Safety Evaluation Report of License Amendment Request, dated September 24, 2018, United Nuclear Corporation (UNC) submitted a request to the U.S. Nuclear Regulatory Commission (NRC) to amend its Source Materials License No. SUA–1475 for the former UNC Church Rock uranium mill and tailings site under the requirements specified in Title 10 of the Code of Federal Regulations (10 CFR), Part 40, Domestic Licensing of Source Material

Materials License No. SUA-1475

Docket No. 040-08907

United Nuclear Corporation

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

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1. INTRODUCTION

1.1 History and Site Status

The UNC Mill Site is a decommissioning uranium mill and tailings disposal site located approximately 17 miles northeast of Gallup in McKinley County, New Mexico. The Mill Site included an ore processing mill and a tailings disposal area (TDA) that covered approximately 10 and 40 hectares (25 and 100 acres), respectively. The previous reclamation plan for the TDA was approved by NRC on March 1, 1991. UNC operated the Church Rock uranium milling facility from 1977 to 1982 under a license issued by the State of New Mexico. An estimated 3.2 million metric tons [3.5 million tons] of tailings were disposed in the tailings disposal area (TDA) at the UNC Mill Site. On June 1, 1986, the NRC assumed regulatory authority for uranium and thorium milling activities and mill tailings in the State of New Mexico (51 FR 19432; May 29, 1986) and subsequently issued Source Material License SUA–1475 for the UNC Mill Site (ML101050393).

The mill, which was designed to process 4,000 tons of ore per day, extracted uranium using conventional crushing, grinding, and acid-leach solvent extraction. Uranium ore processed at the site came from the Northeast Church Rock [NECR] and the Old Church Rock mines. The average ore grade processed was approximately 0.12 percent uranium oxide. The milling of uranium ore produced an acidic slurry of ground waste rock and fluid (tailings) that was pumped to the TDA. The TDA is subdivided by dikes into three cells identified as the South Cell, Central Cell, and North Cell.

In June 1987, UNC submitted a proposed reclamation plan for the UNC Mill Site to the NRC (ML111160200) which was approved by NRC on March 15, 1991 (ML20070P728) and revised on August 30, 1991 (Canonie, 1991(ML20085N776). The reclamation plan was later modified by UNC submittals dated March 5, April 10, and June 21, 1996 (ML19063B437), which were approved by the NRC on July 18,1996 (ML20115H028)

Remaining site reclamation activities, as detailed in License Condition 35 of the NRC license SUA-1475 (NRC, 2019a | SUA–1475 June 3, 2019; ML19143A147), are specific to the area of the existing evaporation ponds located on the South Cell of the TDA and include placement of a final radon barrier and erosion protection and the completion of groundwater corrective actions in accordance with the groundwater corrective action plan (GCAP) approved by NRC and EPA (EPA, 2013. March 29, 2013; ML13095A352). The GCAP is detailed in License Condition 30 of the NRC License.

1.2 Proposed Activities

By letter dated September 24, 2018, United Nuclear Corporation (UNC) submitted a request to the U.S. Nuclear Regulatory Commission (NRC) to amend its Source Materials License No. SUA–1475 for the former UNC Church Rock uranium mill and tailings site under the requirements specified in Title 10 of the *Code of Federal Regulations* (10 CFR), Part 40, Domestic Licensing of Source Material. UNC's application included a license amendment request (LAR) and a Supplemental Environmental Report (ER), requesting that the NRC grant a license amendment to UNC that would allow disposal of NECR mine waste within the boundary of the tailings impoundment at the UNC Church Rock Mill. This action would address the need for disposal capacity to support the cleanup of the abandoned NECR uranium mine site being overseen pursuant to the U.S. Environmental Protection Agency (EPA) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also called Superfund) Program.

UNC submitted the license amendment request to fulfill an Administrative Settlement Agreement and Order on Consent (AOC) for the UNC Church Rock mine and mill sites (EPA 2015). The removal action described in the AOC includes removal of mine waste from the Mine Site and placement of this material on top of the existing uranium mill tailings disposal area (TDA) at the Mill Site. The mine waste is not 11e.(2) byproduct material because it was not processed primarily for its source material content, and is thus not directly regulated by the NRC like the mill tailings in the TDA. Mine waste is also not source material, which includes s ores that contain by weight one-twentieth of one percent (0.05%) or more of uranium, thorium, or any combination thereof. As part of the proposed activity, the licensee will segregate mine waste containing 0.05 or more weight percent uranium for disposal elsewhere (i.e., not at the NECR mill site).

On December 21, 2018, the NRC staff informed the licensee that the application had been deemed acceptable for review and the formal review process would begin. On March 7, 2019, the NRC staff sent a formal acceptance letter, (ADAMS Accession Number ML19044A592) that contained an initial schedule for the review.

As mentioned above, UNC submitted its license amendment request on September 24, 2018. During the course of the review, the NRC staff issued requests for additional information (RAI) on May 7, July 31, and August 6, 2019 (ADAMS Accession Numbers ML19114A028, ML19198A085 and ML19170A375, respectively). UNC's RAI response dates, clarification response dates, and ADAMS accession numbers are summarized in Table 1 below. Hereafter in this safety evaluation report (SER), the September 24, 2018 license amendment request, RAI responses, and clarification submittals are collectively referred to as license amendment request or LAR (UNC, 2020). License condition 34 contains the licensee's current commitments, representations, and statements made in the existing reclamation plan. As discussed in SER Section 4.3.4, this condition will be modified to include the revisions to the reclamation plan presented in this LAR, as approved. For convenience, the submittals that make up the LAR are summarized in Table 1 below. Note that where a calculation or narrative section of the LAR was revised or updated, the NRC staff considers the most recent version to be operative, pursuant to the revised condition 34 in license SUA-1475. The revised license condition 34 is provided in Table 3 below and justified in SER Section 4.3.4.

Table 1: Documents that make up the LAR

Date	Title	ADAMS Package Number
September 24, 2018	Application for Amendment of License SUA-1475 for UNC Mill Site Near Church Rock, New Mexico, Volumes I and II.	ML18267A235
May 16, 2019	Supplemental Ecological Survey for Updated Closure Design at the Northeast Church Rock Mine Site and Remedial Action at the UNC Mill Site	ML20132A276

June 6, 2019	Responses to Request for Additional Information on the Application for Amendment of USNRC Source Material License SUA-1475 for the United Nuclear Corporation Mill Site, McKinley County, New Mexico	ML19157A165
June 28, 2019	Appendixes A, B, and C from Attachment G.7 in Appendix G. License Number: SUA-1475, Docket Number 040-8907	ML19182A017
November 18, 2019	Supplemental Submittal for Application for Amendment of USNRC Source Material License SUA-1475 for the United Nuclear Corporation Mill Site, McKinley County, New Mexico	ML19322D036
September 5, 2019	Response to August 6, 2019 Environmental Request for Additional Information (RAI), United Nuclear Corporation (UNC) License Amendment Request to Move Mine Waste from the Northeast Church Rock Mine to the Church Rock Mill Site,	ML19248D035
October 7, 2019	Response to August 6, 2019 Environmental Request for Additional Information (RAI) No. AQ-9, United Nuclear Corporation (UNC) License Amendment Request to Move Mine Waste from the Northeast Church Rock Mine to the Church Rock Mill Site, McKinley County	ML19280A935
October 14, 2019	Responses to Request for Additional Information (Group 2) on the Application for Amendment of USNRC Source Material License SUA-1475 for the United Nuclear Corporation Mill Site, McKinley County, New Mexico	ML19287A007
November 11, 2019	Responses to Request for Additional Information (Group	ML19315A006

	2) on the Application for Amendment of USNRC Source Material License SUA-1475 for the United Nuclear Corporation Mill Site, McKinley County, New Mexico (2nd submittal)	
November 1, 2019	Stantec Consulting Services, Inc., Responses to Request for Additional Information (Group 1) on the Application for Amendment of USNRC Source Material License SUA-1475 for the United Nuclear Corporation Mill Site, McKinley County, New Mexico	ML19305D526
December 4, 2019	Stantec Consulting Services Inc - Responses to Request for Additional Information (Group 1) on the Application for Amendment of USNRC Source Material License SUA-1475 for the United Nuclear Corporation Mill Site, McKinley County, NM (Revised Section)	ML19338D979
February 2, 2020	Updated List of Threatened and Endangered Species for Church Rock Uranium Mill Site Proposed License Amendment	ML20156A413
March 30, 2020	Email from Melanie Davis- regarding Church Rock Mill site - Docket 040-8907 - with 5 revised documents to YCheng Attached. 1. NECR Reply to Cheng 2. Appendix D Haul Roads 3. Attachment D.1 Hail Road SW 4. Attachment I NECR Hydrolo Calc. 5 NECR revise	ML20091H049
June 4, 2020	Response from UNC Church Rock regarding data from Shapefiles	ML20160A140
July 8, 2020	Clarification on November 18, 2019 Supplemental Submittal to the Application for Amendment of USNRC	ML20190A167

	Source Material License SUA-1475	

The NRC's guidance for disposal of non-11e.(2) byproduct material in uranium mill tailings disposal areas is contained in the NRC's Regulatory Information Summary (RIS) 2000-23, which is also included in Appendix I to NUREG-1620 (NRC 2003).

1.3 Scope of Review

Scope of Review and Applicability of 10 CFR Part 40 Appendix A criteria

The Atomic Energy Act of 1954, as amended by the Uranium Mill Tailings Radiation Control Act of 1978, authorizes the NRC to issue licenses for the possession and use of source material and byproduct material. The NRC must license facilities in accordance with NRC regulatory requirements to protect public health and safety from radiological hazards. In accordance with 10 CFR 40.44, "Amendment of licenses at request of licensee," the license amendment request shall specify the respects in which the licensee desires the license to be amended and the grounds for such amendment.

This SER documents the safety portion of the NRC staff's review of the license amendment request, and includes an analysis to determine UNC's compliance with the applicable 10 CFR Part 40 requirements, and applicable requirements set forth in 10 CFR Part 40, Appendix A, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content." This SER also evaluates UNC's compliance with applicable requirements in 10 CFR Part 20, "Standards for Protection Against Radiation." An Environmental Impact Statement (EIS) is being prepared in parallel with this SER to address environmental impacts of the proposed action in accordance with 10 CFR Part 51, which contains NRC's implementation regulations for the National Environmental Policy Act (NEPA) of 1969, as amended.

The NRC staff's safety review of the license amendment request was performed using NUREG-1620, "Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings under Title II of the Uranium Mill Tailings Radiation Control Act of 1978, Revision 1 (NRC, 2003) (referred to as either the standard review plan or SRP).

UNC is currently performing reclamation activities in accordance with condition 34 of license SUA-1475. Condition 34 requires that reclamation activities be performed in accordance with the reclamation plan submitted by UNC on August 30, 1991 as modified by UNC submittals dated March 5, April 10, and June 21, 1996. The NRC staff reviewed and approved the reclamation plan and modifications thereto in amendments 10 (NRC, 1991), 17 (NRC, 1993), 24 (NRC, 1996a), and 25 (NRC, 1996b) to license SUA-1475.

In the current submittal, UNC intends to modify the existing reclamation plan referenced in condition 34 of license SUA-1475 to allow for placement of mine waste on top of the existing tailings impoundment. In addition to relocation of mine waste, the LAR also addresses several issues related to erosion protection design that were identified during an NRC site visit in 2002 and documented in a letter dated January 7, 2003 (NRC, 2003 - ML030080471). The erosion protection issues that UNC is addressing in the LAR include sedimentation in the branch swales and the north upstream diversion channel; damage to the jetty located in the

Pipeline Arroyo; and differential settlement in the eastern part of the central cell of the existing tailings impoundment.

In SECY 95-155, the NRC staff sought guidance from the Commission on the proper approach for the review of previously approved reclamation plans. As described in the SECY paper, the NRC staff recognized that reviews of erosion protection aspects of reclamation plans were not being performed uniformly and resulted in inconsistent designs. The NRC staff recognized that the development of guidance on erosion protection and radon barrier design was not completed until the early 1990's and that as a result, some reclamation plans may not have had as rigorous a review as those that were reviewed after the guidance was complete. In its SRM, the Commission directed the NRC staff to accept most previous reviews unless degradation of the site occurred, or other significant health and safety concerns were identified. While the UNC Church Rock reclamation plan was not identified in the SECY, the NRC staff is following the Commission's approach in the SRM when conducting the review of the LAR, consistent with the licensee's proposed amendments to the reclamation plan. The NRC staff is focusing its review on the parts of the reclamation plan that would be changed, including an evaluation of the slope stability, settlement, and erosion resistance of the revised design presented in the LAR.

It should be noted that UNC operated the Church Rock uranium milling facility from 1977 to 1982 under a license issued by the New Mexico Environmental Improvement Division. On July 16, 1979, the Church Rock tailings dam failed, which resulted in the release of approximately 94 million gallons of tailings liquid into the Pipeline Arroyo (NRC, 1981). The embankment was repaired, and the mill tailings impoundment continued to be used. The NRC staff assumed responsibility for regulatory oversight of Church Rock starting on June 1, 1986. Initiation of operations at Church Rock occurred before the UMTRCA legislation was passed and the NRC's implementing regulations were promulgated. Additionally, the Church Rock facility is in decommissioning and no longer operates as a uranium milling facility. Finally, as noted above, the mine waste material is not NRC-regulated material and is thus not directly regulated by the NRC. EPA listed the Site on the NPL in September 1983 and conducted a Site Remedial Investigation (RI) and Feasibility Study (FS) from 1984 through 1988. The guidance in Appendix I of NUREG 1620 further notes that a reclamation plan revised to accommodate placement of non 11e.(2) byproduct material must still meet the applicable regulations in 10 CFR Part 40, Appendix A. Table 2 below summarizes the Appendix A criteria, identifies if particular criteria are addressed in the SER, and provides an explanation as to why certain Criteria are not applicable to this LAR SER. The NRC staff's evaluation of the LAR against the guidance in Appendix I of NUREG 1620 can be found in Section 7 of this SER.

