
STANDARD REVIEW PLAN

for the Review of a Reclamation Plan
for Mill Tailings Sites
Under Title II of the Uranium Mill Tailings
Radiation Control Act of 1978

**U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Division of Fuel CYCLE Safety and Safeguards
Washington, DC 20555-0001**



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AVAILABILITY NOTICE

ABSTRACT

A U.S. Nuclear Regulatory Commission source and byproduct materials license is required by 10 CFR Part 40 for the operation of uranium mills and the disposal of “tailings,” wastes produced by the extraction or concentration of source material from ores processed primarily for their source material content. Appendix A to Part 40 establishes technical and other criteria relating to siting, operation, decontamination, decommissioning, and reclamation of mills and of tailings at mill sites. The licensee’s site reclamation plan documents how the proposed activities demonstrate compliance with the criteria in Appendix A to Part 40 and the information needed to prepare the environmental assessment on the effects of the proposed reclamation activities on the health and safety of the public and on the environment.

This standard review plan is prepared for the guidance of staff reviewers in the Office of Nuclear Material Safety and Safeguards in performing safety and environmental reviews of reclamation plans for uranium mill tailings sites covered by Title II of the Uranium Mill Tailings Radiation Control Act of 1978 as amended. It provides guidance for new reclamation plans, license renewals, and license amendments. The principal purpose of this standard review plan is to ensure the quality and uniformity of staff reviews and to present a well-defined base from which to evaluate changes in the scope and requirements of a review.

This standard review plan is written to cover a variety of site conditions and reclamation plans. Each section contains a description of the areas of review, review procedures, acceptance criteria, and evaluation findings. Revision 1 also incorporates information to address new Commission policy on several issues related to uranium recovery.

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EXECUTIVE SUMMARY

A U.S. Nuclear Regulatory Commission (NRC) source and byproduct materials license is required in accordance with the provisions of Title 10 of the U.S. Code of Federal Regulations, Part 40 (10 CFR Part 40), "Domestic Licensing of Source Material," in conjunction with uranium or thorium milling, or with byproduct material at sites formerly associated with such milling. At the termination of a uranium mill license, the mill tailings impoundment and some adjoining land will be turned over to the U.S. Department of Energy (DOE), another Federal agency designated by the President, or the State in which the site is located for long-term care. Requirements applicable to a license consist of the regulations in 10 CFR Part 40, Appendix A to 10 CFR Part 40, and any license conditions. The specific sections in this standard review plan that address the criteria of 10 CFR Part 40, Appendix A, are shown in Appendix A of the review plan.

An application for a new license, license renewal, or an amendment to or termination of an existing license should contain, as appropriate, proposed specifications relating to the milling operations, and the information on the disposal of tailings or wastes resulting from such milling activities and information on decommissioning of the site. General guidance on (i) contents and filing of an application and (ii) producing an environmental report appears in 10 CFR 40.31, "Application for specific licenses," and in 10 CFR 51.45, "Environmental report," respectively. The staff uses the information in the application to determine whether the proposed activities will be protective of public health and safety and be environmentally acceptable. General provisions for issuance, amendment, transfer, and renewal of licenses are described in 10 CFR Part 2, Subpart A. Guidance on considering environmental justice issues during licensing of Title II uranium or thorium mills is presented in NUREG-1748 (NRC, 2001).

This standard review plan provides the staff in the Office of Nuclear Material Safety and Safeguards with specific guidance on the review of reclamation plans and license amendments related to reclamation plans. The reclamation plan, submitted by an applicant (in the case of a new application) or a licensee (in the case of an amendment to a previously approved reclamation plan or termination of an existing license) should demonstrate compliance with the applicable criteria in Appendix A to 10 CFR Part 40. The introduction to 10 CFR Part 40 specifically states that "In many cases, flexibility is provided in the criteria to allow achieving an optimum tailings disposal program on a site-specific basis. However, in such cases the objectives, technical alternatives and concerns which must be taken into account in developing a tailings program are identified." The principal purpose of the standard review plan is to present guidance to the NRC staff to ensure a consistent quality and uniformity in NRC reviews of reclamation plans. Each section in this standard review plan contains guidance on what is to be reviewed, the basis for the review, how the staff review is to be done, what the staff will find acceptable in a demonstration of compliance with the regulations, and the conclusions that are sought regarding compliance with the regulations in 10 CFR

Part 40. This standard review plan is intended to cover only those aspects of the NRC regulatory mission related to the reclamation of mill tailings sites, including soil and ground-water cleanup, at conventional uranium mills. As such, the standard review plan helps focus the staff review on determining if a tailings impoundment can be constructed, operated, and reclaimed in compliance with the applicable NRC regulations. The standard review plan is also intended to make information about regulatory matters widely available to improve communication, and to help interested members of the public and the uranium recovery industry gain a better understanding of the staff review process. In any of these reviews, the staff will consider licensee-proposed alternatives to Appendix A criteria as described in the Introduction in Appendix A to 10 CFR Part 40. The review would cover the level of protection to the public health and safety and the environment and the level of stabilization and containment of the site. All site-specific licensing decisions based on Appendix A criteria or proposed alternatives will consider the risk to health and safety and the environment and the economic costs involved. Staff guidance for review of environmental reports and preparing environmental assessments is found in NUREG-1748 (NRC, 2001).

For license amendments, the review should focus on the changes proposed in the amendment [see NUREG-1748 (NRC, 2001) for guidance on reviewing historical aspects of site performance]. Reviewers should not review previously accepted actions if they are not part of the proposed amendment, unless the review of the amendment package identifies an impact on previously accepted actions.

