactorily, any reservations or issues will be stated in sufficient detail and clarity to convey the precise nature of the staff's concern.

5.5 References

Austin, S.R., and Droullard, R.F., "Radon Emanation from Domestic Ore Determined by Modification of Closed-Can Gamma-Only Assay Method," U.S. Bureau of Mines, Report of Investigations 8264, 1978.

Baver, L.D., Soil Physics, John Wiley and Sons, N.Y., pp. 283-303, 1956.

Code of Federal Regulations, Title 40, Protection of Environment, Part 192,"Health and Environmental Protection Standards for Uranium Mill Tailings," 1983.

Rawls, W.J., and Brakensiek, D.L., "Estimating Soil Water Retention From Soil Properties," Journal of the Irrigation and Drainage Division, Proceedings of the American Society of Civil Engineers, vol 108, No.IR2, 1982.

U.S. Atomic Energy Commission, Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors," June 1974.

U.S. Nuclear Regulatory Commission, "Radon Attenuation Handbook for Uranium Mill Tailings Cover Design," NUREG/CR-3533, April 1984a.

---"Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct or Source Materials," Branch Position Paper WM-7601, September, 1984b.

---"Monitoring Methods for Determining Compliance With Decommissioning Cleanup Criteria at Uranium Recovery Sites," NUREG/CR-4118 (PNL-5361), June 1985.

---Office of Nuclear Regulatory Research, "Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers.", Regulatory Guide 3.64, March 1989a.

---Staff Technical Position, "Standard Format and Content for Documentation of Remedial Action Selection at Title 1 Uranium Mill Tailings Sites," 1989b

---"Recommendations to the NRC for Soil Cover Systems Over Uranium Mill Tailings and Low-Level Radioactive Wastes," NUREG/CR-5432, Vol.1-3, February, 1991.

APPENDIX A

COMMON UMTRA PROJECT ACRONYMS

ACL - Alternate Concentration Limit

LLUR - Low Level Uranium Recovery

LTSP - Long-term Surveillance Plan

MCL - Maximum Concentration Limit

POC - Point of Compliance

POE - Point of Exposure

RAC - Remedial Action Contractor

RAP - Remedial Action Plan

RAS - Remedial Action Section

SIP - Stabilization in Place

SOS - Stabilization on Site

TAC - Technical Assistance Contractor

TER - Technical Evaluation Report

UMTRA - Uranium Mill Tailings Remedial Action

UMTRCA - Uranium Mill Tailings Radiation Control Act of 1978

APPENDIX B
SEISMIC-TECTONIC GLOSSARY

CAPABLE FAULT - A fault which has exhibited one or more of the following characteristics:

1) Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years;

2) Macro-seismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault;

3) A structural relationship to a capable fault according to characteristics (1) or (2) of this paragraph such that movement on one could be reasonably expected to be accompanied by movement on the other. [10 CFR 100, App. A, III(g)]

FAULT - A tectonic structure along which differential slippage of the adjacent earth material has occurred parallel to the fracture plane. It is distinct from other types of ground disruptions such as landslides, fissures, and craters. A fault may have gouge or breccia between its two walls and includes any associated monoclinal flexure or other similar geologic structural feature [10 CFR 100, App. A III (e)]

MAXIMUM CREDIBLE EARTHQUAKE (MCE) - That earthquake which would cause the maximum vibratory ground motion based upon an evaluation of earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material. [10 CFR 40, App. A, Criterion 4(e)]

SURFACE FAULTING - A differential ground displacement at or near the surface that is caused directly by fault movement and is distinct from nontectonic types of ground disruptions, such as landslides, fissures and craters. [10 CFR 100, App. A III(f)]

TECTONIC PROVINCE - A region of the North American continent characterized by a relative consistency of the geologic structural features contained therein. [10 CFR 100, App. A III (h)]

TECTONIC STRUCTURE - A large scale dislocation or distortion within the earth's crust. Its extent is measured in kilometers (miles). [10 CFR 100, App. A III(i)]

APPENDIX C

GLOSSARY OF WATER RESOURCES PROTECTION TERMS

Aquifer - A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Background Quality - The chemical and hydrochemical characteristics of a material (generally water or soil) that would exist independent of the effects of the designated facility.

Bedload - Sediment that moves on or near the stream bed and is in almost continuous contact with the bed.

Brackish Water - Water that contains more than 1,000 but less than 10,000 milligrams per liter of dissolved solids.