Table 2: Summary of Appendix A Criteria

10 CFR Part 40 Appendix A Criterion	SRP Section	Section in this SER where regulatory finding is reached, as appropriate	Explanation
Criterion 1: Optimize site selection to achieve permanent isolation of tailings without maintenance.	2.1.4, 3.1.4, 3.2.4, 3.3.4, 3.4.4, 3.5.4	Not applicable to this review	Siting and construction of tailings impoundment is not at issue in this review, which concerns an amendment to allow mine waste to be disposed of on top of the currently sited and approved mill tailings disposal site.
Criterion 2: Avoid proliferation of small waste disposal sites.	Not applicable to this review	Not applicable to this review	The licensee is not an ISR facility or a small remote above ground extraction operation
Criterion 3: Dispose of tailings below grade or provide equivalent isolation.	2.1.4	Not applicable to this review	The current tailings impoundment meets this criterion; mine waste material is not subject to this requirement.
Criterion 4: Adhere to siting and design criteria.			
(a) Upstream catchment areas must be minimized	3.2.4	Not applicable to this review	Siting and construction of the currently sited and approved tailings impoundment is not at issue in this LAR review.
(b) Topographic features should provide good wind protection	3.5.4	4.5.4	
(c) Embankment and cover slopes must be relatively flat after final stabilization	2.2.4, 2.4.4, 2.5.4, 2.6.4, 3.4.4, 3.5.4	3.2.4, 3.4.4, 3.5.4, 3.6.4, 4.4.4, 4.5.4	
(d) A full, self-sustaining vegetative cover must be established, or a rock cover employed	2.2.4, 2.6.4, 3.4.4	3.2.4, 3.6.4, 3.7.4, 4.4.4	
(e) The impoundment must not be located near a capable fault	1.1.4, 1.2.4, 1.4.4, 2.1.4, 2.2.4	2.4, 3.1.4, 3.2.4	
(f) The impoundment, where feasible, should be designed to	3.4.4	4.4.4	

incorporate features which will promote deposition			
Criterion 5A: Meet the primary groundwater protection standard.			
(1) Design, construct, and install an impoundment liner that prevents migration of wastes to subsurface soil, groundwater, or surface water.	Not applicable to this review	Not applicable to this review	Siting and construction of the currently sited and approved tailings impoundment is not at issue in this LAR review.
(2) Construct liner of suitable materials, place it on an adequate base, and install it to cover surrounding earth likely to be in contact with wastes or leachate	Not applicable to this review	Not applicable to this review	Siting and construction of the currently sited and approved tailings impoundment is not at issue in this LAR review.
(3) Apply alternate design or operating practices that will prevent migration of hazardous constituents into groundwater or surface water.	Not applicable to this review	Not applicable to this review	The facility is in a decommissioning, not operating status
(4) Design, construct, maintain, and operate impoundments to prevent overtopping.	4.4.4	Not applicable to this review	Siting and construction of the currently sited and approved tailings impoundment is not at issue in this LAR review. No changes are proposed to operation of evaporation ponds in this LAR.
(5) Design, construct, and maintain dikes to prevent massive failure.	2.2.4, 4.4.4	3.2.4	Section 4.4.4 of SRP is not applicable to this review as the LAR does not contain any new impoundments supporting the groundwater corrective action plan.
Criterion 5B: Conform to the secondary groundwater protection standards.			
(1) Prevent hazardous constituents from exceeding specified concentration limits in the uppermost aquifer beyond the point of compliance.	4.1.4, 4.2.4, 4.3.4, 4.4.4	Not applicable to this review	While outside scope of the LAR, a groundwater corrective action plan (CAP) is underway

(2) Define hazardous constituents as those expected to be in or derived from the byproduct material, those detected in the uppermost aquifer, and those listed in Criterion 13.	4.1.4, 4.2.4, 4.3.4, 4.4.4	Not applicable to this review	While outside scope of the LAR, a groundwater corrective action plan (CAP) is underway
(3) Exclude hazardous constituents if they are not capable of posing a substantial present or potential hazard to human health or the environment.	4.1.4, 4.2.4, 4.3.4, 4.4.4	Not applicable to this review	While outside scope of the LAR, a groundwater corrective action plan (CAP) is underway
(4) Consider identification of underground sources of drinking water and exempted aquifers.	4.1.4, 4.2.4, 4.3.4, 4.4.4	Not applicable to this review	While outside scope of the LAR, a groundwater corrective action plan (CAP) is underway
(5) Ensure hazardous constituents at the point of compliance do not exceed the background concentration, the value in Paragraph 5C, or an approved alternate concentration limit.	4.1.4, 4.2.4, 4.3.4, 4.4.4	Not applicable to this review	While outside scope of the LAR, a groundwater corrective action plan (CAP) is underway
(6) Establish alternate concentration limits, if necessary, after considering practical corrective actions, as low as is reasonably achievable requirements, and potential hazard to human health or the environment.	4.1.4, 4.2.4, 4.3.4, 4.4.4	Not applicable to this review	While outside scope of LAR, a groundwater corrective action plan (CAP) is underway
Criterion 5C: Comply with maximum values for groundwater protection.	4.1.4, 4.2.4, 4.3.4, 4.4.4	Not applicable to this review	While outside scope of the LAR, a groundwater corrective action plan (CAP) is underway
Criterion 5D: Implement a groundwater corrective action program if groundwater protection standards are exceeded.	4.4.4	Not applicable to this review	While outside scope of the LAR, a groundwater corrective action plan (CAP) is underway
Criterion 5E: Consider appropriate measures when developing and conducting a groundwater protection program.			
(1) Incorporate leak detection systems for synthetic liners and conduct appropriate testing for clay/soil liners.	4.1.4, 4.4.4	Not applicable to this review	Siting and construction of the currently sited and approved tailings impoundment is not at issue in this LAR review.
(2) Use process designs that maximize solution recycling and water conservation.	4.1.4, 4.4.4	Not applicable to this review	Facility is in decommissioning status

(3) Dewater tailings by process devices or properly designed and installed drainage systems.	4.1.4, 4.4.4	Not applicable to this review	The facility is in decommissioning status. Siting and construction of the currently sited and approved tailings impoundment is not at issue in this LAR review.
(4) Neutralize hazardous constituents to promote immobilization.	4.1.4, 4.4.4	Not applicable to this review	While outside scope of the LAR, a groundwater corrective action plan (CAP) is underway
Criterion 5F: Alleviate seepage impacts where they are occurring and restore groundwater quality.	4.1.4, 4.3.4, 4.4.4	Not applicable to this review	While outside scope of the LAR, a groundwater corrective action plan (CAP) is underway
Criterion 5G: Provide appropriate information for a disposal system.			
(1) Define the chemical and radioactive characteristics of waste solutions.	4.1.4, 4.3.4, 4.4.4	Not applicable to this review	Mine waste material is not subject to this requirement.
(2) Describe the characteristics of the underlying soil and geologic formations.	1.1.4, 2.1.4, 4.1.4, 4.3.4, 4.4.4	2.4, 3.1.4	Sections 4.1.4, 4.3.4, 4.4.4 of SRP are outside the scope of this LAR, however a groundwater CAP is underway
(3) Define the location, extent, quality, capacity, and current uses of groundwater.	4.1.4, 4.3.4, 4.4.4	Not applicable to this review	Sections 4.1.4, 4.3.4, 4.4.4 of SRP are outside the scope of this LAR, however groundwater CAP underway
Criterion 5H: Minimize penetration of radionuclides into underlying soils when stockpiling.	4.1.4, 4.4.4	Not applicable to this review	Mine waste material is not subject to this requirement.
Criterion 6: Install an appropriate cover and close the waste disposal area.			
(1) Ensure the cover meets lifetime and radioactive material release specifications.	1.1.4, 1.2.4, 1.3.4, 1.4.4, 2.1.4, 2.2.4, 2.3.4, 2.4.4, 2.5.4, 2.6.4, 2.7.4, 3.2.4, 3.3.4, 3.5.4, 4.3.4, 5.1.4	2.4, 3.1.4, 3.2.4, 3.3.4, 3.4.4, 3.5.4, 3.6.4, 3.7.4, 4.2.4, 4.3.4, 4.4.4, 4.5.4, 6.1.4	While mine waste material is not subject to this requirement, as a cover for the mill tailings impoundment, that the mine waste impoundment and cover design are evaluated to determine if they meet the design life requirements and don't impact the ability of the tailings previously

			approved tailings impoundment to meet the 1000 year performance period.
(2) Demonstrate the effectiveness of the final radon barrier prior to placement of the erosion protection barriers or other features	5.1.2.1(b)	Not applicable to this review	While mine waste material is not subject to this requirement, the NRC staff is making a finding that the existing cover maintains its integrity. The existing radon barrier over the mill tailings impoundment would remain in place over the tailings under the LAR.
(3) Demonstrate the effectiveness of phased emplacement of radon barriers as each section is completed, if applicable	5.1.4	Not applicable to this review	While mine waste material is not subject to this requirement, the NRC staff is making a finding that the existing cover maintains its integrity. The existing radon barrier over the mill tailings impoundment would remain in place over the tailings under the LAR.
(4) Document verification of radon barrier effectiveness to the U.S. NRC and maintain records of the verification	2.7.4	6.1.4	While mine waste material is not subject to this requirement, the NRC staff is making a finding that the existing cover maintains its integrity. The existing radon barrier over the mill tailings impoundment would remain in place over the tailings under the LAR. additional radon flux measurements would be taken on top of emplaced mine waste.
(5) Ensure that radon exhalation does not significantly exceed background because of the cover material.	5.1.4	6.1.4	
(6) Clean up residual contamination from byproduct material consistent with the radium benchmark dose	5.2.4	Not applicable to this review	While outside scope of the LAR, a groundwater CAP is underway.

(7) Prevent threats to human health and the environment from non-radiological hazards	5.2.4	Not applicable to this review	Mine waste material is not subject to this requirement, although a groundwater CAP is underway
Criterion 6A: Ensure expeditious completion of the final radon barrier.			
(1) Complete the radon barrier as expeditiously as practical after ceasing operations in accordance with a written, Commission-approved reclamation plan.	2.6.4, 5.2.4	Not applicable to this review	While mine waste material is not subject to this requirement, the existing radon barrier over the mill tailings impoundment would remain in place over the tailings under the LAR.
(2) Extend milestone completion dates if justified by radon release levels, cost considerations consistent with available technology	Requirement on Commission	Not applicable to this review	While mine waste material is not subject to this requirement, the existing radon barrier over the mill tailings impoundment would remain in place over the tailings under the LAR.
(3) Authorize disposal of byproduct materials or similar materials from other sources if appropriate criteria are met.	Requirement on Commission	7.3	Documentation of disposal of mine waste is provided in SER Section 7 – per guidance in NUREG 1620
Criterion 7: Conduct preoperational and operational monitoring programs.	4.1.4	Not applicable to this review	Facility is in decommissioning status
Criterion 7A: Establish a detection monitoring program to set site-specific groundwater protection standards, a compliance monitoring system once groundwater protection standards have been established, and a corrective action monitoring program in conjunction with a corrective action program.	4.1.4, 4.2.4, 4.3.4, 4.4.4	Not applicable to this review	Outside scope of LAR, groundwater CAP underway
Criterion 8: Conduct milling operations, including ore storage, tailings placement, and yellowcake drying and packaging operations so that airborne releases are as low as is reasonably achievable. Dust emissions from	Not applicable to this review	Not applicable to this review	Facility is in decommissioning status, milling operations have ceased

tailings that are not covered by standing liquids will be minimized using methods that include wetting or chemical stabilization.			
Criterion 8A: Conduct and record daily inspections of tailings or waste retention systems, and report failures or unusual conditions to NRC.	4.4.4	Not applicable to this review	Facility is in decommissioning status, milling operations have ceased
Criterion 9: Establish appropriate financial surety arrangements for decontamination, decommissioning, and reclamation.	4.4.4, 5.2.4	Not applicable to this review	Financial assurance update addressed in separate annual reviews.
Criterion 10: Establish sufficient funds to cover the costs of long-term surveillance and control.	4.4.4	Not applicable to this review	This would be finalized prior to license termination but is not at issue in the consideration of this LAR.
Criterion 11: Ownership of tailings and their disposal sites requirements.			
11A: Comply with effective date for site and byproduct material ownership requirements.	Requirement on Commission	Not applicable to this review	This would be finalized prior to license termination but is not at issue in the consideration of this LAR.
11B: Establish license conditions or terms to ensure that licensees comply with ownership requirements prior to license termination for sites used for tailings disposal.	Requirement on Commission	Not applicable to this review	This would be finalized prior to license termination but is not at issue in the consideration of this LAR.
11C: Transfer title to byproduct material and land to the United States or the State in which the land is located.	Not applicable to this review	Not applicable to this review	This would be finalized prior to license termination but is not at issue in the consideration of this LAR.
11D: Permit use of surface and subsurface estates if the public health, safety, welfare, or environment will not be endangered.	Requirement on Commission	Not applicable to this review	This would be finalized prior to license termination but is not at issue in the consideration of this LAR.
11E: Transfer material and land to the United States or State without cost other than administrative legal costs.	Not applicable to this review	Not applicable to this review	This would be finalized prior to license termination but is not at issue in the consideration of this LAR.

11F: Follow specific requirements for land held in trust for or owned by Indian Tribes.	Requirement on Commission	Not applicable to this review	This would be finalized prior to license termination but is not at issue in the consideration of this LAR.
Criterion 12: Minimize or avoid long-term active maintenance and conduct and report on annual inspections.	3.2.4, 3.3.4, 3.4.4, 3.5.4	4.2.4, 4.3.4, 4.4.4, 4.5.4	
Criterion 13: Establish standards for constituents reasonably expected to be in or derived from byproduct materials and detected in groundwater.	4.1.4, 4.2.4, 4.4.4	Not applicable to this review	Groundwater CAP underway

As detailed in the SER below, the NRC staff's review of UNC's license amendment request identified a number of facility specific issues that require additional or modified license conditions to ensure that the changes proposed in the reclamation plan will be adequately protective of public health and safety and would meet applicable NRC requirements. Table 3 includes proposed license condition language as well as the section of the SER where the regulatory need for the license condition is identified.

Table 3: Conditions Added or Modified in License SUA-1475

License Condition Number	SER Section	License Condition
30	5.4	See SER Section 5.4.
34	4.3.4	*The licensee shall implement the revisions to the reclamation plan submitted by the licensee on September 24, 2018 and as modified by the submittals on May 16, 2019; June 6, 2019; June 28, 2019; November 18, 2019; September 5, 2019; October 7, 2019; October 14, 2019; November 11, 2019; November 1, 2019; December 4, 2019; February 2, 2020; March 30, 2020; June 4, 2020; and July 8, 2020.*
34A	3.6.3	*The licensee shall conform to the final grading plan shown on engineering drawing sheet 7-07 of the LAR. Deviations from this plan that result in steeper slopes, longer slope lengths, or a higher final elevation shall be requested by license amendment and reviewed by the NRC staff.*
34B	4.3.4	*The impact of future restoration for the Branch Swale H outlet on the local drainage system in the areas adjacent to the two evaporation ponds must be verified when the ponds are removed. The removal of the ponds provides extension space for the Branch Swale H to create its downstream outlet. The licensee shall provide the design of the Branch Swale H extension to the NRC staff for written verification that it is capable of conveying the flow from its contributing drainage area of the mine waste repository within the design approved in the 1991 reclamation plan.*

34C	4.3.4	*The licensee shall monitor the combined mine waste repository/mill waste impoundment for a minimum of 5 years after relocation of the mine waste and construction of the riprap chute is complete. The purpose of this observation period is to verify the performance of the site features, with a focus on the riprap chute constructed to convey flow through the Pipeline Arroyo.* *During the observation period, the licensee shall:* *1. Document any observed movement of riprap in the riprap chute.* *2. Verify that the 20 percent side slope on the eastern portion of the mine waste repository is functioning as intended.* *3. Observe the perimeter drainage channels for evidence of sedimentation.* *4. Observe the slopes of the mine waste repository for signs of depressions or grade reversals.* *5. Submit an annual report documenting items 1-4 above. This can be submitted* with *one of the semiannual reports required by 10 CFR 40.65* *Prior to license termination, the licensee shall:* *1. Repair any observed damage.* *2. Determine if any design changes are necessary to provide control of radiological hazards for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.* *3. Use the information gained during the observation period to identify any long-term maintenance needs and funding requirements. Any funding requirements will be integrated into the long-term care fee required by Criterion 12.*

1.4 References

EPA, 2013. Record of Decision, United Nuclear Corporation Site, McKinley County, New Mexico, EPA ID: NMD030443303 – Operable Unit OU02- Surface Operable Unit. March 29, 2013. ADAMS Accession No. ML13095A352

NRC, 1981. NUREG/CR-2449, PNL-4122 – Survey of Radionuclide Distributions Resulting from the Church Rock, New Mexico, Uranium Mill Tailings Pond Dam Failure. Published December 1981.

NRC, 1991. Amendment 10 to License SUA-1475, dated March 15, 1991. ADAMS Accession No. ML20070P734

NRC, 1993. Amendment 17 to License SUA-1475, dated June 4, 1993. ADAMS Accession No. ML20045B112

NRC, 1996a. Amendment 24 to License SUA-1475, dated May 3, 1996. ADAMS Accession No. ML20108C890

NRC, 1996b. Amendment 25 to License SUA-1475, dated July 18, 1996. ADAMS Accession No. ML20115H022.

UNC, 2020. License Amendment Request dated September 24, 2018, as updated. ADAMS Accession No. ML18267A235, ML20132A276, ML19157A165, ML19182A017, ML19322D036, ML19248D035, ML19280A935, ML19287A007, ML19315A006, ML19305D526, ML19338D979, ML20156A413, ML20091H049, ML20160A140, ML20190A167

2. GEOLOGY AND SEISMOLOGY

In this chapter of the SER, the NRC staff documents its evaluation of portions of the LAR (UNC 2018) that address topics covered in Chapter 1, “Geology and Seismology,” of the SRP (NRC 2003). These topics include: (1) Stratigraphic Features, (2) Structural and Tectonic Features, (3) Geomorphic Features, and (4) Seismicity and Ground Motion Estimates.

2.1 Regulatory Requirements

As discussed in detail below, the NRC staff evaluates whether the licensee has demonstrated that the LAR meets the requirements of 10 CFR Part 40, Appendix A, Criterion 5G(2). These state that the licensee shall supply information concerning the characteristics of the underlying soil and geologic formations. This includes detailed information concerning extent, thickness, uniformity, shape, and orientation of underlying strata.