For changes to previously approved reclamation plans, the licensee need only submit information pertinent to the proposed change. The licensee need not resubmit a complete reclamation plan covering all aspects of site reclamation, but should present information on the proposed changes to the previously approved plan and its updates as identified in the current NRC license. Reviewers should also analyze the inspection history and operation of the site to see if any major problems have been identified over the course of the license term that would have an effect on reclamation. The operating history of the facility is often a valuable source of information concerning the adequacy of site characterization, the acceptability of radiation protection and monitoring programs, and the sufficiency of other data that may influence staff determination of compliance. NUREG-1757, Volume I, Section 16.2 (NRC, 2002) presents guidance for review of these historical aspects of facility performance. If the changes are found to be acceptable, the license is then amended to identify the revised reclamation plan as the required design for reclamation.

License termination usually involves a confirmation that all applicable reclamation requirements have been met. This includes ensuring completion of stabilization work for the tailings consistent with the accepted reclamation plan and a determination that the licensee has complied with all standards applicable to land structures, and ground-water cleanup. As such, the information in this review plan will be used to help make the necessary conclusions concerning license termination. The four aspects of license

termination addressed in this review plan included (i) mill decommissioning, decontamination and disposal; (ii) surface soil cleanup and post cleanup verification; (iii) mill tailings surface stabilization; and (iv) ground water corrective action. Compliance with these four aspects of reclamation, taken together, forms the basis for the staff finding that the design and ground-water cleanup program meet applicable requirements, and that the design and cleanup program have been acceptably completed at the sites and that the licensee has, therefore, met the applicable requirements.

The staff will prepare the following reports to document the review: a technical evaluation report and an environmental assessment. The guidance in NUREG-1748 (NRC, 2001) will be used to prepare the environmental assessment. The provisions of 10 CFR 51.21 require preparation of an environmental assessment unless: (i) the staff finds, based on the environmental assessment, that NRC needs to prepare an environmental impact statement; (ii) another federal agency also involved in the action as a cooperating agency needs to prepare an environmental impact statement; (iii) the effects on the quality of the human environment are likely to be highly controversial; or (iv) 10 CFR 51.22 categorically excludes the necessity to prepare an environmental assessment. Applications for new mills require NRC to prepare an environmental impact statement in accordance with 10 CFR 51.20(b)(18). This standard review plan is intended to guide the preparation of the technical evaluation report.

It is important to note that the acceptance criteria noted in this standard review plan are for the guidance of the Office of Nuclear Material Safety and Safeguards staff responsible for the review of license applications. Review plans are not substitutes for the Commission's regulations, and compliance with a particular standard review plan is not required. Methods and solutions different from those set out in the standard review plan may be acceptable if they provide a basis for the findings requisite to the issuance or continuance of a license by NRC. Use of this standard review plan does not obviate the need for professional judgement; it helps assure overall completeness and uniformity of the staff review.

GENERAL REVIEW PROCEDURE

A licensing review is not intended to be a detailed evaluation of all aspects of facility operations. Specific information about implementation of a program or construction of a design outlined in an application is obtained through the NRC review of procedures and operations done as part of the inspection function. However, some procedures may be required during review of a reclamation or decommissioning plan. The differences between licensing reviews and inspections are shown in Figure 1. For a new license application, the staff will review the proposed reclamation plan and ground water protection program for compliance with the criteria in Appendix A to 10 CFR Part 40. For a license renewal or an amendment to an existing license, the staff will only review proposed changes to the NRC-approved reclamation plan for compliance with criteria in Appendix A to 10 CFR Part 40. If the changes proposed

have an adverse impact on the performance or functionality of some of the approved features at the site, then the staff will review those items for their compliance with regulations.

In the case of an amendment application concerning confirmation of site or ground-water cleanup or completion of construction, the reviewer will focus on ensuring that the applicable activities have been completed consistent with the approved review plan. Reviewers will not revisit accepted designs or plans unless the as-completed activity presents problems, such as degradation or reformation.

Changes to existing licensed activities and conditions require the issuance of an appropriate license amendment. An application for such an amendment should describe the proposed changes in detail and should discuss the potential environmental and health and safety impacts. Amendment requests should be reviewed using the appropriate sections of this document for guidance. NUREG-1757, Volume I (NRC, 2002), contains guidance for examining the historical aspects of facility operations in connection with amendment reviews. The steps of the reclamation plan review are described in the paragraphs that follow.

Acceptance Review

The staff will conduct an acceptance review of a new reclamation plan or changes to a previously approved plan to determine the completeness of the information submitted. The reclamation plan will be considered acceptable for docketing if the information in it is sufficiently complete to initiate a detailed technical review, and reflects an adequate reconnaissance and physical examination of the regional and site conditions, and contains appropriate analyses and design information to demonstrate that the applicable regulatory criteria will be met. Completeness of the environmental report will be determined using the information requirements in 10 CFR 51.45 and the guidance in NUREG-1748 (NRC, 2001). The staff should complete the acceptance review and transmit the results to the applicant within 30 days of the receipt of the application, along with a projected schedule for the remainder of the review. In this transmittal, the staff should note any additional information needed to make the reclamation plan or environmental report complete. Detailed technical questions, although not required, can be included, if they are identified during the acceptance review. If the contents of the reclamation plan or environmental report do not clearly demonstrate compliance with applicable regulatory criteria, then the staff may decline to docket the reclamation plan and will return it to the licensee for revisions.