Brine - Water that contains more than 35,000 milligrams per liter of dissolved solids.

Cation exchange capacity (CEC) - the number of milliequivalents of cations that can be exchanged from solution to a solid with a dry mass of 100 grams.

Confined - The condition in which the static water level or potentiometric surface in a hydrogeologic unit is above the top of the unit; artesian.

Confined Aquifer - An aquifer bounded above and below by hydrogeologic units of distinctly lower permeability than that of the aquifer.

Confining Unit - A hydrogeologic unit with distinctly low permeability above or below one or more aquifers.

Contaminant Plume - A contaminated area or volume of a stream or aquifer.

Desorption - Release of gas molecules, ions, or molecules into solution that had previously adhered to a solid surface.

Discharge Area - That portion of a subsurface drainage basin or hydrogeologic system in which the net saturated flow of groundwater is directed toward the water table.

Dispersion Coefficient - A measure of the spreading of a flowing fluid, which equals the sum of the coefficient of molecular diffusion and the product of dispersivity times the average interstitial velocity in a porous medium.

Dispersivity - A proportionality constant that describes the mechanical mixing of solutes and heat during advective transport, which equals the ratio between the coefficient of mechanical dispersion and the average interstitial velocity along a flow path.

Distribution Coefficient - The equilibrium sorption ratio of the amount of solute sorbed by the solid per unit weight of solid and the quantity of solute dissolved in solution per unit volume of solution.

Effective Porosity - The ratio of (1) the total volume of voids that conduct fluid flow and advective solute and heat transport to (2) the total volume of the porous medium.

Evapotranspiration - The amount of water discharged to the atmosphere as a result of evaporation from earth materials and surface-water bodies and transpiration from plants.

Flow Path - The subsurface, macroscopic course a water molecule or solute would follow in a given water velocity field.

Freshwater - Water that contains less than or equal to 1,000 milligrams per liter of dissolved solids.

Groundwater - Water that occurs below the surface of the earth, including water within the unsaturated and saturated zones and excluding primordial water and waters bound within crystal lattices.

Groundwater Divide - A ridge in the water table or potentiometric surface from which groundwater flows in opposite directions.

Groundwater Mound - A rise in the water table or other potentiometric surface created by groundwater recharge.

Head, Static - A measure of the potential of water represented as the height above a standard datum of the surface of a column of water that can be supported by the static pressure at the point of measurement; the sum of the elevation head and pressure head.

Hydraulic Conductivity - A proportionality constant that relates hydraulic gradient to specific discharge, which may be expressed as the volume of water at an existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured normal to the direction of flow for an isotropic medium and homogenous fluid.

Hydraulic Gradient - The change in static head per unit distance in a given direction, which is generally assumed to coincide with the direction of maximum rate of decrease in head.

Hydrodynamic Dispersion - The spreading of a solute or thermal energy during transport caused by mechanical dispersion and molecular diffusion as described on a macroscopic scale.

Hydrogeologic Unit - Any discrete and continuous porous medium or porous zone that influences the storage or movement of groundwater because of its porosity or permeability.

Infiltration - The downward entry of water into soil, sediment, or rock. Leakage - The

uncontrolled transfer of water from one aquifer to another.

Matrix Potential - The energy required to extract water from a porous medium against capillary and adsorptive forces of the medium.

Mechanical Dispersion - Physical mixing of solutes or thermal energy during advective transport caused by variations of flow velocities at the microscopic scale.

Moisture Content - The ratio, expressed as a percentage, of (1) the weight of water to (2) the weight of solid particles in a given volume of a porous medium.

Perched Groundwater - A saturated body of unconfined groundwater separated from an underlying saturated body of groundwater by an unsaturated zone.

Piezometer - A device emplaced in the subsurface to measure accurate changes in groundwater levels.

Porosity - The ratio of the total volume of voids to the total volume of a porous medium.

Potentiometric Surface - An imaginary surface representing the static head of groundwater described by the level to which water would rise in a piezometer.

Protective Action - Any action implemented to prevent, control, or mitigate water contamination.

Recharge Area - That portion of a drainage basin or discrete hydrogeologic system in which the net saturated flow of groundwater is directed away from the water table.

Saline Water - Water that is generally considered unsuitable for human consumption or for irrigation because of its high content of dissolved solids ranging from 10,000 to 35,000 milligrams per liter.

Seep - An area where water percolates to the land surface at flow rates less than 1 liter per minute per square meter.