The NRC staff also evaluates whether the licensee has demonstrated that the LAR meets the requirements of 10 CFR Part 40, Appendix A, Criterion 4(e). 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.

An additional regulatory requirement relates to 10 CFR Part 40, Appendix A, Criterion 6(1). This criterion requires that the design provide reasonable assurance to control radiological hazards be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.

2.2 Regulatory Acceptance Criteria

Chapter 1 of the SRP (NRC, 2003) provides guidance to the NRC staff on the review of the geology and seismology near the site of the planned repository. Section 1.1.3 provides the acceptance criteria for topics related to stratigraphic features. For example, the repository plans should describe surface and subsurface strata and the interpretation of their orientation, occurrence, thickness, composition, age, depositional environment, and interrelationships. Providing information and/or data to fulfill the criteria allows staff 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 design, construction, and usage of the repository. Specific information needed includes a sufficiently detailed regional and site-specific stratigraphy description, and associated information and data, to be able to produce an adequate understanding of the site-specific subsurface characteristics likely to affect site stability or ground-water resource protection, to provide input to a geotechnical stability analysis, to provide input for an analysis of ground water resources, and to support site-specific information. In addition, maps should be at a scale sufficient to show the locations of all site explorations such as borings, geophysical surveys, trenches, and sample locations. Since the mill tailings impoundment at Church Rock has been previously approved, information relevant to the acceptance criteria is already available to the NRC staff. Therefore, NRC staff will be principally evaluating differences between the previously approved mill tailings impoundment and the addition of the planned mine waste repository to determine if additional or updated information is needed due to technical or time-based differences between the past and current plans.

Section 1.2.3 of the SRP provides the acceptance criteria for topics related to the regional and site-specific structural and tectonic setting. For example, the repository plans 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. Providing information and/or data to fulfill the criteria allows staff to determine if there is sufficient information to support an analysis of structural and tectonic features as they affect the facility. Specific information needed includes a sufficiently detailed description of regional structural and tectonic features, particularly faults, and collection of data, to present an adequate understanding of the structural geologic conditions, to analyze site stability, to adequately address the uncertainties and variability within the site area and the potential impacts on the disposal facility, to identify structural and tectonic provinces that influence the site seismicity, and to support an analysis of the potential for disruption of the site by tectonic activity. Since the mill tailings impoundment at Church Rock has been previously approved, information relevant to the acceptance criteria is already available to the NRC staff. Therefore, NRC staff will be principally evaluating differences between the previously approved mill tailings impoundment and the planned addition of the mine waste repository to determine if additional or updated information is needed due to technical or time-based differences between the projects.

Section 1.3.3 of the SRP provides the acceptance criteria for topics related to geomorphic features. For example, the repository plans 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. Providing information and/or data to fulfill the criteria allows staff to determine if there is sufficient information to support an analysis of geomorphic features as they affect the facility. Specific information needed includes a sufficiently detailed description of the regional and site specific geomorphology as it relates to geomorphic stability of the site, and collection of data, to be able to identify distinguishing characteristics such as elevation and relief, to identify active processes, such as erosion, mass wasting, and stream encroachment, to discuss the age, occurrence, and origin of geomorphic features. In addition, 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. Since the mill tailings impoundment at Church Rock has been previously approved, information relevant to the acceptance criteria is already available to the NRC staff. Therefore, NRC staff will be principally evaluating differences between the previously approved mill tailings impoundment and the planned addition of the mine waste repository to determine if additional or updated information is needed due to technical or time-based differences between the projects.

Section 1.4.3 of the SRP provides the acceptance criteria for topics related to seismicity and ground motion estimates. For example, the repository plans should present information 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. Providing information and/or data to fulfill the criteria allows staff to determine the potential for seismic events to affect the site. Specific information needed includes a sufficiently detailed regional and site-specific seismicity description as it relates to seismic stability of the site, and collection of data, 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. In addition, the use of a deterministic seismic hazard analysis is acceptable if the criteria in Section 1.4.3(2)(a) of the SRP are fulfilled. 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 if the criteria in Section 1.4.3(2)(a) of the SRP are fulfilled. Since the mill tailings impoundment at Church Rock has been previously approved, information relevant to the acceptance criteria is already available to the NRC staff. Therefore, staff will be principally evaluating differences between the previously approved mill tailings impoundment and the addition of the planned mine waste repository to determine if additional or updated information is needed due to the technical or time-based differences between projections.

2.3 Staff Review and Analysis

The SRP establishes guidance for NRC staff to conduct and document the review of amendments to previously approved reclamation plans in the areas of geology and seismology. The LAR and its supporting documents were evaluated to determine if sufficient regional and site-specific geologic and seismologic information related to the proposed repository site, including regional and site-specific stratigraphy, structure, geomorphology, and seismology have been provided.

2.3.1 Stratigraphic Features

The NRC staff finds that adequate information related to stratigraphic features at the disposal site was provided. The licensee presented information related to stratigraphic features in the LAR (UNC, 2018), for example in Section 2.5 of the LAR. Older documents discussing stratigraphic features are relevant and were reviewed by NRC staff include: “Reclamation Engineering Services: Geohydrologic Report Church Rock Site Gallup, New Mexico” by Canonie Environmental Services Corp. (Canonie) from 1987; and “Tailings Reclamation Plan as Approved by NRC March 1, 1991 License No. SUS-1475” by Canonie (1991). The “Pre-Design Studies (PDS)” were documented in MWH, Inc. (MHW, 2014) and provided information on the stratigraphy of the impoundment on top of which the repository will be built.

The Church Rock site is located in the San Juan Basin region of the Colorado Plateau and the stratigraphy of the San Juan Basin region is characterized by sedimentary rocks such as sandstones, shale, siltstone/mudstone, and coal and include in descending order the Dilco Coal Member, the Upper Gallup Sandstone, and the Mancos Shale. The Upper Gallup Sandstone is most closely associated with the groundwater and divided into Zone 3, an upper sandstone; Zone 2, a shale and coal parting member; and Zone 1, a lower sandstone unit. Pleistocene erosion created varying topography on top of the Upper Gallup Sandstone so that the thickness of the alluvium deposited on to also varies up to 46 m (150 ft) thick and underlies most of the tailings at the Church Rock site.

The Canonie geohydrologic report (1987) contained the results of an investigation conducted to characterize the groundwater regime at UNC's Church Rock mill and tailings site in New Mexico. Detailed information was provided on the regional and local geology, hydrogeology, and hydrogeochemistry. The Canonie reclamation plan (1991) described the approved composite reclamation plan and described the existing site conditions. This included a detailed section on the geological, hydrological, and hydrogeochemical settings. Stratigraphic units such as the alluvium above the Zone 3 and Zone 1 units of the Gallup Sandstone were described in detail (see Figure 1 for a cross sectional view of these units). The documents describe surface and subsurface strata and the interpretation of their orientation, occurrence, thickness, composition, age, depositional environment, and interrelationships in sufficient detail.

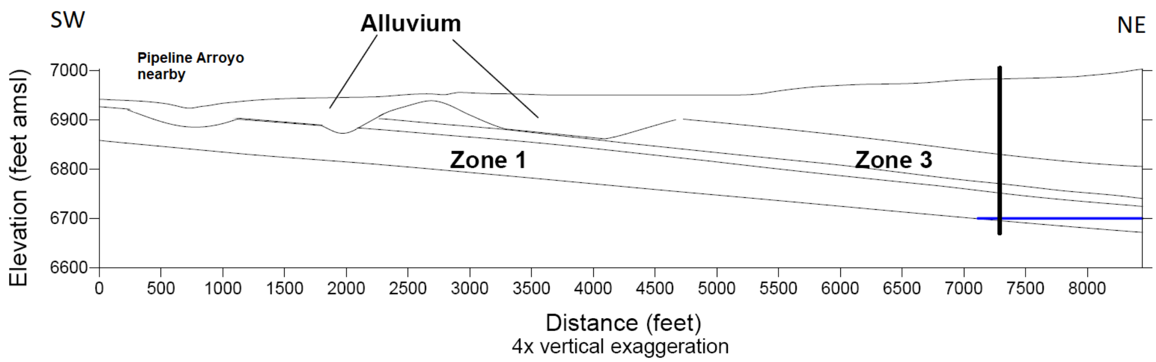

Figure 1: Cross section along the Pipeline Arroyo showing the subsurface geology

Alluvium and the stratigraphic Zone 3 and Zone 1 units of the Upper Gallup Sandstone. [Source: Modified figure of Figure 11B from Chester Engineers (2012)]

Additional information and documentation collected from the PDS investigation within the tailings impoundment (MWH, 2014) augmented existing information. This information was used to update impoundment thickness maps and cross sections. The licensee developed a map showing the distribution and thickness of fine-grained tailings across the impoundment. Impoundment cross sections were included in the report and the orientation were adjusted to intercept locations of thick tailings and illustrate subsurface conditions within the area of the proposed repository. Although bedrock (i.e., the Gallup Sandstone) was not a focus of the PDS, information on the interface of the bedrock surface with unconsolidated material above was updated in areas where new information was obtained. For example, depressions in the bedrock surface previously interpreted to be isolated depressions are now interpreted to be paleochannels, represented by a deeply eroded bedrock surface and thick alluvial deposits. One paleochannel is in general alignment with the present-day Pipeline Arroyo, and another is a tributary to that paleochannel that trends east-west through Borrow Pits 1 and 2 in the impoundment (MWH, 2014). Based on the depth to resistant material followed by non-resistant material in several boreholes, the licensee noted that some of these paleochannels appear to have encountered either resistant boulders situated within the paleochannel or a hard clay layer within the alluvium above the actual bedrock surface.

The licensee presented regional and site-specific stratigraphy 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, and thicknesses. Published reports, maps, logs, and cross sections were of sufficient detail to perform a geotechnical stability analysis and to adequately understand groundwater resources. Adequate information on stratigraphic features has been presented to support the license amendment request. 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 5G(2) have been met, i.e., sufficient description of the physical and chemical properties of the underlying soils and geologic formations of the site was provided.

2.3.2 Structural and Tectonic Features

The NRC staff has completed its review and determination of adequate information related to structural and tectonic features at the disposal site. The licensee presented information related to structural and tectonic features in the LAR (UNC, 2018), for example in Section 2.5 of the LAR. Older documents discussing structural and tectonic features are relevant and were reviewed by NRC staff: “Reclamation Engineering Services: Geohydrologic Report Church Rock Site Gallup, New Mexico” by Canonie Environmental Services Corp. (Canonie) from 1987; and “Tailings Reclamation Plan as Approved by NRC March 1, 1991 License No. SUS-1475” by Canonie (1991).

The Church Rock site is located near the juncture of several major fold structures such as the San Juan Basin, the Zuni Uplift, and the Defiance Uplift with the mill disposal site lying on the Chaco slope of the Zuni Uplift in proximity to the southwest rim of the San Juan Basin (Canonie, 1987). In addition, three local structural features are near the site: The Pipeline Canyon Lineament, the Fort Wingate Lineament, and the Pinedale Monocline. Monoclinal folds are the most distinctive smaller-scale structures near the site and frequently form the boundaries of the larger uplifts and basins; however, large-scale faulting is uncommon. Groundwater flow in the area is affected more by small-scale joints and fractures related to the monoclines, are prevalent and affect groundwater flow.

The Canonie geohydrologic report (1987) contains the results of an investigation conducted to characterize the groundwater regime at UNC's Church Rock mill and tailings site in New Mexico. The results of the investigation were used to assist UNC in the evaluation of the reclamation needs for the Church Rock site. Detailed information was provided on the regional and local geology, hydrogeology, and hydrogeochemistry. The Canonie reclamation plan (1991) described the approved composite reclamation plan and described the existing site conditions. This included a detailed section on the geological, hydrological, and hydrogeochemical settings. The alluvium, and the Zone 3 and Zone 1 units of the Gallup Sandstone, are described in detail. Structural features within the site were identified in cross sections developed from geophysical and lithological logs of wells drilled on site. Cross sections identified several areas of flexure with associated fracturing and/or faulting in Zone 3 and Zone 1 of the Upper Gallup Sandstone. Orthogonal fracture pattern striking north-northeast and west-northwest is evident in the sandstone outcrops throughout the site.

Although Canonie (1987) describes both the Pipeline Canyon Lineament and the Fort Wingate Lineament as monoclinal hinge zones with sufficient fracturing to modify flow (e.g., direction of flow) within the site, it was not clear if the processes that formed the lineaments with its associated fault-like zones were still active. If the lineaments were some type of fault, it was not clear why they were not included in the seismic hazard analysis (SHA) in UNC (2018). NRC staff asked about these two lineaments, and about the nature of the Pinedale Monocline, in a request for additional information (RAI) from July 31, 2019 (NRC, 2019). In UNC/GE’s response (UNC, 2019b), data pertaining to the Pipeline Canyon Lineament, Fort Wingate Lineament, and the Pinedale Monocline were reevaluated and a conclusion was reached that the Pipeline Canyon and Fort Wingate Lineament features were not active faults due to the overall lack of geomorphology, a lack of offset in older bedrock, and that these features are not included on published USGS geologic and structural maps. The Pinedale Monocline was also not considered to be an active fault based on its structure. UNC/GE did not revise the SHA, but the SHA report was updated to reflect the evaluation of the lineaments and monocline. A 1994 Lawrence Livermore National Laboratory (LLNL) study, used in an NRC seismic evaluation (NRC, 1997), analyzed a random background earthquake and reported values for a range of magnitude and return periods. The updated SHA report sections now include results of the 1994 LLNL study and provides clarification for previous studies. This is acceptable to the NRC staff as the lineaments were not found to be active faults.

The licensee presented regional and site structural and tectonic features such as faults in sufficient detail for an analysis of site stability and to present an adequate understanding of the structural geologic conditions while addressing the uncertainties and variability within the site area and the potential impacts on the future repository. In addition, the regional tectonic history, and structural and tectonic features, that have the potential to affect seismicity at the site were identified and adequately described.

The reviewed documents described regional and site-specific structural and tectonic setting and the interpretation of their origin, occurrence, age, and potential impacts on the stability of the site in sufficient detail. Adequate information has been presented to support an analysis of structural and tectonic features as they affect the disposal site. This information is required for the NRC staff to determine whether 10 CFR Part 40, Appendix A, Criterion 4(e) is met with respect to the proposed amendment, which requires that an acceptable alternate method of determination of seismic hazard has been used or that tailing impoundments are not located near a capable fault. This information is also needed to determine whether Criterion 6(1) is met, i.e., the ability of the cover to provide adequate protection during the performance period. NRC staff concludes that the information is sufficient to support a decision with reasonable assurance and that the requirements listed above are met.

2.3.3 Geomorphic Features

The NRC staff has completed its review and determination of adequate information related to geomorphic features at the disposal site. The licensee presented information related to geomorphic features in the LAR (UNC, 2018), for example in Section 2.5 and Appendix I of the LAR. Previous documents discussing stratigraphic features are relevant and were reviewed by NRC staff: "Reclamation Engineering Services: Geohydrologic Report Church Rock Site Gallup, New Mexico" by Canonie Environmental Services Corp. (Canonie) from 1987; and "Tailings Reclamation Plan as Approved by NRC March 1, 1991 License No. SUS-1475" by Canonie (1991).

As described in the Canonie geohydrologic report (Canonie, 1987) and reclamation plan (Canonie, 1991), the Church Rock site is situated on alluvial valley fill and the sandstones and shales of the Upper Gallup Sandstone. The tailings disposal site is located in the alluvial valley named the Pipeline Canyon, which is drained by the Pipeline Arroyo, one of the most important geomorphic features of the Church Rock site. The Pipeline Arroyo is an ephemeral channel that traverses the site to a point southwest where it joins the Rio Puerco, a larger ephemeral drainage. Beginning in 1968, mine water discharge to the arroyo, and later seepage of tailings liquids from the tailings impoundment and Borrow Pit No.2, saturated the alluvium and the sandstone creating a temporary, artificial groundwater system. Prior to mining and milling activities, no contiguous groundwater system was known to exist in the near-surface geologic units. After 17 years, discharge of the mine water ceased, and the artificial system has been dissipating and returning to the natural unsaturated conditions since then.