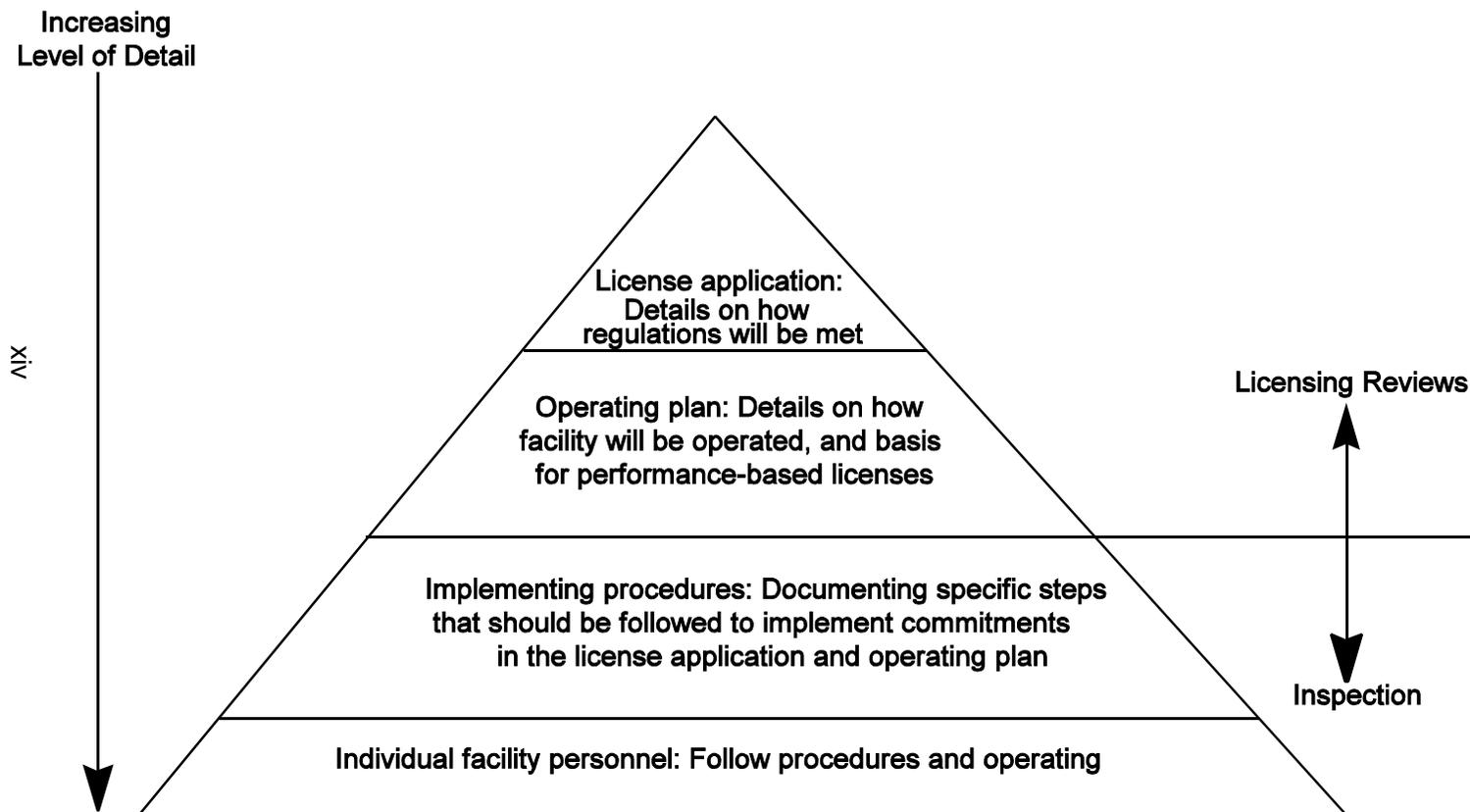


Figure 1. Schematic of NRC Licensing and Inspection Process and Applicability to Different License Documents

Detailed Review

Following completion of the acceptance review, the staff will conduct a detailed technical review of the reclamation plan. During the detailed review, if there is a need for additional information, the staff will send to the licensee a request for additional information identifying the issue or concern, basis for the concern, and the kind of information needed to resolve the concern. After the staff receives a satisfactory response to the request for additional information, the detailed review will be concluded. NRC documents the results of this review and the basis for acceptance or denial of the requested licensing action in a technical evaluation report, and in an environmental assessment (10 CFR 51.21) if there is a finding of no significant impact, or in an environmental impact statement (10 CFR 51.20) if the reclamation plan is part of an application for a new mill or if one of the other requirements for an environmental impact statement have been met (10 CFR 51.20). The detailed review should evaluate the environmental, economic, and technical evidence presented by the applicant to support the ability of the proposed facility to meet applicable regulatory requirements. In the case of amendments to an existing license as a result of changes to a previously approved reclamation plan, the need for an environmental assessment will be determined on a case-by-case basis.

In determining the acceptability of any aspect of tailings reclamation, the staff will evaluate the use of alternatives to meeting the specific requirements in 10 CFR Part 40, Appendix A. In evaluating the use of alternatives, the staff will determine if the proposed reclamation design satisfactorily demonstrates the requisite requirements of economic benefit and equivalent protection. In this standard review plan, we identify alternatives that have been found to be acceptable by the staff in previous reviews. Alternatives developed by licensees need not be limited to those discussed here. Other alternatives can be proposed, as long as the economic benefit and equivalent protection can be demonstrated.