Semiconfined Aquifer - An aquifer that is partially bounded above or below by a confining unit.

Sole-Source Aquifer - As determined by the U. S. Environmental Protection Agency, an aquifer that supplies at least 50 percent of the drinking water for an area.

Sorption - One or more physiochemical processes, excluding precipitation of stoichiometric (fixed composition) solid phases, in which solutes are removed from a liquid or gas phase by interaction with a solid phase or phases.

Specific Discharge - The rate of discharge of groundwater per unit area of a porous medium measured perpendicular to the direction of flow.

Specific Storage - The volume of water released from or taken into storage per unit volume of the porous medium per unit change in head.

Specific Yield - The ratio of the volume of water that a saturated porous medium will yield by gravity flow to the total volume of the porous medium.

Spring - A discrete area where groundwater discharges naturally onto the land surface or into a body of surface water at flow rates greater than or equal to 1 liter per minute per square meter.

Storage Coefficient - The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head; storativity.

Total Dissolved Solids - The total concentration of dissolved constituents in solution, which is generally expressed in milligrams per liter.

Transmissivity - The rate at which water of a given kinematic viscosity is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

Unconfined - The condition of water in the zone of saturation whose upper surface is the water table.

Unsaturated Flow - The movement of water in a porous medium whose pores are not completely filled with water.

Unsaturated Zone - The portion of hydrogeologic systems between the land surface and the deepest water table, which includes the capillary fringe and may contain zones in which water pressure is locally greater than atmospheric pressure; vadose zone.

APPENDIX D

Chapter 40 PART 192

Health and Environmental Protection Standards
for Uranium Mill Tailings
(EPA, 1987)

This document was compiled from published Federal Register notices as an internal reference resource for the NRC Low Level Uranium Recovery Branch. Although every effort has been made to ensure completeness and accuracy, the user should refer to the appropriate Federal Register notices as the primary source for making authoritative citations.

Proposed Rule: FR vol. 52, no.185

TITLE 40

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

Subpart A — Standards for the Control of Residual Radioactive Materials from Inactive Uranium Processing Sites

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

Subpart C — Implementation

Authority: Section 275 of the Atomic Energy Act of 1954, 42 U.S.C. 2022, as added by the Uranium Mill Tailings Control Act of 1978, Pub. L. 95-604.
[48 FR 590 Jan. 5, 1983 as amended 52 FR 36000 September 24, 1987]

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

§ 192.00 Applicability

This subpart applies to the control of residual radioactive material at designated processing or disposal sites under Section 108 of the Uranium Mill Tailings Radiation Control Act of 1978 (henceforth designated "the Act"), and to restoration of such sites following any use of subsurface minerals under Section 104(h) of the Act.

[48 FR 590 Jan. 5, 1983]

§ 192.01 Definitions

(a) Unless otherwise indicated in the subpart, all terms shall have the same meaning as Title I of the Act. Reference to Part 264 of the Code of Federal Regulations is to that Part as codified on January 1, 1983.

(b) *Remedial action* means any action performed under Section 108 of the Act.

(c) *Control* means any remedial action intended to stabilize, inhibit future misuse of, or reduce emissions or effluents from residual radioactive materials.

(d) *Disposal site* means the region within the smallest perimeter of residual radioactive material (excluding cover materials) following completion of control activities.

(e) *Depository site* means a disposal site (other than a processing site) selected under Section 104(b) or 105(b) of the Act.

(f) *Curie (Ci)* means the amount of radioactive material that produces 37 billion nuclear transformations per second. One picocurie (pCi) = 10^{-12} Ci.

(g) *Remedial period* means the period of time beginning March 7, 1983 and ending with the completion of requirements specified under the remedial action plan.

(h) *Remedial Action Plan* means a written plan for a specific site that incorporates the results of site characterization studies, environmental assessments or impact statements, and engineering assessments into a plan for disposal and cleanup which satisfies the requirements of Subparts A and B.

(i) *Post-disposal period* means the period of time beginning immediately after the completion of the requirements of Subpart A and ending at completion of monitoring requirements established under §192.02(b).

(j) *Ground water* is subsurface water within a zone in which substantially all the voids are filled with water under pressure equal to or greater than that of atmospheric pressure.