The landscape of the Pipeline Arroyo watershed is comprised of upland mesas and buttes that flow steeply over rock outcrops. These mesas and hillslopes are vegetated with a mixture of grasses, shrubs, and trees. Stability of the Pipeline Arroyo is important for the long-term viability of the proposed repository and of the disposal cells. An area of concern along the Pipeline Arroyo is the "nickpoint," or rock outcrop, and the "jetty," a buried riprap slope located perpendicular to, and between, the disposal site and the Pipeline Arroyo (see Figure 2). Progressive erosion and undermining of the jetty have caused lateral southeastward migration of the arroyo toward the tailings embankment and could lead to stability issues for the disposal site. Although historical images show no significant lateral movement in the last decade, further downcutting in the pathway and undercutting of the banks could cause episodic bank failures and pathway shifting toward the mill tailings disposal site. UNC has proposed modifications to the Pipeline Arroyo to further protect this area of the site; the NRC staff's review of this is presented in Section 4 of this SER.

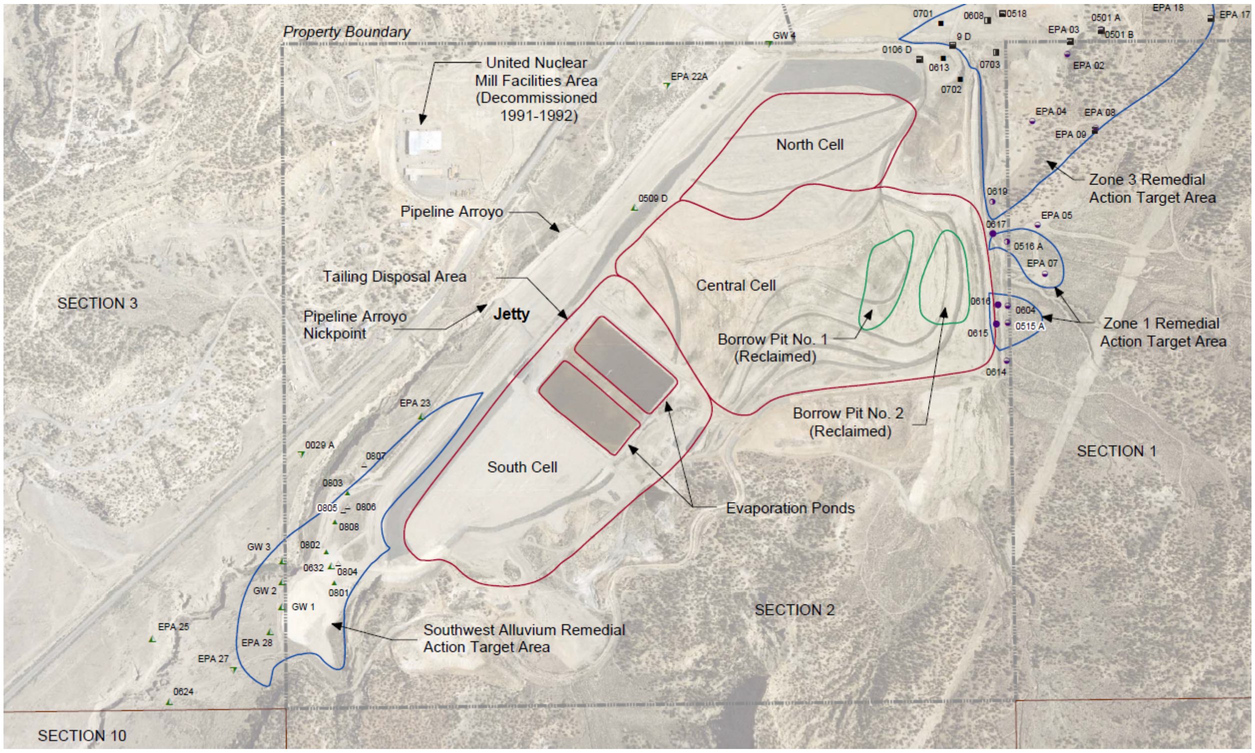

Figure 2: The Church Rock Disposal Cells, and the Nickpoint and Jetty of the Pipeline Arroyo

[Source: Modified figure of Figure 2 from Chester Engineers (2012)]

The licensee provided documentation of regional and site-specific geomorphology and geomorphic processes including sufficient information to evaluate geomorphic altering processes that may still be active. The documents described regional and local landforms in sufficient detail 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. This information includes published reports, maps or site data, and topographic base maps. Therefore, adequate information had been presented to support an analysis of geomorphic features as they affect the disposal site. Therefore, the NRC staff's review finds that the subsurface conditions at the UNC Mill Site are conducive to placement of the mine waste on top of the existing tailings impoundment by providing sufficient stability from geomorphic processes. The NRC staff observes that the licensee addresses the stability issues within the Pipeline Arroyo in the LAR as well, as discussed in more detail in Section 4 of this SER. Based on its review, the NRC staff has determined that regulatory requirement relating to 10 CFR Part 40, Appendix A, Criterion 6(1) has been satisfied. The included documentation demonstrates the ability of geomorphic aspects of the site to provide adequate protection for the performance period.

2.3.4 Seismicity and Ground Motion Estimates

The NRC staff has completed its review and determination of adequate information related to seismicity and ground motion estimates at the disposal site. The licensee presented the information related to seismicity and ground motion estimates in Section 2.5 of the LAR, Appendix G, Section G.7, Appendix G, Attachments G.1, and other attachments of the LAR (UNC, 2018). A supplemental submittal for application for amendment of the Church Rock site was transmitted to the NRC on November 18, 2019 (UNC, 2019c) including the revised Appendices A, G, and H (UNC, 2019d). Other documents discussing seismicity and ground motion estimates are relevant and were reviewed by NRC staff: “Reclamation Engineering Services: Geohydrologic Report Church Rock Site Gallup, New Mexico” by Canonie Environmental Services Corp. (Canonie) from 1987; and “Tailings Reclamation Plan as Approved by NRC March 1, 1991 License No. SUS-1475” by Canonie (1991).

The Canonie geohydrologic report (1987) contains the results of an investigation conducted to characterize the groundwater regime at UNC's Church Rock mill and tailings site in New Mexico. Detailed information was provided on the regional and local geology, hydrogeology, and hydrogeochemistry. The Canonie reclamation plan (1991) described the approved composite reclamation plan and described the existing site conditions. This included a detailed section on the geological, hydrological, and hydrogeochemical settings. Cross sections identified several areas of flexure with associated fracturing and/or faulting in Zone 3 and Zone 1 of the Upper Gallup Sandstone. The fracturing was evident in three areas along the east and north sides of the borrow pits and two areas north and east of North Cell.

In 1997, NRC staff reevaluated seismic design aspects of the previously approved reclamation plan for the UNC's Church Rock uranium mill tailings site (NRC, 1997). The staff had concluded that UNC's design was acceptable, and the seismic design evaluation issue was closed. Based on the reevaluation of available data, and with a peak ground acceleration (PGA) of 0.196 g (1 g = 9.81 m/s^2) for a 6.25 magnitude earthquake, NRC staff concluded that a magnitude of 6.25 earthquake is appropriate for the Church Rock tailings impoundment to comply with the requirement of being stable for 1,000 years to the extent reasonably achievable, and in any case for at least 200 years. Therefore, NRC (1997) found that the site met 10 CFR Part 40, Appendix A, Criterion 4(e), i.e., the impoundment remains at a sufficient distance from a capable fault that could cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand.

Section G.7, “Seismic Hazard Analysis,” or SHA, of Appendix G in the original LAR (UNC, 2018) and Section G.7 in the supplemental submittal for the LAR (UNC, 2019d) were identical and discuss a site-specific probabilistic seismic hazard analysis (PSHA) and a deterministic seismic hazard analysis (DSHA) that were conducted to develop seismic design criteria for the repository. The complete SHA report is included as Attachment G.1 of Appendix G (UNC, 2018). Attachment G.1 was not included in UNC (2019d). A seismotectonic model and source characterization of the disposal site and surrounding area provided the information in the PSHS. The SHA was performed to estimate the seismic hazard at the project site within a probabilistic and deterministic framework by characterizing potential seismic sources.

As stated above, a new SHA was conducted and included as Appendix G.1 in the LAR (UNC, 2018). Historical seismic events with a moment magnitude (M_w) greater than or equal to 2.5 ($M_w \geq 2.5$) were compiled from 1887 through 2016. The final combined catalog used in the PSHA included 413 earthquakes, where over 99 percent of the earthquakes have a relatively small magnitude of $M_w < 5.0$. The largest event recorded was a M_w 6.5. The closest seismic event to the Church Rock site was an M_w 4.7 event that occurred on January 5, 1976 approximately 26 km (16 mi) from the site. This earthquake was included in a study performed by Wong et al. (1984) that concluded that the source of the earthquake had an unusually deep focal depth and was not likely associated with a geologic structure expressed at the surface. Due to this, the earthquake was included in the development of the background seismic source.

Ground motion prediction equations (GMPEs), mathematical expressions that use magnitude, distance, and site conditions to define how seismic waves propagate from the source to the site, were applied to earthquakes to estimate design ground motion at the Church Rock disposal cells. Ground motions at the site were calculated by a PSHA for the average horizontal component of motion in terms of PGA. The shear wave velocity, V_{S30}, are estimated in the top 100 feet, or 30 meters, of the original ground surface. The tailings were not considered in estimating the shear wave velocity. For the Gallup Sandstone, published values for sandstone were used in the PSHA, a V_{S30} value of 566 m/s (1860 ft/s) was chosen, since no site-specific shear wave velocity measurements are available. A V_{S30} value of 275 m/s (900 ft/s) was used for the alluvium obtained via cone penetration testing. The PSHA also used an average of the alluvium and sandstone values in the analysis, which resulted in V_{S30} of 420 m/s (1380 ft/s). The three values were selected to represent the range of alluvium thickness within the foundation. The smallest V_{S30} value, that for alluvium, resulted in the highest mean PGA of 0.30 g for the 10,000-year return period with a mean magnitude of M_w 5.8 at a mean distance of 26 km (16 mi) and a modal magnitude calculated to be M_w 5.5 at a modal distance of 20 km (12.4 mi), so that the design seismic event is the 10,000-year return period earthquake, which has a maximum PGA of 0.30 g and a magnitude of 5.5. Results of the site-specific PSHA from the LAR were compared to the analysis documented in NRC (1997) (see Section 8 in Appendix G, Attachments G.1 of the LAR) and show that PGA values used were conservative compared to the value in NRC's seismic evaluation, i.e., all three PGA values used in the LAR are greater the PGA value of 0.196 g used in the seismic evaluation.

The licensee conducted a DSHA for the Church Rock site using the same GMPEs used in the PSHA and a V_{S30} value of 275 m/s (900 ft/s). The DSHA results for four considered faults, the unsegmented Nacimiento fault, the Interbasin faults on the Llano de Albuquerque, the unsegmented Jemez-San Ysidro fault, and the unsegmented San Felipe fault, are similar with PGA values for the 84th percentile ranging from 0.04 to 0.07 g. Mean PGA values for long-term conditions of 0.25 g to 0.30 g are associated with an average return period of 10,000 years, or a probability of exceedance of 2 percent to 10 percent for a design life of 200 to 1,000 years, respectively. Comparing the DSHA results to the PSHA results for a V_{S30} of 275 m/s (900 ft/s), the Uniform Hazard Spectra for the 10,000-year return period is well above the 84th percentile of the Nacimiento fault, which had the highest ground motions of the sources considered in the DSHA.

Although the Appendix G, Attachment G.1 of the LAR stated that the tailings were not considered in estimating the shear wave velocity because the site-wide SHA was performed to estimate peak accelerations at the original ground surface, NRC staff asked that UNC/GE provide a technical basis for not considering the tailings in estimating the shear wave velocity in an RAI from July 31, 2019 (NRC, 2019). In UNC/GE's response (UNC, 2019a), it was pointed out that calculating the V_{S30} from the top of the existing tailings, the resulting average V_{S30} would be similar to the lower bound V_{S30} (275 m/s, or 900 ft/s) developed for the SHA. The design PGA of 0.3 g used in the analyses corresponds with the lower bound V_{S30} and no change would be anticipated if the V_{S30} accounted for the existing tailings.

Therefore, the licensee presented seismicity and ground motion estimates for faults in sufficient detail for a SHA and analyses of seismic settlement and potential liquefaction of the future repository. In addition, the licensee presented an adequate understanding of the structural geologic conditions while addressing the uncertainties and variability within the site area and the potential impacts on the future repository. Specific information presented included a sufficiently detailed regional and site-specific seismicity description as it relates to seismic stability of the site and the collection of data to determine the vibratory ground motion (peak horizontal acceleration) at the site caused by seismic events. A DSHA and a PSHA were provided to select peak horizontal accelerations for a site. The DSHA used suitable methods, such as using the applicable attenuation relationship between earthquake magnitude and distance to determine peak horizontal acceleration at the site, and when determining peak horizontal acceleration, all capable faults, tectonic sources, and tectonic provinces were considered. The PSHA used suitable methods, such as considering local conditions when estimating the seismic design of the facility, and by presenting sufficient information to support interpretations and conclusions.

The documents described regional and site-specific seismicity in sufficient detail to determine a PGA at the site from seismic events. The PGA value used in the LAR is relatively conservative as it is lower than the value used in the seismic evaluation. Adequate information had been presented to determine the potential for seismic events to affect the disposal site. The NRC staff was able to verify that the information was incorporated into the analysis. Therefore, the NRC staff concludes that the information supports a decision with reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 4(e) have been met, i.e., the impoundment remains at a sufficient distance from a capable fault that could cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand. Additionally, the NRC staff recognizes that the time component of the historical ground motion record and peak ground acceleration have been incorporated into the analysis. Therefore, the NRC staff finds that these aspects of the subsurface conditions demonstrate that adequate protection will be provided for the performance period. Therefore, the NRC staff has determined that regulatory requirement relating to 10 CFR Part 40, Appendix A, Criterion 6(1) has been satisfied.

2.4 Evaluation Findings

The staff has completed its review of the characterization of the regional and site stratigraphy at the repository and disposal facility. This review included using procedures and acceptance criteria outlined in Chapter 1 of the SRP.

The licensee has previously 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. The licensee has acceptably described the regional and site-specific structural and tectonic features by having presented discussions and interpretations of pertinent data and reports that may have an impact on the site or 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. The licensee has previously provided an 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. 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 NRC staff concludes that the information presented is sufficient to support an analysis of the geotechnical stability. The NRC staff's geotechnical stability analysis can be found in Section 3 of this SER.

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.

Based on the information and analysis on geologic and seismologic features and processes at the disposal 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.

As discussed above, by incorporating a time component into the analysis, the NRC staff has reasonable assurance has also been provided that the requirements of 10 CFR Part 40, Appendix A, Criterion 6(1), which requires that the disposal facility continues to 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.

2.5 References

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3. GEOTECHNICAL STABILITY

In this chapter of the SER, the NRC staff documents its evaluation of portions of the LAR (UNC 2018) that address topics covered in Chapter 2, “Geotechnical Stability,” of the SRP (NRC 2003). These topics include: (1) site characteristics; (2) slope stability; (3) settlement; (4) liquefaction potential; (4) cover design; (5) construction considerations; and (6) hydraulic conductivity.

3.1 Site and Uranium Mill Tailings Characteristics

In this section of the SER, the NRC staff documents its evaluation of the site characteristics and uranium mill tailings properties, including the licensee’s plan to construct the mine waste repository and cover system.

3.1.1 Regulatory Requirements

The NRC staff determines if the licensee has demonstrated compliance with the following criteria in 10 CFR Part 40 Appendix A: Criterion 4(e), which relates to the seismic design; Criterion 5(G)(2), which relates to the permeability characteristics of the site; and Criterion 6(1), which identifies the 200 to 1000 year timeframe for the control of radiological hazards to be effective.

3.1.2 Regulatory Acceptance Criteria

Unless specifically stated otherwise, the LAR was reviewed for compliance with the applicable requirements of 10 CFR 40 using the acceptance criteria presented in SRP Section 2.1, “Site and Uranium Mill Tailings Characteristics” (NRC 2003).