The Standard Review Plan

The standard review plan is written to cover a variety of site conditions and reclamation designs. Each section presents the complete review procedure and acceptance criteria for all the areas of review pertinent to that section. The review plan is intended as general guidance to the NRC staff, and does not contain regulatory requirements. For any given application, the staff reviewer may select and emphasize particular aspects of each standard review plan section as appropriate for the reclamation plan. Because of this, the staff may not carry out, in detail, all of the review steps listed in each standard review plan section, in the review of every reclamation plan.

I. Areas of Review

This subsection describes the scope of the review (i.e., what is being reviewed). It

contains a brief description of the specific technical information and analyses in the reclamation plan that need to be reviewed by each technical reviewer.

II. Review Procedures

This subsection discusses the appropriate review technique. It is generally a step-by-step procedure that the reviewer uses to determine whether the acceptance criteria have been met.

III. Acceptance Criteria

This subsection delineates criteria that the reviewer can apply to determine the acceptability of the applicant's compliance demonstration. Although acceptance criteria are not regulatory requirements, the technical bases for these criteria have been derived from 10 CFR Parts 20, 40, and 51, NRC regulatory guides, general design criteria, codes and standards, NRC branch technical positions, standard testing methods (e.g., American Society for Testing and Materials standards), technical papers, and other similar sources. These sources typically contain solutions and approaches previously determined by the staff to be acceptable for making compliance determinations for the specific area of review. These acceptance criteria have been defined so that staff reviewers can use consistent and well-documented approaches for review of all reclamation plans. In the absence of well-defined acceptance criteria, the staff will rely on "professional judgment" and what is normally practiced in the profession. Licensees may take approaches to demonstrating compliance that are different from those in this standard review plan. However, they should recognize that, as is the case for regulatory guides, substantial staff time and effort have gone into the development of these procedures and criteria, and a corresponding amount of time and effort may be required to review and accept new or different solutions and approaches. Thus, licensee-proposed solutions and approaches to safety problems or safety-related design areas other than those described in this standard review plan may require longer review times and NRC requests for more extensive supporting information. The staff is willing to consider proposals for other solutions and approaches on a generic basis, apart from a specific review, to avoid the impact of the additional review time for individual cases.

IV. Evaluation Findings

This subsection presents the staff's general conclusions and findings that result from review of each area of the reclamation plan, as well as identification of the applicable regulatory requirements. Conclusions and findings for a specific site and review area are dependent on the site characteristics and type of licensing action being considered. For each standard review plan section, a conclusion is included in the technical evaluation report/safety evaluation report or in the environmental assessment/environmental impact statement, in which results of the review are published. These documents contain a description of the review; the basis for the staff

findings, including aspects of the review selected or emphasized; where the reclamation design or the licensee's plans deviate from the criteria stated in the standard review plan; and the evaluation findings.

Standard Review Plan Updates

The standard review plan will be revised and updated periodically as the need arises to clarify the content or correct errors and to incorporate modifications approved by NRC management.

REFERENCES

NRC. NUREG-1757, "Consolidated NMSS Decommissioning Guidance." Vol. I. Washington, DC: NRC. January 2002.

NRC Draft NUREG-1748, "Environmental Review Guidance for Licensing Actions Associated with NMSS Programs." Washington, DC: NRC, Office of Nuclear Material Safety and Safeguards. 2001.

1.0 GEOLOGY AND SEISMOLOGY

The reclamation plan and its supporting documents must contain sufficient regional and site-specific geologic and seismologic information related to the proposed disposal site and reclamation design, including regional and site-specific stratigraphy, structure, geomorphology, and seismology. This standard review plan establishes the requirements for staff of the U.S. Nuclear Regulatory Commission (NRC) to conduct and document the review of new reclamation plans for mill tailings impoundments, or amendments to previously approved reclamation plans in the areas of geology and seismology.

1.1 Stratigraphic Features

1.1.1 Areas of Review

The staff should review information presented in the reclamation plan on the regional and site-specific stratigraphy and geology. The reclamation plans should describe surface and subsurface strata and the interpretation of their orientation, occurrence, thickness, composition, age, depositional environment, and interrelationships. The reviewer should coordinate the stratigraphic information with the evaluation of the site's geotechnical stability, surface water and erosion protection, and ground-water resources protection information as described in standard review plan Chapters 2.0, 3.0, and 4.0, respectively. The purpose of this review is to determine if there has been an acceptable characterization of site and regional stratigraphy so that sufficient information has been presented for use in the reclamation plan and design of the tailings cell.

1.1.2 Review Procedures

The reviewer should examine the description and discussion of the regional and site-specific features to determine if a thorough evaluation of the regional and site stratigraphy has been presented.

The following specific descriptive information should be reviewed to determine its adequacy for characterizing the regional and site-specific stratigraphic features:

- (1) Description of regional stratigraphic units by rock classification and type.
- (2) Distribution of regional stratigraphic units.
- (3) Age relationships of regional and site-specific stratigraphic units.
- (4) Detailed site stratigraphy based on outcrop and well borings conducted to determine rock types and their texture, composition, distribution, thickness, and environment of deposition.

Geology and Seismology

The staff determination of compliance should be based in part on professional judgment, considering the complexity of the subsurface conditions at the site.