[48 FR 590 Jan. 5, 1983 as amended 52 FR 36000 September 24, 1987]

§ 192.02 Standards

(a) Control of residual radioactive materials and their listed constituents shall be designed[1] to:

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

(2) Provide reasonable assurance that releases of radon—222 from residual radioactive materials to the atmosphere will not:

(i) Exceed an average[2] release rate of 20 picocuries per square meter per second, or

(ii) Increase the annual average concentration of radon—222 in air at or above any location outside the disposal site by more than one-half picocurie per liter.

(3) Conform to the ground-water protection provisions of §264.92 — §264.95 of Part 264 of this chapter, except that, for the purposes of this subpart:

(i) To the list of constituents referenced in §264.93 of this chapter are added molybdenum, radium, uranium, and nitrate.

TABLE A.

CONSTITUENT	LIMIT
Combined radium—226 and radium—228	5 pCi/L
Combined uranium—234 and uranium—238	30 pCi/L
Gross Alpha Activity (excluding radon and uranium)	15 pCi/L
Nitrate (as N)	10 mg/L
Molybdenum	0.1 mg/L

(ii) To the concentration limits provided in Table 1 of §264.94 of this chapter are added the constituent limits in Table A of this subpart.

(iii) The Secretary shall determine what listed constituents are present in the tailings at a disposal site.

(iv) A monitoring program shall be established upgradient of the disposal site adequate to determine background levels of listed constituents.

(v) The Secretary may propose and, with the Commission's concurrence, apply alternative concentration limits, provided that, after considering practicable corrective actions, the Commission determines that these are as low as reasonably achievable, and that, in any case, §264.94 (b) is satisfied, and

(vi) The functions and responsibilities designated in referenced paragraphs of Part 264 of this chapter as those of the "Regional Administrator" with respect to "facility permits" shall be carried out by the Commission.

(4) Comply with the performance standard in §264.111(a) and (b) of this chapter.

(b) The Secretary shall propose and, following the concurrence by the Commission, implement a monitoring plan, to be carried out over a period of time which shall constitute the post-disposal period, which is adequate to demonstrate that initial performance of the disposal is in accordance with the design requirements of §192.02(a).

(c) If the ground-water standards established under provisions of §192.02(a) are found or projected to be exceeded, as a result of the monitoring program established for the post-disposal period under §192.02(b), a corrective action program to restore the disposal to the design requirements of §192.02(a) and, as necessary, to clean up ground water in conformance with Subpart B shall be put into operation as soon as practicable, and in no event later than eighteen (18) months after a finding of exceedance.

[48 FR 590 Jan. 5, 1983 as amended 52 FR 36000 September 24, 1987]

Subpart B - Standards for Cleanup of Land and Buildings Contaminated With Residual Radioactive Materials From Inactive Uranium Processing Sites

§ 192.10 Applicability

This subpart applies to land and buildings that are part of any processing site designated by the Secretary of Energy under Section 102 of the Act. Section 101 of the Act, states, in part, that "processing site" means —

(a) Any site, including the mill, containing residual radioactive materials at which all or substantially all of the uranium was produced for sale to any Federal agency prior to January 1, 1971, under a contract with any Federal agency, except in the case of a site in or near Slick Rock, Colorado, unless-

(1) Such site was owned or controlled as of January 1, 1978, or is thereafter owned or controlled, by any Federal agency, or

(2) A license (issued by the (Nuclear Regulatory) Commission or its predecessor agency under the Atomic Energy Act of 1954 or by the States permitted under Section 274 of such Act) for the production at site of any uranium or thorium products derived from ores is in effect on January 1, 1978, or is issued or renewed after such date; and

(b) any other real property or improvement thereon which —

(1) is in the vicinity of such site, and

(2) is determined by the Secretary, in consultation with the Commission, to be contaminated with residual radioactive materials derived from such site.

[48 FR 590 Jan. 5, 1983]

§ 192.11 Definitions

(a) Unless otherwise indicated in this subpart, all terms shall have the same meaning as defined in Title I of the Act or in Subpart A.

(b) *Land* means (1) any surface or subsurface land that is not part of a disposal site and is not covered by an occupiable building, and (2) subsurface land that contains ground water contaminated by listed constituents from residual radioactive material from the processing site.

(c) *Working Level (WL)* means any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of alpha particles with a total energy of 130 billion electron volts.

(d) *Soil* means all unconsolidated materials normally found on or near the surface of the earth including, but not limited to, silts, clays, sands, gravel, and small rocks.