The acceptance criteria in SRP Section 2.1.3 address: (1) site stratigraphy; (2) information on local faults and seismicity; (3) sampling scope and techniques; (4) potential for unstable soils; (5) standards used in the investigation; (6) laboratory sample preparation; (7) parameters used for engineering properties; (8) discussion of soil stratigraphy and relevant engineering parameters; and (9) ground water level fluctuations.

3.1.3 Staff Review and Analysis

Unless specifically stated otherwise, the information reviewed in this SER section is from information, data, and maps submitted by the licensee in its LAR (UNC 2018).

The NRC staff reviewed the information related to the subsurface conditions described in the Section 3.5 as well as the results of the site investigation work in attachment G.2 and the pre-design investigation in Appendix Z of the LAR. The licensee’s site investigation activities included subsurface drilling, cone penetration testing, test pits, and laboratory testing of collected samples. The licensee’s field investigation informed its understanding of the subsurface conditions. The description of the subsurface conditions included discussion of the bottom of the tailings, location of fine-grained tailings, potential borrow areas, mine waste, and other structural features. Therefore, consistent with its previous reviews, the NRC staff finds that the site stratigraphy is described in sufficient detail to provide an adequate understanding of the site, and that acceptance criteria (1) has been met.

The NRC staff's review of the local and regional faults and seismicity can be found in Section 2.3 of this SER. The NRC staff's review of faults and seismicity determined that sufficient information has been provided for the NRC's evaluation. Information on faults and seismicity has been incorporated into this geotechnical stability analysis, as further discussed in Section 3.2 of this SER. The NRC staff's geotechnical stability evaluation finds that the impoundment is not located near a capable fault that could cause an earthquake larger than the impoundment could withstand. As the stability analysis includes appropriate information on faults and seismicity, acceptance criteria (2) has been satisfied.

For this LAR, the NRC staff recognizes the importance of understanding the range of in situ soil conditions as well as the characteristics of the mine waste. The licensee obtained soil samples from a variety of locations around the proposed mine waste repository. Figures 3-1, 3-6, and 3-7 of Appendix Z show the sampling locations in the existing tailings, east and west borrow areas, as well as the north, south, and Dilco Hill borrow areas, respectively. The NRC staff therefore finds that the sample locations used by the licensee are representative of the range of potential soil conditions that exist at the site. Therefore, acceptance criteria (3) has been satisfied.

The licensee's field investigation included cone penetrometer testing (CPT) to identify the location and characteristics of fine-grained soils located within the existing tailings impoundment. For this LAR, the NRC staff recognizes that layers of fine-grained soils represent potential weak layers that could impact the geotechnical stability of the mine waste repository. Results of the CPTs can be found in Appendix B.2-4 of Appendix Z of the LAR. The location of the fine-grained soils is included in the cross sections analyzed for geotechnical stability by the licensee. An example of this can be found in the cross sections presented in the slope stability calculations in Attachment G.2 of Appendix G of the LAR. The NRC staff therefore finds that the location of fine-grained soils have been identified and incorporated into the stability analysis, and that acceptance criteria (4) has been met.

The NRC staff reviewed the laboratory test data presented in the LAR. Specifically, Table 6 in Appendix Z lists the testing standards used by the licensee to determine soil properties. The NRC staff observes that the licensee followed applicable testing standards published by ASTM International (ASTM) when performing laboratory tests on samples collected during the field investigation. Therefore, the NRC staff determines that acceptance criteria (5) has been met.

The licensee's field investigation included obtaining samples of the existing radon barrier, tailings material, borrow areas, and existing stockpiles adjacent to the mill site. The licensee described its sample collection techniques in Appendix Z of the LAR. The licensee followed ASTM standards when performing laboratory tests. Therefore, the NRC staff determines that a detailed discussion of laboratory sample preparation techniques is not necessary in the LAR and acceptance criterion (6) is not relevant in this situation.

The licensee summarized the results of the laboratory and field investigation in Appendix G, Section G.6. The detailed results are contained in Appendix Z. The licensee evaluated compressibility and coefficient of consolidation; shear strength properties; liquefaction potential; and permeability. The NRC staff reviewed the data and observed that the licensee had considered the soil types in its testing program. The NRC staff also reviewed the in-place moisture content results for the existing radon barrier and the cover cracking analysis and finds that acceptance criteria (7) has been met.

Appendix G, Section G.6 presents a narrative discussion of the material properties used in the geotechnical stability, settlement, and liquefaction potential analyses in the LAR. The NRC staff's review of this section determines that the licensee described the engineering properties in sufficient detail because the narrative discussion identified soil properties for different types of soil and differentiated between coarse and fine tailings. Additionally, the NRC staff verified the use of the appropriate soil properties for the correct soil types in the engineering analyses. Therefore, based on its review of the LAR, the NRC staff determines that acceptance criteria (8) has been met.

The NRC staff reviewed standpipe data and free water assessment in Section 3.2.2.5 of Appendix Z. The NRC staff also reviewed the CPT results of the dynamic pore pressures and pore pressure dissipation tests in Section 3.2.2.4 of Appendix Z to better understand the location of any saturated layers within the tailings. Finally, the slope stability analysis in Attachment G.2 of Appendix G discussed the ground water elevation used in the slope stability analysis. The licensee monitored ground water and identified the likely elevation at which ground water would be encountered, at approximately 6,900 ft MSL. Additionally, the licensee's CPT results did not indicate the presence of saturated tailings within the impoundment. Based on its review, the NRC staff therefore determines that ground water levels have been appropriately incorporated into the slope stability analysis, and that acceptance criteria (9) has been satisfied.

3.1.4 Evaluation Findings

The NRC staff has completed its evaluation of the geotechnical characteristics of the Church Rock site as they relate to the LAR. The NRC staff's review followed the review procedures in Section 2.1.2 of the SRP and the acceptance criteria in Section 2.1.3 of the SRP. The NRC staff determines that the licensee has acceptably described the geotechnical characteristics of the site, including the mine waste, existing tailings, borrow areas, and soil stockpiles. The licensee followed standard practices in obtaining soil samples and when performing laboratory tests on the samples. Therefore, the NRC finds that the licensee's laboratory and field testing acceptably characterizes the engineering properties of the soils.

Based in the information presented in the LAR and the detailed review performed by the NRC staff, the NRC staff concludes that the geotechnical characterization of the site is acceptable. The impoundment is not located near a capable fault that could generate an earthquake larger than the impoundment can withstand. Additionally, UNC has provided detailed information on the subsurface conditions gathered from field investigations. The information gathered and presented in the LAR formed the basis for the staff's evaluation related to the period of performance in Criterion 6(1). Therefore, the NRC staff has reasonable assurance that the licensee has demonstrated compliance with the following Criteria in 10 CFR Part 40, Appendix A: Criterion 4(e), Criterion 5(G)(2); and Criterion 6(1).

3.2 Slope Stability

In this section of the SER, the NRC staff documents its evaluation of slope stability of the proposed mine waste repository and existing mill tailings. The slope stability analysis relies on site characterization information and the proposed final slope configuration of the mine waste repository and final cover system.

3.2.1 Regulatory Requirements

The NRC staff determines if the licensee has demonstrated compliance with 10 CFR Part 40, Appendix A, Criterion 4(c), which relates to the steepest slope of the repository; Criterion 4(d), which relates to use of a vegetative cover; Criterion 4(e), which relates to the ability of the proposed design to withstand the maximum credible earthquake at the site; Criterion 5A(5), which relates to structural integrity of the proposed design; and Criterion 6(1), which identifies the 200 to 1000 timeframe for the control of radiological hazards to be effective.

3.2.2 Regulatory Acceptance Criteria

Unless specifically stated otherwise, the LAR was reviewed for compliance with the applicable requirements of 10 CFR 20 and 10 CFR 40 using the acceptance criteria presented in SRP Section 2.2, “Slope Stability” (NRC 2003).

The acceptance criteria in SRP Section 2.2.3 address the following topics: (1) characteristics of the slopes chosen for analysis; (2) static slope stability design; (3) effect of seismic ground motion on stability; (4) use of a vegetative cover; (5) the applicability of the dam safety program; and (6) use of steep slopes.

3.2.3 Staff Review and Analysis

Unless specifically stated otherwise, the information reviewed in this SER section is from information, data, and maps submitted by the licensee in Appendix G of its LAR (UNC 2018).

The licensee presented its slope stability evaluation in Appendix G, Section G.8 and Attachment G.2 to Appendix G. Figure G.8-1 shows the locations of the cross sections analyzed for slope stability. The licensee has identified three cross sections for its slope stability analysis. Cross section A cuts across the proposed mine waste repository from southwest to northeast and includes the portions of the cover with a 5H:1V slope. Cross Section B is located on the western side of the repository. Cross Section C runs roughly north to south across the repository. The NRC staff reviewed the locations of the cross sections and observed that the licensee: included the area of the site with the steepest slope; included the portion of the site with the longest overall slope; considered the portion of the site with the largest amounts of fill; and considered the underlying soil conditions. The NRC staff determined that the steepest slope proposed is 5H:1V (20 percent) on a portion of the eastern side of the repository. The regulations in 10 CFR Part 40 Appendix A, Criterion 4(c) require additional justification for slopes steeper than 5H:1V. As the licensee has not proposed any slopes steeper than 5H:1V; therefore, no additional technical justification is necessary. Finally, the licensee considered different failure scenarios and loading conditions. The licensee included scenarios that involved flooding of the Pipeline Arroyo near the western side of the repository and extended Cross Section B to evaluate stability within the Pipeline Arroyo. In reviewing the licensee’s analysis, the NRC staff finds that: (1) the licensee has considered slopes where instability could directly or indirectly impact control of radioactive materials; (2) the licensee has proposed slopes that are not steeper than 5H:1V; and (3) has selected cross sections based on maximum slope length, angle, and height, and has considered foundation conditions. Therefore, the NRC staff determined that acceptance criteria (1) has been met.

The licensee presented its static slope stability evaluation and calculations in Attachment G.2 to Appendix G. The NRC staff reviewed the licensee’s input parameters, assumptions, and method used in the analysis. The licensee used Slope-W software (August 2016 release), which is a widely available computer program. Within Slope-W, the licensee's analysis was based on the Morganstern-Price method. The NRC staff observes that the Morganstern-Price is a limit equilibrium method used to evaluate stability of slopes. Therefore, the NRC staff determined that acceptance criteria (2a) has been met.

The licensee discussed the location of the cross sections, material properties used in the analysis, and the subsurface conditions below the proposed mine waste repository in detail in Attachment G.2. As discussed above, the licensee analyzed slope stability of three different cross sections. In reviewing the licensee's analysis, the NRC staff observed that the material properties used in the analysis were based on the range of values identified during the field investigation. Additionally, the NRC staff recognized that the licensee performed a sensitivity analysis by varying the material properties in a more focused analysis on the cross section with the lowest factor of safety (also referred to as the critical cross section). With respect to the forces acting on the slope, the licensee's analysis is based on a 4.5 ft thick cover system. The NRC staff reviewed the licensee's approach to addressing ground water and corresponding pore pressures. The licensee considered the potential for perched zones within the mine waste in its evaluation of the performance of the evapotranspirative cover system in Attachment G.7. The licensee's analysis indicates there will not be a build-up of moisture on the radon barrier. The NRC staff reviewed that portion of the analysis and observes that the existing radon barrier will have a saturated hydraulic conductivity on the order of 10^{-5} cm/sec. As a result, the first low-permeability layer encountered by moisture that makes its way through the cover system is within the tailings itself. This is discussed in more detail in SER Section 3.7.3. Therefore, the NRC staff finds the evaluation described above to be adequate. Within the existing tailings, the NRC staff recognized that the licensee assumed a ground water elevation of approximately 6,900 ft MSL (mean sea level), based on the results of the field investigation. Additionally, the licensee's field investigation indicated that the existing tailings are a mix of coarse and fined grained layers. The licensee observed that some perched, saturated zones exist within in some portions of the fine-grained tailings. However, the depositional method used to place the existing tailings has resulted in a profile that is not fully saturated. The licensee's calculation package in Attachment G.2 described the material properties that were used in the calculation. The material properties are summarized in Table 1 of Attachment G.2. Additionally, the output files from the slope stability analysis located in Attachment D to Attachment G.2 contain sufficient information for the NRC staff to find that the stability analysis used the material properties discussed in the narrative to the calculation package. Therefore, the NRC staff finds that the licensee has considered variability in the geometry and material properties in its analysis. Based on its review, the NRC staff therefore determines that acceptance criteria (2b) has been satisfied.

In reviewing the Slope-W output files, the NRC staff observes that the licensee considered a variety of slope failure scenarios, including shallow surfaces within the slope and deep slip surfaces into the underlying soils. The licensee considered post construction conditions and explained how the post construction conditions bound the slope height and length that are planned to occur during construction. The NRC staff reviewed the mine waste placement plans in Section 7 of the engineering drawings and finds that the post construction conditions represent the maximum slope heights and lengths that are planned. The NRC staff recognizes that slope length and height are the main factors that influence the stability of a slope. As the mine waste placement plans do not call for steeper or taller slopes, the licensee's evaluation of the post construction conditions represents the potential worst-case scenario from a slope stability perspective as the post construction conditions have the longest and tallest slopes. The licensee performed its slope stability analysis on the worst-case scenario and the analysis demonstrated the slope is stable. Therefore, the NRC staff finds that an evaluation of the during-construction condition is not necessary. Therefore, no specific slope stability analysis during construction is needed and acceptance criteria 2(c) has been met. The licensee accounts for adverse conditions, such as high-water levels during flooding, in its slope stability analysis. For example, Figure I.6-3 in Attachment E of Attachment G.2 shows the anticipated extent of flooding during a probable maximum flood (PMF) event. The NRC staff observes that the extent of flooding during a PMF may influence the slope stability analysis for cross sections B and C. The licensee has included results of slope stability analyses in Table 4 in Attachment G.2. The NRC staff reviewed the results of the slope stability evaluation that considered the extent of the PMF event and observes that the factors of safety for cross sections B and C during a PMF event are lower than normal conditions, but the factors of safety are still above the recommended values in NRC Regulatory Guide 3.11. By considering the slope stability during adverse conditions, the NRC finds that the licensee meets acceptance criteria 2(d).

According to the licensee, the extent of the flood plain during a PMF event is anticipated to encroach on the northern portion of the mine waste repository. To minimize the quantity of runoff entering and the flow velocities in this area, the licensee plans to raise the protective berm. This is referred to as the north cell earthen berm on engineering drawings 9-02 and 9-07. Additionally, the licensee plans to upgrade the channel lining for the runoff control ditch on the northwest side of the mine waste repository as well as for the east repository channel on the northeast side of the mine waste repository. The NRC staff reviewed the ability of these features to resist erosive forces in Section 4.4 of this SER. As the NRC staff's review determines that the proposed design is capable of resisting the anticipated erosive forces at the toe of the slopes in these areas, the licensee has satisfied acceptance criteria 2(e). The NRC staff observes that the Slope-W files identify the slip surface corresponding to the lowest factor of safety. The NRC staff reviewed the output files and finds the assumptions and techniques used to determine the factor of safety to be adequate. The NRC staff recognizes that the factors of safety calculated by the licensee are greater than the recommended values in Regulatory Guide 3.11. Therefore, the NRC staff determines that acceptance criteria (2f) is met.

To evaluate overall seismic stability of the proposed design, the licensee performed a pseudo static analysis. The licensee's pseudo static analysis is discussed in Attachment G.2. During its review, the NRC staff found that: (1) the licensee used a seismic coefficient of 0.2g to represent the seismic load during an earthquake; (2) each of the three cross sections evaluated in the static stability analysis were also evaluated under pseudo static conditions; (3) the Morganstern-Price method was used for the evaluation; and (4) the licensee did not rely on peak shear strength values for the various soil layers. The NRC staff recognizes that use of a pseudo static analysis for earthquake loads is consistent with the guidance in NUREG-1620. As discussed above in the NRC staff's review of the static slope stability analysis, the Morganstern-Price method is a limit equilibrium analysis. Given the use of lower strength values in the pseudo static analysis, the NRC staff recognizes the licensee has taken a conservative approach in its analysis. Based on its review, the NRC staff finds that the licensee analyzed seismic stability of the proposed design using a pseudo static analysis based on conservative assumptions and low potential for liquefaction to occur in the fine-grained tailings layers. Additionally, NRC staff finds the use of a seismic design coefficient of 0.2g is adequate. Therefore, the NRC staff determines that acceptance criteria (3a), (3b), (3d), and (3f) are met.