1.1.3 Acceptance Criteria

The characterization of regional and site stratigraphy will be acceptable if the information presented conforms to the following criteria:

- (1) The regional and site-specific stratigraphy are described in sufficient detail to produce an adequate understanding of the site-specific subsurface characteristics, including descriptions of major stratigraphic units and their orientations, age relationships, thicknesses, environments of deposition distributions, and any stratigraphic features (e.g., facies changes) likely to affect site stability or ground-water resource protection.
- (2) Stratigraphic units are described in sufficient detail to provide input to a geotechnical stability analysis.
- (3) Descriptions of regional and site-specific stratigraphic units contain sufficient information for input to an analysis of ground water resources and the protection thereof.
- (4) Regional stratigraphic information is discussed in sufficient detail to support site-specific information.
- (5) Descriptions of the regional and site stratigraphy are based on published literature and site data and conform to standard geological classifications.
- (6) Discussions of regional stratigraphy are adequately referenced and supported by published reports, maps, logs, and cross sections.
- (7) Site descriptions are based on field investigations and adequate sampling to define physical and chemical properties of surface and subsurface materials such as soils and underlying geologic formations at the site.
- (8) Maps are at a scale sufficient to show the locations of all site explorations such as borings, geophysical surveys, trenches, and sample locations.

Where insufficient information is presented to support interpretations and conclusions, the reviewer will request additional investigations or data gathering. Staff determination of compliance should be based in part on professional judgment, considering the complexity of the site conditions.

1.1.4 Evaluation Findings

If the staff review, as described in standard review plan Section 1.1, results in the acceptance of the characterization of regional and site stratigraphy, the following conclusions may be presented in the technical evaluation report.

The staff has completed its review of the characterization of the regional and site stratigraphy at the _____ uranium mill facility. This review included an evaluation using the review procedures in Section 1.1.2 and the acceptance criteria outlined in Section 1.1.3 of this standard review plan.

The licensee has provided an acceptable description of the stratigraphic features by presenting a description of the site and regional stratigraphy using published information and information collected for the specific purpose of supporting determinations of geotechnical stability and ground water analyses at the site. Data gathering, investigations, and analyses have used acceptable standards and practices. Data and interpretations of data are presented to allow effective incorporation into geotechnical and ground-water analyses.

On the basis of the information and analysis presented in the review plan on the stratigraphic features at the _____ uranium mill facility, the NRC staff concludes that the information is sufficient to support a decision with reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 4(e) have been met. These require that tailings impoundments not be located near a capable fault that could cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand , or that an acceptable alternate method of determination of seismic hazard has been used. If a probabilistic seismic hazard analysis is used as an alternate method, the applicant has presented sufficient information to support an analysis of the facility design for the operational and post-operational periods. The description of the physical and chemical properties of the underlying soils and geologic formations of the site is sufficient to meet the requirements of 10 CFR Part 40, Appendix A, Criterion 5G(2) with regard to the extent to which they will control transport of contaminants and solutions. Reasonable assurance has also been provided that the requirements of 10 CFR Part 40, Appendix A, Criterion 6(1), which requires that the design of the disposal facility provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years, have been met.

1.1.5 References

None.

1.2 Structural and Tectonic Features

1.2.1 Areas of Review

The staff should review information presented in the reclamation plan on the regional and site-specific structural and tectonic setting. The reclamation plan should contain a definition of surface and subsurface structural and tectonic features and an interpretation of their origin, occurrence, age, and potential impacts, if any, on the stability of the site. Review of the structural and tectonic information should be coordinated with the evaluation of the site's geotechnical stability, surface water and erosion protection, and ground-water resources protection information as described in standard review plan Chapters 2.0, 3.0, and 4.0, respectively. The reviewer will determine whether the information presented is sufficient to support an analysis of geologic features as they affect the facility.

1.2.2 Review Procedures

The reviewer should examine the description and discussion of the regional and site-specific information to determine if a thorough evaluation of structural and tectonic features has been presented. This may include analyses of photogrammetric data, results of field reconnaissance and detailed mapping, review of pertinent literature, and review of geophysical data and studies. Features that should be considered in the review include structural features such as faults and fractures, crustal deformation, and volcanic features that may affect the site stability or ground-water conditions.

The following specific descriptive information should be reviewed to determine its adequacy for characterizing the regional and site-specific structural features necessary to support the evaluations of reclamation system performance:

- (1) Description and location of regional structural features based on published information and field reconnaissance, including the geologic attitude of key stratigraphic units.
- (2) Description and location of site subsurface structural features from sources such as available borings, drill logs, geophysical logs and data, and existing literature.
- (3) Description of any volcanic features such as flows, cones, plugs, or dikes located in the site region.

- (4) Age relationships of regional and site-specific structural and tectonic features.
- (5) Discussion of published literature containing interpretations of any of the information in previous Items 1, 2, 3, and 4.

Staff determination of compliance should be based in part on professional judgment, considering the complexity of the subsurface conditions at the site.

1.2.3 Acceptance Criteria

The characterization of regional and site structural features will be acceptable if the information presented in the reclamation plan conforms to the following criteria:

- (1) Descriptions of regional and site-specific structural and tectonic features are based on published literature and gathered data.
- (2) Regional structural and tectonic features, particularly faults, are defined in sufficient detail to present an adequate understanding of the structural geologic conditions that may have a likelihood of affecting the site stability or ground-water regime.
- (3) Site-specific structural and tectonic features, particularly faults, are described in sufficient detail to present adequate information for an analysis of the site stability. Information presented adequately addresses the uncertainties and variability within the site area and the potential impacts on the disposal facility.
- (4) The structural and tectonic province or provinces that influence the site seismicity are identified and described.
- (5) The tectonic history of the pertinent province(s) is discussed in sufficient detail to support an analysis of the potential for disruption of the site by tectonic activity.
- (6) Discussions of structural, tectonic, and volcanic features are adequately referenced and are supported by maps, logs, and cross sections showing locations of all site explorations and surveys, and depicting surface and subsurface structural and tectonic features.
- (7) Descriptions contain discussions of age relationships of structural and tectonic features.