(e) *Class III ground water*[3] means ground water that is not a current or potential source of drinking water because (1) the concentration of total dissolved solids is in excess of 10,000 mg/L, (2) widespread, ambient contamination not due to activities involving residual radioactive materials from a designated processing site exists that cannot be cleaned up using treatment methods reasonably employed in public water-supply systems, or (3) the quantity of water available is less than 150 gallons per day.

[48 FR 590 Jan. 5, 1983 as amended 52 FR 36000 September 24, 1987]

§ 192.12 Standards

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

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

(1) 5 pCi/g, averaged over the first 15 cm of soil below the surface, and

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

(b) In any occupied or habitable building —

(1) The objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL. In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL, and

(2) The level of gamma radiation shall not exceed the background level by more than 20 miroroentgens per hour.

(c) The concentration of any listed constituent in ground water as a result of releases from residual radioactive material at any designated processing site shall not exceed the provisions of §264.92 — §264.94 of this chapter as modified by §192.02 (a)(3)(i) and (ii), except for the purposes of this subpart:

(1) The Secretary shall carry out a monitoring program adequate to define the extent of ground-water contamination by listed constituents from residual radioactive materials and to monitor compliance with this Subpart.

(2) The Secretary may propose and, with the Commission's concurrence, apply alternative concentration limits provided that, after considering practicable corrective actions, the Commission determines that these are as low as reasonably achievable, and §264.94(b) is satisfied.

(3) The functions and responsibilities designated in referenced paragraphs of Part 264 of this chapter as those of the "Regional Administrator" with respect to "facility permits" shall be carried out by the Commission.

(4) The remedial period established under Subpart A may be extended by an amount not to exceed 100 years if:

(i) The concentration limits established under this Subpart are not projected to be exceeded at the end of this extended remedial period.

(ii) Institutional controls, which

will effectively protect public health and satisfy beneficial uses of ground water during the extended remedial period, is instituted, as part of the remedial action at the processing site and wherever contamination by listed constituents from residual radioactive materials is found in ground water, or is projected to be found.

(iii) The ground water is not currently or projected to become a source of supply for public drinking water subject to provisions of the Safe Drinking Water Act during the extended remedial period, and

(iv) The requirements of Subpart A are satisfied within the time frame established under Section 112(a) of the Act, or as extended by Act of Congress.

[48 FR 590 Jan. 5, 1983 as amended 52 FR 36000 September 24, 1987]

Subpart C - Implementation

§ 192.20 Guidance for Implementation

Section 108 of the Act requires the Secretary of Energy to select and perform remedial actions with the concurrence of the Nuclear Regulatory Commission and the full participation of any State that pays part of the cost and in consultation, as appropriate, with affected Indian Tribes and the Secretary of the Interior. These parties, in their respective roles under Section 108, are referred to hereafter as "the implementing agencies." The implementing agencies shall establish methods and procedures to provide "reasonable assurance" that the provisions of Subparts A and B are satisfied. This should be done as appropriate through use of analytical models and site-specific analyses, in the case of Subpart A, and for Subpart B, through measurements performed within the accuracy of currently available types of field and laboratory instruments in conjunction with reasonable survey and sampling procedures. These methods and procedures may be varied to suit conditions at specific sites, in particular:

(a)(1) The purpose of Subpart A is to provide long-term stabilization and isolation in order to inhibit misuse and spreading of residual radioactive materials, control releases of radon to air and protect water. Subpart A may be implemented through analysis of the physical properties of the site and the control system and projection of the effects of natural processes over time. Events and processes that could significantly affect the average radon release rate from the entire disposal site should be considered. Phenomena that are localized or temporary, such as local cracking or burrowing of rodents, need to be taken into account only if their cumulative effect would be significant in determining compliance with the standard. Computational models, theories, and prevalent expert judgement may be used to decide that a control system will satisfy the standard. The numerical range provided in the standard for the longevity of the effectiveness of the control of residual radioactive material allows for consideration of various factors affecting the longevity of control and stabilization methods and their costs. These factors have different levels of predictability and may vary for different sites.

(2) Protection of water should be considered on a case-by-case basis, drawing on hydrological and geochemical surveys and all other relevant data. The hydrologic and geologic assessment to be conducted at each site shall include a monitoring program sufficient to establish background ground-water quality through one or more up-gradient wells. New disposal sites for tailings that still contain water at greater than the level of "specific retention" or tailings that are slurried to the new location shall use a liner or equivalent to prevent contamination of ground water.