In reviewing the summary of the pseudo static analysis results in Table 4 as well as the Slope-W output files, the NRC staff observes that the calculated factors of safety are equal to or exceed the recommended minimum values in NRC Regulatory Guide 3.11 (NRC, 2008). In performing its pseudo static analysis, the NRC staff observes that the licensee did not apply the seismic coefficient to the critical surface identified in the static analysis; the licensee conducted a search to identify the location of the critical surface when the seismic coefficient was applied. The NRC staff recognizes that this approach is slightly different than acceptance criteria (3e) identifies. However, the licensee's approach is acceptable to the NRC staff, as it evaluated a larger number of critical surfaces under the seismic coefficient and the minimum factor of safety values were met. Therefore, the NRC staff determined that acceptance criteria (3e) has been satisfied.

As the licensee chose to perform a pseudo static analysis and not a dynamic stability analysis, acceptance criteria (3c) is not relevant to this review. The licensee chose to use a seismic design coefficient of 0.2g in its pseudo static stability analysis. Therefore, following the guidance in acceptance criteria (3g), no additional analysis is needed to evaluate the pseudo static slope stability. Therefore, the NRC staff determines that the licensee's approach is consistent with acceptance criteria (3c) and (3g) and therefore acceptable.

In reviewing the pseudo static slope stability results, the NRC staff observes that the Slope-W contains sufficient information to document the evaluation and material properties used. The licensee's narrative discussion in Attachment G.2 clearly identifies the material properties used in the analysis. The NRC staff has reviewed the licensee's results and finds that the material properties identified in the narrative discussion are used in the slope stability evaluation. Additionally, the NRC staff finds that the seismic coefficient was appropriately applied. Therefore, acceptance criteria (3h) is satisfied.

As discussed above, the licensee's slope stability results for the pseudo static analysis all had factors of safety greater than the minimum recommended values contained in NRC Regulatory Guide 3.11. The NRC staff recognizes that as the factors of safety remain greater than one, that the slope will remain stable and no displacement is anticipated to occur. If no displacement is anticipated, it is not possible to calculate seismically induced displacement. Therefore, the licensee need not provide information about seismically induced displacement to address acceptance criteria (3i).

The NRC staff's review of the liquefaction potential of the proposed action can be found in Section 2.4 of this SER. As discussed in that Section, there is a slight potential for liquefaction of a portion of the fine-grained tailings located near T1-B10 on Figure 1 in Attachment G.6. The potentially liquefiable layer is 33 to 44 feet below the existing ground surface at this location. This layer is located at a depth below the critical slip surfaces in the slope stability calculation. As there is no potential for liquefaction in a soil layer critical to maintaining stability of the proposed mine waste repository, it is not necessary to include changes in pore pressure from cyclic loading in this analysis. Therefore, the licensee need not provide information to address acceptance criteria (3j).

The licensee's seismic hazard analysis is attachment G.1 of the LAR. The NRC staff's review of the seismicity of the Church Rock site can be found in Section 1.8 of this SER. As discussed in more detail in that section of the SER, the NRC staff concluded that the LAR is consistent with the regulations in 10 CFR Part 40, Appendix A, Criterion 4(e), which relate to the location of the impoundment with respect to a capable fault that could cause an earthquake larger than the impoundment could be expected to withstand. As the NRC staff has concluded in Section 3.1.3 of this SER that the regulation has been met, acceptance criteria (3k) has been satisfied.

The licensee's cover design narrative is presented in Section G.12 of the LAR. Additional analysis and calculations supporting the cover design are presented in Attachment G.7. Based on its review of the cover design, the NRC staff understands that the primary functions of the cover are to: (1) maintain control over the mine waste for at least 200 years and up to 1,000 years; (2) minimize the amount of water that infiltrates through the cover system and into the mine waste by relying on the evapotranspiration properties of vegetation on the cover system; (3) minimize the potential for runoff resulting from wind and storm water; (4) limit radon emissions to the radon flux standard of 20 pCi/m^2s; and (5) not rely on active maintenance for the cover system to be able to maintain its performance. The licensee described the cover system profile in Attachment G.7. Broadly speaking, the cover system consists of two layers: (1) a desert pavement layer consisting of a mix of soil and rock and (2) cover soil. The overall thickness of the cover system is 4.5 ft. The thickness of the individual layers within the cover system varies, depending on the catchment size and slope length. The LAR does not assume any strength contribution from the cover system. The NRC staff's review of the erosion protection aspects (both wind and storm water) can be found in Section 4 of this SER. The NRC staff observes that the licensee has described the primary functions of the cover system and that no strength enhancement from the cover system is used in the stability analysis. Therefore, the NRC staff that acceptance criteria (4a) and (4b) have been satisfied.

The NRC staff observes that the existing embankment and impoundment at the Church Rock mill site retains tailings, not free liquids. Additionally, the mine waste considered for placement in the repository constructed on top of the existing impoundment consists of soils and will not be used to retain water. Therefore, the NRC staff has determined that the dam safety program does not apply in this situation and that the licensee need not provide information related to the acceptance criteria (5).

The NRC staff reviewed the licensee's engineering drawings contained in Volume 2 of the LAR. Specifically, drawings 7-04 through 7-08 show the grading plan for the final surfaces of the repository. The NRC staff observes that the minimum slope is 2 percent and that the maximum proposed slope is 20 percent (5H:1V). The 20 percent slope is along the eastern edge of the repository. As the steepest slope proposed in the LAR is no steeper than the limit identified in criterion 4c, the NRC staff determines that no additional justification is required. Therefore, the NRC staff has determined that acceptance criteria (6) has been satisfied.

3.2.4 Evaluation Findings

The NRC staff has completed its review of the slope stability aspects of the revised reclamation plan for placement of mine waste on top of the tailings impoundment at the Church Rock site. This review was performed using the review procedures in Section 2.2.2 and the acceptance criteria in Section 2.2.3 of NUREG-1620.

The licensee has acceptably described slope stability by: (1) providing cross sections and profiles of the slopes in sufficient detail and number to represent significant slope and foundation conditions; (2) ensuring slope steepness is equal to 5H:1V or less; (3) providing measurements of static and dynamic properties of soil and rock using standards such as those set by the American Society for Testing and Materials; (4) selecting locations for slope stability analysis while considering the maximum slope height, slope angle, foundation conditions, and potential for local erosion.

The licensee's static load analysis is acceptance and includes: (1) appropriate uncertainties and variabilities in the soil and rock strength parameters; (2) consideration of appropriate failure modes; (3) a discussion of the effect of assumptions in the analysis used; (4) consideration of adverse conditions, including flooding, with appropriate safety factors; and (5) the effects of toe erosion, incision at the base of the slope, and other deleterious effects of surface runoff.

The licensee's pseudo-static analysis is acceptable as it includes: (1) calculations with appropriate methods and assumptions; (2) treatment of interaction effects in a conservative manner; (3) consideration of the added horizontal force acting in the direction of a potential failure in the pseudo static analysis; (4) selection of an appropriate design level seismic event; (5) evaluation of local site conditions; (6) consideration for potential liquefaction and effect of pore pressure increase on stability; (7) evaluations of the dynamic properties of the underlying soils and mine waste; and (8) design of a cover system that employs both vegetation and rock that is consistent with common engineering practice.

On the basis of the information presented in the LAR and the detailed review conducted by the NRC staff of the slope stability at the Church Rock site described, the NRC staff concludes that the slope stability and associated conceptual and numerical model pertaining to the design of the mine waste repository provide an acceptable input to demonstration of compliance with the criteria in 10 CFR Part 40, Appendix A: Criterion 4(c), which provides requirements for the long-term stability of the embankment and cover slope for tailings; Criterion 4(d), which requires establishment of a self-sustaining vegetative cover or use of a rock cover to reduce wind and water erosion to negligible levels, and that impoundment surfaces are contoured to avoid concentrated surface runoff or abrupt changes in slope gradient; Criterion 4(e), which requires that the impoundment not be located near a capable fault on which a maximum credible earthquake larger than that which the impoundment could be reasonably expected to occur; Criterion 5(A)(5), which requires structural integrity of slopes (dikes) to prevent massive failure; and Criterion 6(1), which requires that impoundment designs provide reasonable assurance of control of radiological hazards for 1,000 years to the extent reasonably achievable, and in any case for at least 200 years.

3.3 Settlement

In this section of the SER, the NRC staff documents its evaluation of settlement of the proposed mine waste repository and cover system.

3.3.1 Regulatory Requirements

The NRC staff determines if the licensee has demonstrated compliance with 10 CFR Part 40, Appendix A, Criterion 6(1), which requires that that impoundment designs provide reasonable assurance of control of radiological hazards for 1,000 years to the extent reasonably achievable, and in any case for at least 200 years.

3.3.2 Regulatory Acceptance Criteria

Unless specifically stated otherwise, the LAR was reviewed for compliance with the applicable requirements of 10 CFR 20 and 10 CFR 40 using the acceptance criteria presented in SRP Section 2.3, "Settlement" (NRC 2003).

The acceptance criteria in SRP Section 2.3.3 address: (1) calculation of immediate settlement; (2) assessment of consolidation; (3) material properties used in the analysis to represent compressible soil layers; (4) material properties used in the analysis to represent embankment zones; (5) pore pressure values used in the analysis; (6) methods used to estimate settlement; (7) evaluation of settlement across different areas of the impoundment; (8) documentation of results; and (9) analysis of potential cracks in radon barrier.

3.3.3 Staff Review and Analysis

Unless specifically stated otherwise, the information reviewed in this SER section is from information, data, and maps submitted by the licensee in its LAR (UNC 2018). Specifically, the licensee included a narrative discussion of its approach to addressing total and differential settlement in Section 4.4 of the LAR. The licensee provides further discussion in Section G.9 (Settlement Analysis) and Section G.10 (Cover Cracking Analysis) of Appendix G. The licensee's detailed calculations are provided in Attachments G.3 (Repository Settlement Analysis), G.4 (Repository Seismic Settlement Analysis), and G.5 (Repository Existing Radon Barrier Cover Cracking Analysis) to Appendix G.

UNC's LAR describes its plan to relocate mine waste from areas near the Church Rock mill tailings impoundment into a mine waste repository constructed on top of the existing mill tailings impoundment. The existing tailings would remain in place and that placement of the mine waste will result in new overburden stress that would result in further consolidation of the existing tailings. While conducting its review based on the acceptance criteria in Section 2.3.3 of the SRP, the NRC staff focused on the possibility of cracking within the existing radon barrier and differential settlement of the final slopes.

The licensee evaluated immediate settlement of the existing tailings following the guidance in NAVFAC DM-7.1 (Navy, 1986). During its review, the NRC staff observed that the licensee focused its analysis of immediate settlement on the southwest edge of the repository. The licensee's plans call for a transition between mine waste placement to no mine waste placement in this area. The NRC staff recognizes this transition area represents the highest potential for differential settlement of the existing tailings and radon barrier given the change in overburden stress over a relatively short lateral distance. Therefore, the NRC staff finds that the licensee's focus on the immediate settlement analysis in this area is appropriate.

The NRC staff reviewed the licensee's approach and calculations and found them to be consistent with the NAVFAC guidance. The NRC staff observes that the immediate settlement in this portion of the tailings cell will range from 0.1 to 1 ft. The NRC staff's evaluation of cracking of the radon barrier can be found below in the discussion of acceptance criteria (9). As the licensee followed the NAVFAC guidance, the NRC staff determined that acceptance criteria (1) has been satisfied.

In calculating primary and secondary consolidation, the licensee's calculations considered the increase in overburden pressure resulting from the placement of mine waste into the repository. The NRC staff observes that the location of thickest mine waste placement is in an area where the existing tailings thickness is minimal. Therefore, the NRC staff does not anticipate significant changes in water level due to consolidation of the tailings. The NRC staff recognizes that no excavation of the tailings is planned; therefore, the licensee need not provide information to address acceptance criteria (2a). Additionally, the NRC staff understands that the license does not plan to dewater the tailings. Therefore, the licensee need not provide information to address acceptance criteria (2d). With respect to acceptance criteria 2(e), the licensee anticipates the groundwater levels to remain at or near elevation 6,900 ft MSL in the long term. Based on its review of consolidation and groundwater flow, the NRC staff finds that the licensee's evaluation is sufficient for the calculation of consolidation. As no changes in the groundwater levels are anticipated, the licensee does not need to provide information to address acceptance criteria 2(e). In reviewing the licensee's calculations, the NRC staff observed that the thickness of the overburden (mine waste) is considered in the analysis. Based on the NRC staff's review, the overburden thickness is consistent with the planned final grading plan shown in Figure 1 of Attachment G.3. The NRC staff observes that the licensee's analysis is based on effective stresses, and as a result, changes in pore pressure are captured in the analysis. As both the overburden stresses and pore pressure changes were considered in the settlement analysis, the NRC staff determined that acceptance criteria (2b) and (2c) have been satisfied.

The NRC staff reviewed the material properties and assumptions for the soil layers and mine waste. The NRC staff finds that the material properties used in the settlement analysis are consistent with those used in the geotechnical stability analysis and reflect the results of the field and laboratory investigation of the Church Rock site obtained during the pre-design investigation (see Appendix Z of the LAR). Additionally, the NRC staff reviewed the settlement calculations and soil profiles to compare the thicknesses of the various soil layers considered in the analysis to the grading plans and documented subsurface conditions. For example, at location CPT-20, the final grading plan in Figure 1 of Attachment G.4 shows the final elevation as being approximately 6,985.5 ft above MSL. The existing ground surface at this location is approximately 6,979 ft above MSL. The cover/fill layer, coarse tailings layer, and fine tailings layer have thicknesses of approximately 12 feet, 9 feet, and 10 feet, respectively at this location. The NRC staff observes that these values are consistent with those shown in the licensee's settlement calculation for CPT-20. As the material properties and thicknesses used in the analysis reflect established site values, the NRC staff determines that acceptance criteria (3) has been satisfied.

The licensee's plan calls for placement of the mine waste over the existing tailings impoundment, but the limits of the mine waste would remain at least 50 ft away from the existing embankment along the west side of the tailings impoundment. As no additional mine wastes are planned for placement near the existing embankment, the licensee did not evaluate additional settlement of the embankment. The NRC staff finds that this approach is sufficient as the stress conditions near the embankment would not change. The NRC staff recognizes that western side of the impoundment is the only area contained by an embankment; the remaining parts of the tailings impoundment tie into the natural ground surface. As the mine waste is located away from the only embankment location, the NRC staff determined that the licensee need not provide information to address acceptance criteria (4).

The licensee's pre-design investigation (see Appendix Z of the LAR) indicated that the existing tailings are a mix of coarse and fine grained layers. The licensee observed that some perched saturated zones exist within in some portions of the fine-grained tailings. In addition, some of the fine-grained layers are only partially saturated. The NRC staff finds that the licensee's assessment that the depositional method is appropriate for evaluating the saturation of the tailings. The licensee's assessment identified that the method used to place the existing tailings has resulted in a profile that is not fully saturated, consistent with the observations from the field investigation. In its evaluation of settlement, the licensee's assumption that all of the fine-grained layers are fully saturated results in a more conservative settlement analysis and is therefore acceptable to the NRC staff.

The licensee's detailed settlement calculations are provided in Attachment G.3 (static settlement) and G.4 (seismic settlement). In its static evaluation, the licensee evaluated total settlement at 25 locations across the mine waste repository following the approach used in NAVFAC Design Manual 7.01. The NRC staff recognizes that the 25 settlement evaluation locations are spread across the area of the repository and capture a range of thicknesses in the mine waste and subsurface layers. The NRC staff recognizes that the licensee's approach considers both primary consolidation and secondary consolidation effects and is consistent with the guidance in NUREG-1620 and NRC Regulatory Guide 3.11. In its seismic settlement analysis, the licensee evaluated seismically induced settlement at six locations. The NRC staff reviewed the licensee's methods and assumptions and observed that the site conditions were appropriately incorporated into the analysis. Additionally, the NRC staff observed that the licensee's followed a suitable approach in calculating the seismic settlement. Therefore, the NRC staff finds that the licensee's evaluation is adequate for the purposes of calculating the settlement of the mine waste and cover system at Church Rock.