Where insufficient information is presented to support interpretations and conclusions, the reviewer will request additional investigations or data gathering. Staff determination of compliance should be based in part on professional judgment, considering the

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complexity of the site conditions.

1.2.4 Evaluation Findings

If the staff review, as described in standard review plan Section 1.2, results in the acceptance of the characterization of the structural and tectonic features of the region and site, the following conclusions may be presented in the technical evaluation report.

The staff has completed its review of the characterization of structural and tectonic features at the _____ uranium mill facility. This review included an evaluation using the review procedures in Section 1.2.2 and the acceptance criteria outlined in Section 1.2.3 of this standard review plan.

The licensee has acceptably described the regional and site-specific structural and tectonic features by presenting discussions and interpretations of pertinent data and reports that may have an impact on the site or tailings disposal system. Information presented includes descriptions of any faults capable of disrupting the site and any other information necessary to support an analysis of the geotechnical stability or ground-water conditions at the site. In addition, the staff concludes that the licensee has used acceptable methods of investigation and analysis to support its conclusions.

On the basis of the information and analysis presented in the review plan on the structural and tectonic features at the _____ uranium mill facility, the NRC staff concludes that the information is sufficient to support a decision with reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 4(e) have been met. These require that tailings impoundments not be located near a capable fault that could cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand, or that an acceptable alternate method of determination of seismic hazard has been used. If a probabilistic seismic hazard analysis is used as an alternate method, the applicant has presented sufficient information to support an analysis of the facility design for the operational and postoperational periods. Reasonable assurance has also been provided that the requirements of 10 CFR Part 40, Appendix A, Criterion 6(1), which requires that the design of the disposal facility provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years, have been met.

1.2.5 References

None.

1.3 Geomorphic Features

1.3.1 Areas of Review

The staff should review the information presented in the reclamation plan on the regional and site-specific geomorphic features. The reclamation plan should analyze regional and local landforms to determine evidence for geomorphic processes that may impact the long-term stability of the site, including information to support an evaluation of the potential for any destructive geomorphic processes, such as mass wasting, extreme erosion, and stream encroachment. The reviewer should coordinate the geomorphic information with the evaluation of the site's geotechnical stability and surface water and erosion protection information as described in standard review plan Chapters 2.0 and 3.0, respectively. The results of this review will be used to determine the acceptability of the design during operation and long-term stabilization.

1.3.2 Review Procedures

The reviewer should examine the description and discussion of the regional and site-specific geomorphic information to determine if a thorough evaluation has been presented. Information should be detailed enough for the reviewer to make a determination regarding the geomorphic stability of the site.

The following specific descriptive information should be reviewed to determine the acceptability of the assessment of the regional and site-specific geomorphology as it relates to geomorphic stability of the site:

- (1) Description of the physiographic (geomorphic) province(s) in which the site is located, including a discussion of the distinguishing characteristics such as elevation and relief.
- (2) Discussion of the active processes, such as erosion, mass wasting, and stream encroachment within the site region and the nature and extent of those processes.
- (3) Topographic maps depicting geomorphic surfaces, physiographic provinces, landforms, drainage networks, rivers, surficial geologic units, areas of subsidence, and geomorphic hazards.
- (4) Aerial photographs of the site area.
- (5) Discussion of the age, occurrence, and origin of geomorphic features, in particular those that may adversely affect site stability.

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1.3.3 Acceptance Criteria

The characterization of regional and site geomorphic features and geomorphic stability will be acceptable if the information presented conforms to the following criteria:

- (1) Descriptions of the regional and site-specific geomorphology and geomorphic processes include information sufficient to allow the reviewer to assess the nature and extent of major active processes that may modify the present-day topography of the geomorphic province(s) and the site area.
- (2) The geomorphic features, particularly potential geomorphic hazards, are clearly delineated on topographic base maps of adequate scale to enable the reviewer to assess their occurrence and distribution.
- (3) Descriptions are adequately referenced and are supported by published reports and maps or site data.
- (4) The regional and site-specific geomorphology and geomorphic processes are described in sufficient detail to support an analysis of the geomorphic and geotechnical stability of the site.

Where insufficient information is presented to support interpretations and conclusions, the reviewer will request additional investigations or data gathering. Staff determination of compliance should be based in part on professional judgment, considering the complexity of the site conditions.

1.3.4 Evaluation Findings

If the staff review, as described in standard review plan Section 1.3, results in the acceptance of the characterization of the geomorphic features of the region and site and provides information sufficient to support an assessment of the geomorphic stability, the following conclusions may be presented in the technical evaluation report.

The NRC has completed its review of the information concerning the characterization of geomorphic features at the _____ uranium mill facility. This review included an evaluation using the review procedures in Section 1.3.2 and the acceptance criteria outlined in Section 1.3.3. of this standard review plan.

The licensee has acceptably described the geomorphic features by presenting an adequate description of regional and site geomorphology using published information and information collected for the specific purpose of supporting determinations of the stability of site. Data gathering, investigations, and analyses have used acceptable standards and practices. Data and interpretations are presented to allow effective

incorporation into other site analyses.