(3) The remedial action plan, receiving approval by the Commission, shall specify how applicable requirements of Subpart A are to be satisfied. The plan shall include the schedule and steps necessary to complete disposal operations at the site. It shall include an estimate of the inventory of wastes to be disposed of in the pile and their listed constituents and address (i) any need to eliminate free liquids; (ii) stabilization of wastes to a bearing capacity sufficient to support the final cover; and (iii) the design and construction of a cover to manage the migration of liquids through the stabilized pile, function with minimum maintenance, promote drainage and minimize erosion or abrasion of the cover, and accommodate settling and subsidence so that the cover's integrity is maintained.

(b)(1) Compliance with §192.12(a) and (b) of Subpart B, to the extent practical, should be demonstrated through radiation surveys. Such surveys may, if appropriate, be restricted to locations likely to contain residual radioactive materials. These surveys should be designed for compliance averaged over limited areas rather than point-by-point compliance of the standards. In most cases, measurements of gamma radiation exposure rates above and below the land surface can be used to show compliance with §192.12(a). Protocols for making such measurements should be based on assuming realistic radium distributions near the surface rather than extremes rarely encountered.

(b)(2) In §192.12(a), "background level" refers to native radium concentration in soil. Since this may not be determinable in the presence of contamination by residual radioactive materials, a surrogate "background level" may be established by simple direct or indirect (e.g., gamma radiation) measurements performed nearby but outside the contaminated location.

(b)(3) Compliance with §192.12(b) may be demonstrated by methods that the Department of Energy has approved for use under Pub. L. 92-314 (10 CFR 712), or by other methods that the implementing agencies determine are adequate. Residual radioactive materials should be removed from buildings exceeding 0.03 WL so that future replacement buildings will not pose a hazard (unless removal is not practical — see §192.21 (c)). However, sealants, filtration, and ventilation devices may provide reasonable assurance of reductions from 0.03 WL to below 0.02 WL. In unusual cases, indoor radiation may exceed the levels specified in §192.12(b) due to sources other than residual radioactive materials. Remedial actions are not required in order to comply with the standard when there is reasonable assurance that residual radioactive materials are not the cause of such excess.

(4) The remedial action plan, following approval by the Commission, will specify how applicable requirements of Subpart B would be satisfied. The plan should include the schedule and steps necessary to complete the cleanup of ground water at the site. It should document the extent of contamination due to releases prior to final disposal, including the identification and location of listed constituents and the rate and direction of movement of contaminated ground water. In addition, the assessment should consider future plume movement, including an evaluation of such processes as attenuation and dilution. In cases where §192.12(c)(4) is invoked, the plan should include a monitoring program to verify projections of plume movement and attenuation throughout the remedial period. Finally, the plan should specify details of the method to be used for cleanup of ground water.

[48 FR 590 Jan. 5, 1983 as amended 52 FR 36000 September 24, 1987]

§ 192.21 Criteria for applying supplemental standards

Unless otherwise indicated in this subpart, all terms shall have the same meaning as defined in Title I of the Act or in Subparts A and B. The implementing agencies may (and in the case of Subsection (h) shall) apply standards under §192.22 in lieu of the standards of Subparts A or B if they determine that any of the following circumstances exists:

(a) Remedial actions required to satisfy Subparts A or B would pose a clear risk of injury to workers or to members of the public, notwithstanding reasonable measures to avoid or reduce risk.

(b) Remedial actions to satisfy the cleanup standards for land, §192.12(a) and (c), or the acquisition of minimum materials required for control to satisfy §192.02(a)(2) and (3), would, notwithstanding reasonable measures to limit damage, directly produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near the site, now or in the future. A clear excess of environmental harm is harm that is long-term, manifest, and grossly disproportionate to health benefits that may be reasonably by anticipated.

(c) The estimated cost of remedial action to satisfy §192.12(a) at a "vicinity" site (described under Section 101(6)(B) of the Act) is unreasonably high relative to long-term benefits, and the residual radioactive materials do not pose a clear presence of future hazard. The likelihood that buildings will be erected or that people will spend long periods of time at such a vicinity site should be considered in evaluating this hazard. Remedial action will generally not be necessary where residual radioactive materials have been placed semi-permanently in a location where site-specific factors limit their hazard and from which they are costly or difficult to remove, or where only minor quantities of residual radioactive materials are involved. Examples are residual radioactive materials under hard surface public roads and sidewalks, around public sewer lines, or in fence post foundations. Supplemental standards should not be applied at such sites; however, if individuals are likely to be exposed for long periods of time to radiation from such materials at levels above those that prevail under §192.12(a).