The licensee's settlement results are tabulated in Table 3 of Attachment G.3 while Figure 1 of Attachment G.3 shows the calculated settlement across the repository. For the seismic settlement analysis, the licensee summarized the results in Table 4 of Attachment G.4. The licensee estimates that the total settlement of the final surface of the mine waste repository will range from 0 ft to 1.8 ft. If an earthquake were to occur, the licensee estimated that an additional 0.08 ft to 0.14 ft of settlement may occur. The NRC staff reviewed the licensee's detailed calculations and did not identify errors. The NRC staff observes that these settlement values are not anticipated to create a grade reversal on the proposed final cover system. That is, positive drainage off the cover system is expected to be maintained. Based on its review, the NRC staff determined that the licensee used appropriate methods, evaluated settlement across the mine waste repository, and documented the results in tabular and graphical form. Therefore, the NRC staff determined that acceptance criteria (6), (7) and (8) have been met.

The licensee evaluated the potential for cracking of the existing radon barrier in Appendix G.10 and Attachment G.5. The LAR describes the licensee's plans to place the mine waste on top of a portion of the existing tailings impoundment. While the licensee plans to construct a new cover on top of the mine waste, a low permeability layer serving as a radon barrier is not a planned component of the new cover system. The addition of mine waste will result in increased overburden pressures on the existing tailings. The NRC staff recognizes that the transition area between the existing cover system (with a radon barrier) and the mine waste repository is the portion of the site with the highest potential for differential settlement and corresponding cracking of the existing radon barrier. The NRC staff reviewed the licensee's approach and calculations to address the potential for differential settlement and cracking of the radon barrier. The NRC staff observed that the licensee's approach followed the method identified by Lee and Shen (1969). The licensee estimated that estimated slope reduction at the transition between the mine waste repository and the existing cover will range from 0.29 to 0.61 percent. The NRC staff observes that the new cover system is designed with a slope of 5 percent; therefore, positive drainage off of the cover will be maintained. The licensee estimates the horizontal strain in the existing radon barrier will be approximately 0.01 percent, which is less than the calculated tolerable strain of 0.1 percent. The NRC staff reviewed the detailed calculations and did not identify any errors. Based on its review, the NRC staff found that the licensee used appropriate methods and calculations to evaluate differential settlement and cracking of the radon barrier. Therefore, the NRC staff determined that acceptance criteria (9) has been satisfied.

3.3.4 Evaluation Findings

The NRC staff has completed its review of settlement resulting from placement of mine waste onto the existing tailings impoundment at the Church Rock facility. This review included an evaluation using the review procedures in Section 2.3.2 and acceptance criteria 2.3.3 of the standard review plan.

The licensee has acceptably evaluated settlement by presenting calculations based on NAVFAC methods and evaluated horizontal movement and cover cracking based on methodology described by Lee and Shen (1969). Material properties, thicknesses, and load increments used to calculate settlement are representative of site conditions. The licensee has acceptably considered: (1) increase in overburden pressure from addition of mine waste; (2) excess pore pressure generated within the tailings; and (3) changes in ground water levels within the tailings and the surrounding area. Methods used to calculate settlement are appropriate for the conditions present at the site. The results of the calculations have been properly documented. The settlement data provided information to assess the possibility of ponding water on the surface of the cover system or a gradient change resulting from settlement. The licensee presented an acceptable analysis for evaluating differential settlement and cracking of the cover system in the transition area between the existing cover and new cover atop the mine waste.

On the basis of the information provided in the LAR and the detailed review conducted of the anticipated settlement at the Church Rock mill site, the NRC staff concludes that the settlement calculations present information needed to demonstrate compliance with 10 CFR Part 40, Appendix A, Criterion 6(1), which requires that impoundment designs provide reasonable assurance of control of radiological hazards to be effective for 1,000 years to the extent achievable, and in any case for at least 200 years.

3.4 Liquefaction Potential

In this section of the SER, the NRC staff documents its evaluation of the seismicity and ground motion estimates used in the design of the mine waste repository.

3.4.1 Regulatory Requirements

The NRC staff determines if the licensee has demonstrated that the LAR has met the requirements of 10 CFR Part 40, Appendix A, Criterion 4(c). This criterion requires long term stability of the embankment and cover. Additionally, the NRC staff determines if the LAR provides reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 6(1) have been satisfied. This criterion requires that the design provide reasonable assurance to control radiological hazards be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.

3.4.2 Regulatory Acceptance Criteria

Unless specifically stated otherwise, the LAR was reviewed for compliance with the applicable requirements of 10 CFR 20 and 10 CFR 40 using the acceptance criteria presented in SRP Section 2.4, “Liquefaction Potential” (NRC 2003).

The acceptance criteria in SRP Section 1.4.3 address: (1) field or laboratory testing; (2) collection of data for use in the analysis; (3) method of evaluation; (4) correction between laboratory and field data; (5) time history of earthquake ground motions; (6) impact on settlement and slope stability; (7) mitigation measures for global liquefaction; and (8) minor liquefaction impacts.

3.4.3 Staff Review and Analysis

Unless specifically stated otherwise, the information reviewed in this SER section is from information, data, and maps submitted by the licensee in its LAR (UNC 2018). The licensee presented the information used to estimate the ground motion in Section 4.3.2 and Appendix G.11 of the LAR. The licensee's detailed liquefaction triggering analysis is presented in Attachment G.6 of the LAR.

The licensee conducted a pre-design study to characterize the subsurface conditions in and below the existing tailings impoundment. The licensee's study included cone penetration tests (CPTs), standard penetration tests (SPTs), soil sampling, and laboratory testing to characterize the index properties of the various soil layers. The NRC staff's detailed analysis of the site characteristics can be found in Section 2.1.3 of this SER. The NRC staff observes that the field and laboratory tests performed by the licensee were used to identify potentially liquefiable soils. The CPTs were used to identify saturated soil layers and soil liquid and plastic limit results were used to identify potentially liquefiable soil layers. As discussed in SER Section 2.1.3, the NRC staff determined that the licensee had followed appropriate ASTM standards when performing laboratory tests. In reviewing the licensee's narrative discussion and detailed calculations, the NRC staff observed that the relevant parameters for assessing liquefaction potential have been identified and collected. During its review, the NRC staff found that the licensee properly conducted appropriate field and laboratory studies by following ASTM guidelines and collected relevant data. Therefore, the NRC staff determines that acceptance criteria (1) and (2) have been satisfied.

The licensee's liquefaction evaluation consisted of a liquefaction triggering analysis based on the subsurface soil profile and anticipated earthquake induced stresses. The NRC staff observes that the licensee followed a methodology developed by Youd et al (2001), which is based on Seed and Idriss (1971). This approach is consistent with the NRC guidance in NUREG-1620. The licensee also evaluated the potential for liquefaction based on a method developed by Bray (2009) to determine if the subsurface soils were 'susceptible' or 'moderately susceptible' to liquefaction based on laboratory results. The NRC staff reviewed the licensee's calculations and observed that: (i) the CPT and SPT data were obtained from a variety of locations around the proposed mine waste repository; (ii) the licensee applied the methodology in a reasonable manner; (iii) the laboratory data used in the liquefaction screening evaluation was consistent with the data discussed in Section 2 of this SER. The licensee identified a few areas that are moderately susceptible to liquefaction, the implications of this finding are discussed in more detail in a subsequent paragraph below. During its review, the NRC staff observed that the licensee analyzed the potential for liquefaction based on a method developed by Seed and Idriss (1971). The NRC staff finds that the potentially liquefiable layer does not represent a threat to the radon barrier or stability of the slopes of the mine waste repository as a result of its depth (between 33 and 44 ft) below ground surface. Additionally, the NRC staff observed that the proposed mine waste repository maintains a setback from the existing embankment present along the west side of the site. Based on its review as described above, the NRC staff determines that acceptance criteria (3) is therefore satisfied.

The licensee used a combination of field and laboratory testing to inform its liquefaction analysis. Specifically, the licensee performed field cone penetrometer tests (CPT) and standard penetration test (SPT) to document the conditions in the field as well as laboratory tests to understand the index properties of the soil. As the licensee's liquefaction analysis was based on both field and laboratory conditions, with the field CPT and SPT results being the primary source of data. The NRC staff recognized that the that the laboratory results were used to supplement the liquefaction analysis. As the liquefaction analysis was based on the results of field tests, the NRC staff recognizes there is no need to correct the laboratory results to account for the difference between field and laboratory conditions. Therefore, the NRC staff determined that the licensee need not provide information to address acceptance criteria (4).

In its liquefaction analysis, the licensee's design seismic event is the 10,000-year return period earthquake. The NRC staff recognizes that the horizontal ground surface acceleration and earthquake magnitude are incorporated into the methodology developed by Youd et al (2001). The NRC staff observes that this design seismic event is consistent with what is used elsewhere in this LAR. Therefore, the NRC staff determines that acceptance criteria (5) has been satisfied.

As discussed above, the licensee's liquefaction triggering analysis identified one location as potentially liquefiable. The potentially liquefiable location is T1-B10 on Figure 1 in Attachment G.6. At this location, the licensee estimated liquefaction induced settlement would be approximately 6 inches. The NRC staff reviewed the proposed grading plan on Figure 1 in Attachment G.6 and recognized that given the depth of the potentially liquefiable layer at this location (between 33 and 44 ft below ground surface), that the potential for grade reversal of the final cover system at this location is low. Additionally, the NRC staff recognizes this potentially liquefiable layer is not located near the critical slip surface evaluated for stability in Section 2.2 of this SER. Therefore, the NRC staff finds that the potentially liquefiable layer does not represent a threat to the radon barrier or stability of the slopes of the mine waste repository. Therefore, the NRC staff determined that acceptance criteria (6) and (8) are satisfied.

The licensee's liquefaction evaluation did not identify the potential for global liquefaction. The NRC staff reviewed the data presented in the LAR and finds no potential for global liquefaction; therefore, the application need not address acceptance criteria (7).

3.4.4 Evaluation Findings

The NRC staff has completed its evaluation of liquefaction potential at the UNC mill site related to the LAR. This included an evaluation using the review procedures identified in Section 2.4.2 and the acceptance criteria outlined in Section 2.4.3 of the SRP (NRC, 2003).

The licensee has acceptably evaluated the potential for liquefaction at the Church Rock tailings impoundment and mine waste repository as proposed. The NRC staff determines that the methods used in the analysis are consistent with current engineering practice. The NRC staff finds that the limited potential for liquefaction induced settlement will not compromise the radon barrier or waste isolation.

On the basis of the information presented in the LAR and the detailed review of liquefaction potential at the Church Rock mill site above, the NRC staff concludes that the results of the evaluation of liquefaction potential demonstrate compliance with the requirements in 10 CFR Part 40, Appendix A, Criterion 4(c), which provides long term stability requirements, and Criterion 6(1), which requires that the design 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.

3.5 Disposal Cell Cover Engineering Design

In this section of the SER, the NRC staff documents its evaluation of the engineering design of the cover for the mine waste repository.

3.5.1 Regulatory Requirements

The NRC staff determines if the licensee has demonstrated that the LAR has met the requirements of 10 CFR Part 40, Appendix A, Criterion 4(c). This criterion provides requirements for the embankment and cover slopes. Additionally, the NRC staff determines if the LAR provides reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 6(1) has been satisfied. This criterion requires that the design provide reasonable assurance to control radiological hazards be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.

3.5.2 Regulatory Acceptance Criteria

Unless specifically stated otherwise, the LAR was reviewed for compliance with the applicable requirements of 10 CFR 20 and 10 CFR 40 using the acceptance criteria presented in SRP Section 2.5, “Disposal Cell Cover Engineering Design” (NRC 2003).

The acceptance criteria in SRP Section 2.5.3 address: (1) soil types used in the cover system; (2) field and laboratory investigations and resulting material properties; (3) disposal cell cover termination; (4) identification of the cover system layers; (5) freeze-thaw effects on soil strength and radon barrier effectiveness; (6) penetrations through the cover system; (7) evaluation of potential for cracking resulting from differential settlement and shrinkage; (8) description of geomembranes used in the cover system; and (9) information used in the cover design.

3.5.3 Staff Review and Analysis

Unless specifically stated otherwise, the information reviewed in this SER section is from information, data, and maps submitted by the licensee in its LAR (UNC 2018). The licensee presented the information related to the cover system design in Section 3.7 and Appendix G.12 and Attachment G.7 of the LAR. Appendix H contains detailed information on the sources of borrow material for the project. Appendix J contains the technical specifications for the project.

The licensee’s proposed final cover system is an evapo-transpirative (ET) cover consisting of a layer of rock and soil (desert pavement) underlain by a layer of soil. The total thickness of the final cover system is 4.5 ft, the thickness of the desert pavement and soil layers varies depending on slope and upstream drainage area. Details 2, 3, 4, and 5 on sheet 7-09 of the engineering drawings show the various cross sections of the proposed final cover system. The licensee plans to use soil obtained from on-site borrow areas in the cover system. Appendix H contains the characterization information from the on-site borrow areas. The NRC staff reviewed the information available in Appendix H and finds that it contains detailed information on the soils planned for use in the cover system. The NRC staff observes that Table H.4-1 contains an estimate of the amount of soil needed to construct the proposed cover system. According to Table H.4-1, approximately 430,000 cubic yards of soil will be needed to construct the final cover system atop the approximately 1,000,000 cubic yards of mine waste that would be emplaced on top of the mill tailings. Table H.4-5 identifies the quantities of rock needed for the cover system; approximately 60,000 cubic yards of rock will be needed. An additional 150,000 cubic yards of rock will be needed to for erosion control features on and around the repository. Table H.4-3 contains an estimate of the amount of soil available in the on-site borrow areas. According to that table, approximately 930,500 cubic yards of soil are available for use in constructing the cover system. Based on the information presented in the LAR, the NRC staff observes that sufficient soil volumes are available from on-site borrow areas for use in the final cover system. The licensee plans to obtain rock from three off-site quarries. Figure H.4-2 compares the soil classification in the borrow areas to the soil used in the existing cover system. Using the Unified Soil Classification System (USCS), most of the soil would be classified as CL material (fine grained, low plasticity clay). The NRC staff recognizes that use of this type of material in a cover system is consistent with the guidance in NUREG 1620 (acceptance criteria 1 in section 2.5.3). The NRC staff recognizes that the cover system is designed as an ET cover, with the goal of supporting vegetation on the top slopes of the cover system. Therefore, resistance to root penetration is not a consideration in this design. Additionally, given the depth of mine waste placement over the existing tailings, the NRC staff does not anticipate root penetration or burrowing animals being able to compromise the existing radon barrier. Note that the NRC staff's evaluation of erosion resistance of the cover can be found in Chapter 3 of this SER. As the licensee has described the soil types planned for use in the cover, evaluated soil quantity needs and availability in planned borrow areas, and identified the soil type planned for use, the NRC staff determines that acceptance criteria (1) is satisfied. Further discussion on ET cover system can be found in section 3.7 of this SER.

As discussed above, Appendix H contains details on the field and laboratory investigations of the soil and rock borrow sources. The NRC staff reviewed the data in Appendix H and observes that the licensee evaluated the index properties, compaction, gradation, strength characteristics, permeability, and information related to the soil water characteristic curve. The NRC staff recognizes that the soil samples were obtained from a series of test pits and geotechnical borings and that laboratory testing followed the applicable ASTM requirements. After its review of the detailed field and laboratory study, the NRC staff determined that the licensee adequately characterized the borrow sources. Therefore, the NRC staff determines that acceptance criteria (2) has been satisfied.

The licensee included a series of engineering drawings showing the detailed plans for constructing the mine waste repository. The drawings show the proposed grading plan, cover system cross section, and details associated with the cover system. Specifically, detail number 6 on sheet 7-10 and details A, B, C, and D on sheet 7-10 show the various terminations of the proposed cover system where it meets the existing radon barrier. These details show how the licensee intends to tie in the cover over the mine waste into the existing cover system. By providing this information, the licensee has acceptably addressed acceptance criteria (3).