On the basis of the information and analysis presented in the review plan on the geomorphic features at the _____ uranium mill facility, the NRC staff concludes that the information is sufficient to support a decision with reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 6(1), which requires that the design of the disposal facility provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years, have been met.

1.3.5 References

None.

1.4 Seismicity and Ground Motion Estimates

1.4.1 Areas of Review

The staff should review information presented in the reclamation plan on the regional and site-specific seismicity and the basis for determining the vibratory ground motion (peak horizontal acceleration) at the site from seismic events. The purpose of this review is to determine the potential for seismic events to affect the site. The reviewer will determine whether the information presented is sufficient to support an analysis of the design for the operational and closure periods.

1.4.2 Review Procedures

The reviewer should examine the description and discussion of the regional and site-specific information to determine if a thorough evaluation of the potential for seismic activity has been presented. The information should be sufficient to enable the reviewer to determine the vibratory ground motion (peak horizontal acceleration) at the site from seismic events.

The following specific descriptive information should be reviewed to determine the acceptability of the characterization of the seismicity and the assessment of the stability of the site and geotechnical design:

- (1) A listing of all recorded earthquakes in the tectonic province in which the site is located and in other tectonic provinces within 200 km [124 mi] of the site. This listing should contain the date of occurrence of the earthquake, its magnitude, and the location of the epicenter. Since earthquakes have at times been reported in terms of intensity at a given location, or effect on ground, structures, and people at a specific location, some of this information may have to be

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estimated by use of appropriate empirical relationships.

- (2) Data obtained by standard photogeologic analysis and field reconnaissance of the study area and from review of the pertinent literature. Information in the form of maps, papers, or other data, specific to the area or region, generated by state and federal agencies or published in the literature, should be utilized.
- (3) An association of epicenters or locations of highest intensity of historic earthquakes with tectonic structures, where possible. Epicenters or locations of highest intensity that cannot be reasonably identified with tectonic structures should be identified with tectonic provinces.
- (4) Maps on which the locations of epicenters of historic earthquakes, associated tectonic structures, and tectonic provinces have been depicted.
- (5) The applicant proposed maximum earthquakes associated with each tectonic province or capable fault or structure.
- (6) Deterministic and/or probabilistic seismic hazard analyses.

For a deterministic analysis, the potential ground motion at the site from capable faults that might affect the licensed area should be assessed. The term “capable fault” as used in 10 CFR Part 40, Appendix A, Criterion 4(e), has the same meaning as defined in Section III(g) of Appendix A to 10 CFR Part 100. Alternatively, the licensee may choose to use the term “capable tectonic source” as defined in Appendix A to Regulatory Guide 1.165 (NRC, 1997) to conduct its analysis.

A probabilistic seismic hazard analysis yields a curve of exceedence probability versus peak horizontal acceleration. The 10^{-4} value represents a 1 in 10 chance of the site exceeding the peak horizontal acceleration in a 1,000-year period, which is appropriate for a 1,000-year design life. The seismic hazard analysis of uranium recovery mill sites by Bernreuter, et al. (1994), contains probabilistic analyses for Title II mill sites. The study by Bernreuter, et al. (1994) is intended as a screening study; the probabilistic seismic hazard estimates are not site specific and are only calculated for random earthquakes.

- (7) Seismic design ground motion (peak horizontal acceleration).

Staff determination of compliance should be based in part on professional judgment, considering the complexity of the regional and site-specific seismicity. The reviewer will focus on evaluating the maximum credible earthquake, as required by 10 CFR Part 40, Appendix A, Criterion 4(e), unless an alternate

method of determining ground motion is presented as allowed in the Introduction to Appendix A. One such alternative to the maximum credible earthquake is a probabilistic seismic hazard analysis, which is presented in Section 1.4.3, below.

1.4.3 Acceptance Criteria

The regional and site-specific seismicity and ground motion estimates will be acceptable if the following criteria are met:

- (1) The information presented on the regional and site-specific seismicity contains sufficient detail to allow the staff to determine the vibratory ground motion (peak horizontal acceleration) at the site caused by seismic events and to further use that determination to assess the geotechnical stability of the site. The geotechnical stability of the site is sufficient to control radiological hazards for 1,000 years to the extent reasonably achievable, and, in any case, for at least 200 years.
- (2) In conducting this review, the staff will consider a deterministic and/or a probabilistic seismic hazard analysis as an acceptable method for selecting the peak horizontal acceleration for a site. An analysis of the geotechnical stability of the design proposed in the reclamation plan will be based on the resultant peak horizontal acceleration (Chapter 2.0, "Geotechnical Stability," of this standard review plan).
 - (a) Deterministic Analysis: The use of a deterministic seismic hazard analysis is acceptable if:
 - (i) Capability is determined by suitable methods, such as those outlined by Slemmons (1977).
 - (ii) Fault length versus magnitude relationships for determining the maximum magnitude earthquake that may be produced by each capable fault or capable tectonic source are developed using acceptable approaches such as those of Slemmons, et al. (1982); Bonilla, et al. (1984); or Wells and Coppersmith (1994).
 - (iii) For each maximum magnitude earthquake, the peak horizontal acceleration at the site is determined using the applicable attenuation relationship between earthquake magnitude and distance for the site. Campbell (1997); Campbell and Bozorgnia (1994); and Boore, et al. (1993, 1997) offer examples of acceptable attenuation relationships. In applying the relationship, the site-to-source distance should be the distance between the site and the

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closest approach of the fault.