(d) The cost of a remedial action for cleanup of a building under §19-2.12(b) is clearly unreasonably high relative to the benefits. Factors that should be included in this judgement are the anticipated period of occupancy, the incremental radiation level that would be affected by the remedial action, the residual useful lifetime of the building, the potential for future construction at the site, and the applicability of less costly remedial methods than removal of residual radioactive materials.

(e) There is no known remedial action.

(f) The restoration of ground water quality at any designated processing site under §192.12(c) is technically impracticable from an engineering perspective.

(g) The ground water is Class III.

(h) Radionuclides other than radium—226 and its decay products are present in sufficient quantity and concentration to constitute a significant radiation hazard from residual radioactive materials.

[48 FR 590 Jan. 5, 1983 as amended 52 FR 36000 September 24, 1987]

§ 192.22 Supplemental standards

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

(a) When one or more of the criteria of §192.21(a) through (g) applies, the implementing agencies shall select and perform actions that come as close to meeting the otherwise applicable standard as is reasonable under the circumstances.

(b) When §192.21(h) applies,

remedial actions shall, in addition to satisfying the standards of Subparts A and B, reduce other residual radioactivity to levels as low as reasonably achievable.

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

(d) When §192.21(f) or (g) applies, implementing agencies must apply any remedial actions for the restoration of contaminated ground water that is required to assure, at a minimum, protection of human health and the environment.

[48 FR 590 Jan. 5, 1983 as amended 52 FR 36000 September 24, 1987]

§ 192.23 Effective date

Subparts A,B, and C shall be effective March 7, 1983.

* * *

40 CFR 192.20(a)(2) and (3) were remanded by Tenth Circuit Court of Appeals on September 3, 1985.

Proposed rule was published in the Federal Register on September 24, 1987.

DOE and NRC agreed (DOE—NRC MOU, Nov. 6, 1990) to use proposed EPA standards (52 FR 36000, September 24, 1987) on an interim basis and will use the Final EPA Standards when promulgated.

Final Rule drafted May 6, 1991; currently in review at OMB.

Document Print Date:
June 23, 1993

URANIUM RECOVERY PROGRAM
POLICY AND GUIDANCE DIRECTIVE
LLWM 93-02

STANDARD REVIEW PLAN FOR THE REVIEW OF REMEDIAL ACTION OF INACTIVE MILL TAILINGS SITES UNDER TITLE I OF THE URANIUM MILL TAILINGS RADIATION CONTROL ACT
Revision 1

June 1993

RESPONSIBLE STAFF: Sandra Wastler LLUR	**APPROVED BY:** John Surmeier, Chief, LLUR
REVIEWED BY: Daniel M. Gillen, LLUR	**APPROVED BY:** Richard Bangart, LLWM
REVIEWED BY Myron Fliegel, LLUR	**EFFECTIVE UNTIL: 10/95** Reevaluation Scheduled 6/95

LLWM 93-02
APPROVED: July 1, 1993

PURPOSE: The Standard Review Plan (SRP) provides guidance to the NRC staff to assure that the review of DOE's Uranium Mill Tailings Remedial Action (UMTRA) Project documents are conducted in a thorough, focused, efficient, and consistent manner. The SRP also assures that the staff's findings are properly documented. In addition, the SRP provides DOE, impacted states, Indian tribes, and other interested parties, with an understanding of the review process.

DISCUSSION: The SRP allows for consistency between reviews and among reviewers in technical and regulatory matters related to the NRC review and concurrence in DOE's proposed remedial action at UMTRA sites. This is a revision to the SRP (formerly LLWM 92-09) to reflect comments by the Advisory Committee on Nuclear Waste.

In the absence of an SRP for Title II reclamation activities, this SRP should be used as guidance in that program to the extent practicable.

LIMITATIONS: None

PAGES IN REFERENCED DOCUMENT: 82, A-1, B-1, C-1 to C-4, and D-1 to D-15

BIBLIOGRAPHIC CITATION: "Standard Review Plan for the Review of Remedial Action of Inactive Mill Tailings Sites Under Title I of the Uranium Mill Tailings Radiation Control Act," Revision 1, LLWM, June 1993.