- (iv) The peak horizontal acceleration value adopted for each capable fault or tectonic source is not less than the median value provided by the attenuation relationship. Possible soil amplification effects are considered.
 - (v) To assess potential ground motion at the site from earthquakes not associated with known tectonic structures (i.e., random or floating earthquakes), the largest floating earthquakes reasonably expected within the tectonic province are identified. In addition, the largest floating earthquakes characteristic of any adjacent tectonic provinces are identified, if such earthquakes cause appreciable ground motion at the site. For each of these earthquakes, the peak horizontal acceleration at the site is calculated as stated previously, with 15 km [9 mi] used as the site-to-source distance for floating earthquakes within the host tectonic province. For floating earthquakes in other tectonic provinces, the distance between the site and the closest approach of the province boundary is used as the site-to-source distance.
 - (vi) The peak horizontal acceleration for the site is the maximum value of the peak horizontal accelerations determined for earthquakes from all capable faults, tectonic sources, and tectonic provinces.
- (b) Probabilistic Analysis: The use of a probabilistic seismic hazard analysis as an alternative to the requirements of 10 CFR Part 40, Appendix A, Criterion 4(e), is acceptable, as is stated in the Introduction to Appendix A, if:
- (i) It is shown that the design proposed by the licensee will achieve a level of stabilization and containment, and a level of protection for public health and safety and the environment, which is equivalent to, to the extent practicable, or more stringent than that achieved by the requirements of 10 CFR Part 40, Appendix A.
 - (ii) The licensee takes into account local conditions when estimating the seismic design of the facility because peak horizontal acceleration values are often calculated for hypothetical rock foundations. The effects of local site conditions on the peak ground acceleration are reviewed in Chapter 2.0 in the standard review plan.

- (3) The presentation on seismotectonic stability is acceptable if sufficient information is presented to support interpretations and conclusions. If the staff should conclude that the information presented is insufficient, it will request additional information or investigations. Staff determination of compliance should be based, in part, on professional judgment, considering the complexity of site and seismic conditions.

1.4.4 Evaluation Findings

If the staff review as described in standard review plan Section 1.4 results in the acceptance of the characterization of the seismicity of the region and site and the seismic design ground motion, the following conclusions may be presented in the technical evaluation report.

The staff has completed its review of the characterization of the seismicity at the _____ uranium mill facility. This review included an evaluation using the review procedures in Section 1.4.2 and the acceptance criteria outlined in Section 1.4.3 of this standard review plan.

The licensee has presented information and investigations that support its conclusions about the seismic characterization of the site and the seismic design value. Information presented includes descriptions of historical earthquakes, locations of their epicenters, an analysis of the seismic hazard at the site, and the design peak horizontal acceleration. The staff concludes that the information presented is sufficient to support an analysis of the geotechnical stability. In addition, the staff concludes that the licensee has used acceptable methods of investigation and analysis to support its conclusions.

On the basis of the information and analysis presented in the review plan on the seismicity and ground motion estimates at the _____ uranium mill facility, the NRC staff concludes that the information is sufficient to support a decision with reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 4(e), have been met. These require that tailings impoundments not be located near a capable fault that would cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand, or that an acceptable alternate method of determination of seismic hazard has been used. If a probabilistic seismic hazard analysis is used as an alternate method, the applicant has presented sufficient information to support an analysis of the facility design for the operational and postoperational periods. Reasonable assurance has also been provided that the requirements of 10 CFR Part 40, Appendix A, Criterion 6(1), which requires that the design of the disposal facility provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years, have been met.

1.4.5 References

- Bernreuter, D., E. McDermott, and J. Wagoner. "Seismic Hazard Analysis of Title II Reclamation Plans." Livermore, California: Lawrence Livermore National Laboratory. 1994.
- 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. 2,379–2,411. 1984.
- Boore, D.M., W.B. Joyner, and T.E. Fumal. "Estimation of Response Spectra and Peak Acceleration From Western North American Earthquakes: An Interim Report." Open-File Report 93-509. U.S. Geological Survey. 1993.
- . "Equations for Estimating Horizontal Response Spectra and Peak Acceleration from Western North American Earthquakes: A Summary of Recent Work." *Seismological Research Letters*. Vol. 68. pp. 128,153. 1997.
- Campbell, K. "Empirical Near-Source Attenuation Relationships for Horizontal and Vertical Components of Peak Ground Acceleration, Peak Velocity, and Pseudo-Absolute Acceleration Response Spectra." *Seismological Research Letters*. Vol. 68. pp. 154–179. 1997.
- Campbell, K.W. and Y. Bozorgnia. "Near Source Attenuation of Peak Horizontal Acceleration From Worldwide Accelerograms Recorded From 1975 to 1993." Fifth U.S. National Conference on Earthquake Engineering, Chicago, Illinois, July 10–14. 1994.
- NRC. Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion." Washington, DC: NRC, Office of Standard Development. March 1997.
- Slemmons, D.B. "State-of-the-Art for Assessing Earthquake Hazards in the United States: Report 6, Faults and Earthquake Magnitudes." Miscellaneous Paper S-73-1. Vicksburg, Mississippi: U.S. Corps of Engineers, U.S. Army Engineer Waterways Experiment Station. 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." Publication No. UCID 19125 University of California. Livermore, California: Lawrence Livermore National Laboratory. 1982.
- Wells, D.L. and K.J. Coppersmith. "New Empirical Relationships Among Magnitude, Rupture Length, Rupture Width, Rupture Area, and Surface Displacement." *Bulletin of the Seismological Society of America*. Vol. 84. pp. 974–1,002. 1994.