RESPONSIBLE STAFF: Sandra L. Wastler, LLUR, 301-504-2582

92-02 "Assessments and Audits: Low Level Waste Management (LLWM) Participation in Agreement State Reviews," LLWM, February 1992.

92-03 "Interim Guidance on Evaluation Procedure for Hydraulic Conductivity of Radon/Infiltration Barriers for Title I and Title II Mill Tailings Sites," Memorandum from J.J. Surmeier to R.E. Hall, April 9, 1992.

92-04 "Guiding Principals for EPA-NRC Cooperation and Decisionmaking," March 1992.

92-05 "Air Sampling in the Workplace," Reg. Guide 8.25, Rev. 1, June 1992.

92-06 "Instructions for Recording and Reporting Occupational Radiation Exposure Data," Reg. Guide 8.7, Rev.1, June 1992.

92-07 "Radiation Dose to the Embryo/fetus," Reg. Guide 8.36, July 1992.

92-08 "Monitoring Criteria and Methods to Calculate Occupational Radiation Doses," Reg. Guide 8.34, July 1992.

92-09 "Standard Review Plan for UMTRCA Title I Mill Tailings Remedial Action Plans," Revision 1, LLWM, October, 1992. **SUPERSEDED BY 93-02.**

92-10 "ALARA Levels For Effluents From Materials Facilities," Draft Reg. Guide DG-8013, October 1992.

93-01 "On-Site Construction Reviews of Remedial Action At Inactive Uranium Mill Tailings Sites," Chapter 2620, Inspection and Enforcement Manual, Rev. 1, February 1993.

93-02 "Standard Review Plan for the Review of Remedial Action of Inactive Mill Tailings Sites Under Title I of the Uranium Mill Tailings Radiation Control Act," Rev. 1, June 1993.

LLUR shall incorporate review comments when feasible and reasonable efforts shall be made to resolve the differences. For comments not incorporated, the reasons for non-accommodation shall be discussed with the Director, URFO, and the Director, Division of Radiation Safety and Safeguards, and documented in a record to the file that will be transmitted to the parties involved. A copy of this record to the file will be permanently retained by the LLUR directive system custodian. (The LLUR directive system custodian will be designated by the Chief, LLUR upon implementation of the UR Program Policy and Directive System.)

5.0 CONCURRENCE

For UR directives that have broader policy or legal implications, concurrence should be obtained from other NRC offices (e.g., Office of the General Council, Office of State Programs, Office of Enforcement, etc.) as appropriate. A concurrence block shall be provided on the Title Cover for such concurrence.

6.0 APPROVALS OF UR DIRECTIVES

The Director, LLWM shall review and approve all proposed new or revised UR directives.

7.0 DISTRIBUTION OF UR DIRECTIVES

Upon approval by the Director LLWM, the UR directive will be transmitted to URFO and LLUR for implementation. Additional distribution will be made to usual LLWM and NMSS files; to the Director, DRSS, in Region IV. A copy also will be provided to the Public Document Room and the Advisory Committee on Nuclear Waste.

The Table of Contents and Indexes for the UR Policy and Guidance Directive System will be distributed by memorandum to all URFO and LLUR staff when changes or additions are made to the system. Any deleted directives from the system also will be identified in the above memorandum.

8.0 EFFECTIVE DATES OF AND REVISIONS TO UR DIRECTIVES

8.1 UR Directives.

The provisions of the initial set of UR directives will go into effect on June 1, 1993. All future UR directives will go into effect immediately upon approval by the Director LLWM. When a specific effective date is necessary because of a management determination or to satisfy a legal or administrative requirement, the effective date must be specified in the UR directive.

Title I	89-02, 89-03, 91-02, 92-03, 93-01, 93-02
Title II	92-03, 93-02
Waste Disposal	88-06, 91-03

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92-08	This guide provides acceptable criteria that may be used by licensees to determine whether monitoring is needed and to provide methods for calculating and summing external and internal doses to demonstrate compliance with the dose limits in 10 CFR 20.1201)a)(1) for adults and 10 CFR 20.1207 for minors.
92-09	Provides a standard review plan for Title I Remedial Action Plans. **SUPERSEDED BY 93-02.**
92-10	Provides guidance on designing an acceptable program for establishing and maintaining ALARA levels for gaseous and liquid effluents at materials facilities.
93-01	Provides guidance for construction reviews of remedial actions at Title I sites.
93-02	Provides a standard review plan for Title I Remedial Action Plans which is also to be used for Title II reviews to the extent practicable.