The NRC staff recognizes that details 2, 3, 4, and 5 on sheet 7-09 of the engineering drawings show the various cover system cross sections. The total thickness of the cover system is 4.5 ft (54 inches). The lower portion of the cover system consists of soil and ranges in thickness from 22.5 inches to 40 inches. The remaining cover system thickness consists of a soil/rock mixture. The NRC staff observes that the cover system does not contain a low permeability layer designed to limit radon flux from the mine waste. This is acceptable to the NRC staff as the cover system will be placed over the mine waste. The existing radon barrier will remain in place to control radon emissions from the existing tailings. In areas where the mine waste is placed over the existing tailings, the mine waste repository and cover system will provide an additional level of protection to the existing radon barrier. According to the licensee, the soil/rock mixture is intended to serve as a 'desert pavement', which will provide erosion protection and support plant growth to aid in the ET properties of the cover system. As discussed in more detail in Sections 3.7 and 4.5 of this SER, the NRC staff finds the desert pavement approach acceptable. The thickness of the soil/rock layer varies depending on the cover slope and upstream drainage area. The NRC staff's review of the bedding layer design for the 20 percent cover slope can be found in Section 3.5 of this SER. The NRC staff recognizes the cover system for the 20 percent slope is 4 ft (48 inches). The NRC staff reviewed the engineering drawings and determined that the thickness of the various layers is clearly identified. As the licensee has identified the thicknesses of the various cover system components, the NRC staff determined that acceptance criteria (4) has been satisfied.

As discussed in the preceding paragraph, the licensee's plans do not call for a low permeability radon barrier within the cover system over the mine waste. The existing radon barrier overlying the existing tailings will be covered by the mine waste and new ET cover. As no radon barrier is planned, the NRC staff determined that the licensee need not provide information to address acceptance criteria (5). The NRC staff's evaluation of radon flux from the new ET cover is provided in Section 6.1 of this SER.

Sheets 7-07 and 7-08 of the engineering drawings show the final grading plan for the proposed mine waste repository. The licensee does not plan to create any penetrations (e.g., monitoring wells) through the planned final cover system. Therefore, the NRC staff determined that the licensee need not provide information to address acceptance criteria (6).

The NRC staff's review of differential settlement and cracking of the cover system can be found in Section 2.3.3 of this SER. Specifically, acceptance criteria (9). As discussed in that section of the SER, the licensee estimated that estimated slope reduction at the transition between the mine waste repository and the existing cover will range from 0.29 to 0.61 percent. The NRC staff observes that the new cover system is designed with a slope of 5 percent; therefore, positive drainage off of the cover will be maintained even after accounting for the reduction in slope at the transition between the mine waste repository and the existing cover. The licensee estimates the horizontal strain in the existing radon barrier will be approximately 0.01 percent, which is less than the calculated tolerable strain of 0.1 percent. The NRC staff reviewed the licensee's horizontal strain calculations and finds that the licensee's evaluation is sufficient for calculating strain in the existing radon barrier. Additionally, the NRC staff did not identify any arithmetic errors. Therefore, the NRC staff determined that acceptance criteria (7) is satisfied.

The licensee's plans and engineering drawings do not call for the inclusion of a geomembrane in the cover system over the mine waste repository. Therefore, the NRC staff has determined that the licensee need not provide information to address acceptance criteria (8).

The NRC staff reviewed the information on the cover design, including site characterization of the borrow areas, how the cover system is incorporated into the slope stability and settlement evaluations, as well as the impact that liquefaction may have on the cover system. During its review, the NRC staff observed that the information used in various aspects of the design was consistent, reflected site conditions, and was correctly incorporated into the design calculations. Therefore, the NRC staff determined that acceptance criteria (9) has been satisfied.

3.5.4 Evaluation Findings

The NRC staff has completed its evaluation of the disposal cell engineering design at the UNC mill site. This included an evaluation using the review procedures identified in Section 2.5.2 and the acceptance criteria outlined in Section 2.5.3 of the SRP (NRC, 2003).

On the basis of the information presented in the LAR the NRC staff's detailed evaluation of the cover system design, the NRC staff concludes that the licensee has acceptably described the cover system design. The licensee provided detailed descriptions of the soil and rock types needed for the cover system, identified the quantities of material required, and identified borrow sources. The licensee provided detailed cross sections showing the thicknesses of the different layers planned for the cover system. The licensee described the field and laboratory tests that were used to determine material properties. The material properties were determined by following procedures identified by ASTM. The licensee's engineering drawings contain details on the layout of the cover system as well as termination at the boundaries. The licensee evaluated the potential for cracking resulting from differential settlement.

On the basis of the information presented in the LAR and the detailed review of the disposal cell cover conducted by the NRC staff, the NRC staff concludes that the cover design over the mine waste repository is consistent with the requirements of 10 CFR Part 40, Appendix A: Criterion 4(c), which provides requirements for the embankment and cover slopes for tailings; and Criterion 6(1), which requires that impoundment design 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.

3.6 Construction Considerations

In this section of the SER, the NRC staff documents its evaluation of construction considerations related to the LAR.

3.6.1 Regulatory Requirements

The NRC staff determines if the licensee has demonstrated that the LAR has met the requirements of 10 CFR Part 40, Appendix A, Criterion 4(c). This criterion provides criteria for embankment and cover slopes. The NRC staff also determines if the licensee has demonstrated that the LAR has met the requirements of 10 CFR Part 40, Appendix A, Criterion 4(d), which requires establishment of a self-sustaining vegetative cover or employment of a rock cover to reduce wind and water erosion to negligible levels, and that the impoundment surfaces are contoured to avoid concentrated surface runoff or abrupt changes in slope gradient. The third regulatory requirement relates to 10 CFR Part 40, Appendix A, Criterion 6(1). This criterion requires that the design provide reasonable assurance to control radiological hazards be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. The NRC staff determined that the requirements of 10 CFR Part 40, Appendix A, Criterion 6A(1), which requires that the radon barrier be completed as expeditiously as practical after ceasing operations in accordance with a Commission-approved reclamation plan does not apply in to this review, as no additional radon barrier is proposed, the current radon barrier will remain in place, and the mine waste material is not directly regulated by the NRC. .

3.6.2 Regulatory Acceptance Criteria

Unless specifically stated otherwise, the LAR was reviewed for compliance with the applicable requirements of 10 CFR 20 and 10 CFR 40 using the acceptance criteria presented in SRP Section 2.6, "Construction Considerations" (NRC 2003).

The acceptance criteria in SRP Section 2.6.3 address: (1) engineering drawings; (2) borrow sources and quantities; (3) methods for excavating, hauling, stockpiling, and placing materials; (4) plans for embankment construction; (5) plans for compaction of soil; (6) testing and surveying to determine the extent of cleanup; (7) settlement monitoring; (8) disposal volumes; (9) procedures, specifications, and requirements for riprap, rock mulch, and rock filters; (10) construction sequencing; (11) vegetation or rock cover design; (12) quality control; and (13) below grade placement of tailings.

3.6.3 Staff Review and Analysis

Unless specifically stated otherwise, the information reviewed in this SER section is from information, data, and maps submitted by the licensee in its LAR (UNC 2018). The licensee presented the information related to the cover system design in Section 3.7 and Appendix G.12 and Attachment G.7 of the LAR. Appendix H of the LAR contains detailed information on the sources of borrow material for the project. Appendix J of the LAR contains the technical specifications for the project.

The licensee included a set of engineering drawings as part of its LAR. The engineering drawings show: the site layout; excavation plans for the mine waste; haul road location, profile, and details; storm water management; mine waste repository grading plan; mine waste repository cover design and details; borrow area locations and excavation plans; and revegetation of the mill site. The NRC staff was able to discern the location and key features of the proposed design, such as the extent of the mine waste repository, cover system components and slope, and erosion protection features. Based on its review, the NRC staff determined that the LAR is consistent with acceptance criteria (1).

As discussed in Section 2.5.3 of this SER, the licensee identified several borrow sources for soil and rock necessary to construct the final cover system and its related features. Appendix H contains the characterization information from the on-site borrow areas. The NRC staff reviewed the information available in Appendix H and recognized that it contained detailed information on the quantity and characterization of soils planned for use in the cover system. The NRC staff observes that Table H.4-1 contains an estimate of the amount of soil needed to construct the proposed cover system. According to Tables H.4-1 and H.4-5, approximately 430,000 cubic yards of soil and approximately 60,000 cubic yards of rock will be needed construct the final cover system. An additional 150,000 cubic yards of rock will be needed for erosion control features on and around the repository. Table H.4-3 contains an estimate of the amount of soil available in the on-site borrow areas. According to that table, approximately 930,500 cubic yards of soil are available for use in constructing the cover system. Based on the information presented in the LAR, the NRC staff observes that sufficient soil volumes are available from on-site borrow areas for use in the final cover system. The NRC staff recognizes that the licensee has evaluated background levels of contamination in the borrow soils, along with index properties, compaction, gradation, and strength parameters. Appendix H of the LAR states that the Ra-226 levels range from 0.8 to 1.7 pCi/g. As the licensee has identified sufficient quantities of material, demonstrated their adequacy, and evaluated background contamination levels, the NRC staff determines that acceptance criteria (2) has been satisfied. Further discussion of the cover soils and the NRC staff's evaluation of the infiltration aspects and hydraulic conductivity can be found in Section 3.7 of this SER.

The licensee included a set of technical specifications for the project in Appendix J of the LAR. The technical specifications provide detailed requirements for performance of the activities described in the LAR. The NRC staff reviewed the information provided in Appendix J of the LAR and observed that the specifications contain information on the methods, procedures, and requirements for excavating, hauling, and placing the mine waste, placement of the cover system, and construction of storm water control features. The NRC staff observes that the specifications do include requirements for material placement and compaction, with limits on these activities during adverse weather conditions. The LAR does not call for the relocation of any existing tailings, therefore, the specifications do not address mixing of fine and coarse tailings. By containing information on methods and procedures, the NRC staff observed that the specifications are consistent with those commonly used in engineering practice for earthworks projects. Therefore, the NRC staff determined that acceptance criteria (3) has been satisfied.

The licensee's plans in the LAR do not call for construction of a new embankment. Rather, the LAR calls for placement of the mine waste in a repository on top of the existing surface impoundment. As no embankment construction is planned, the NRC staff determines that the licensee need not provide information to address acceptance criteria (4).

As discussed above in the NRC staff's review of acceptance criteria (2), the licensee has performed compaction testing on the soils to understand the moisture-density relationship. The NRC staff's review of the stability of the mine waste repository and existing surface impoundment in Section 2.2 of this SER concludes that the repository will remain stable over the performance period. As geotechnical stability has been demonstrated and reflects the results of the compaction tests, the NRC staff has determined that acceptance criteria (5) has been satisfied.

The LAR describes UNC's approach to excavating mine waste and relocating it to a repository constructed on top of the existing surface impoundment. The cleanup levels and extent of the cleanup required are described in the Administrative Order on Consent (AOC) that was developed by EPA and UNC. As the mine waste subject to cleanup and placement in the mine waste repository is not subject to direct regulation by the NRC, the NRC staff determined that the licensee need not provide information to address acceptance criteria (6).

Appendix G.9 of the LAR discusses the licensee's evaluation of settlement of the mine waste and underlying tailings. The licensee plans to monitor the surface of the mine waste repository during construction to that the appropriate slopes and fill depths are maintained. The NRC staff recognizes that the LAR does not call for emplacement of a radon barrier on top of the mine waste repository. Rather, the planned cover system is a layer of rock/soil mixture (referred to as a 'desert pavement') underlain by soil. The cover is designed to function as an ET cover and has a total thickness of 4.5-ft. As no radon barrier is planned for the ET cover (note that the existing radon barrier for the mill tailings will remain in place), the NRC staff recognizes that the cover soils and soil/rock layer can be placed at any time during construction once the final grades have been reached. Therefore, the NRC staff determined that acceptance criteria (7) has been satisfied.

Appendix C of the LAR contains the licensees estimates of the amount of mine waste identified for placement into the mine waste repository. The licensee determined that approximately 783,000 cubic yards of mine waste will be excavated and placed into the mine waste repository (LAR Appendix C.4.4.1). The NRC staff reviewed the licensee's approach for estimating the volume of mine waste and observes that it is based on the known site conditions and the difference between the existing ground surface and the anticipated post excavation topography. Appendix G.1 presents the design objectives for the repository. The licensee designed the mine waste repository to have a capacity for approximately 1 million cubic yards of mine waste. The NRC staff reviewed the licensee's approach for estimating the available volume in the mine waste repository and observes that it is based on the difference between the existing topography and the proposed height of the mine waste. The NRC staff observes that the licensee has designed the mine waste repository to have approximately 30 percent more capacity than is expected to be needed. Based on its review, the NRC staff determined that the licensee has identified sufficient capacity for the mine waste. Therefore, the NRC staff determines that acceptance criteria (8) has been satisfied. The licensee has demonstrated that sufficient volume is available to place the anticipated quantity of mine waste. If less mine waste is encountered than anticipated, the licensee has the flexibility to reconfigure the design to use either shallower slopes or a lower overall height, provided that the same rip rap sizes are used for erosion protection. If the licensee identifies additional mine waste for placement and steeper slopes or a greater quantity of mine waste volume is required, the licensee will need to request subsequent authorization for such further modification. Therefore, NRC staff is imposing the following license condition to provide an upper bound on the slopes and mine waste height that can be constructed without requiring additional review and approval by the NRC staff, consistent with the evaluation in this SER:

> *The licensee shall conform to the final grading plan shown on engineering drawing sheet 7-07 of the LAR. Deviations from this plan that result in steeper slopes, longer slope lengths, or a higher final elevation shall be requested by license amendment and reviewed by the NRC staff.*

Appendix J contains the technical specifications for the project, including requirements for the soil/rock mixture and filter material. The NRC staff's review in this section is focused on the adequacy of the specifications; the NRC staff's review of the design and analysis methodology is presented in Section 3.5 of this SER. The NRC staff observes that the specifications identify the gradation requirements for the rock components of the cover system. Additionally, the NRC staff observes that the specifications contain requirements for both placement of the rock components and frequencies for quality control testing. Based on its review of the information in Appendix H, the NRC staff determines that the specifications are consistent with commonly accepted engineering practice as they contain information on methods and procedures. Therefore, the NRC staff determines that acceptance criteria (9) has been satisfied.

Appendix K of the LAR contains the licensee's schedule for the project. In addition to the construction schedule, the licensee also provided a series of engineering drawings showing the phasing of the mine waste placement (engineering drawings 7-02 and 7-03). The NRC staff recognizes that the LAR does not call for the placement of new mill tailings or relocation of the existing tailings. Additionally, the NRC staff recognizes that the existing radon barrier will remain in place, so the acceptance criteria related to expeditious placement of the radon barrier is not relevant to this proposal. The NRC staff reviewed the project schedule in Appendix K and construction sequencing drawings (engineering drawings 7-02 and 7-03). The NRC staff observed that the construction schedule is reasonably achievable based on the assumptions discussed in Appendix K. According to the schedule, the licensee plans to complete construction of the mine waste repository in slightly more than 4 years. The NRC staff observes that the construction sequencing drawings limit the height of mine waste that is placed at one time, which results in a series of lifts for mine waste placement. This approach will minimize the potential differential settlement of the existing tailings. Based on its review of the schedule in Appendix K and the construction sequencing drawings, the NRC staff determines that the licensee has developed a reasonable schedule for the project. Therefore, the NRC staff finds that acceptance criteria (10) is satisfied.

Appendix G.12 as well as Attachments G.7 and G.8 of the LAR contain the details of the licensee's approach to design of the erosion control aspects of the cover system. Briefly, the cover system is designed as an ET cover. The 20 percent slope on the northeast portion of the mine waste repository will be a rip rap slope. The remaining portions of the cover system will be a mixture of rock and soil, which is intended to provide a rooting medium for vegetation. The NRC staff's detailed review of the erosion control aspects of the cover can be found in Section 4 of this SER.

Appendices J and V of the LAR contain the licensee's technical specifications and construction quality assurance plan, respectively. The NRC staff reviewed the information in Appendix J and observed that the technical specifications include material properties to be evaluated, acceptable ranges, and minimum testing frequencies. In reviewing Appendix V, the NRC staff observed that the licensee identified roles and responsibilities for construction quality assurance, as well as identifying its planned approach for recordkeeping. The NRC staff observed that the licensee will perform daily recordkeeping of activities at the site, will generate detailed daily construction reports documenting specific activities and reports of material testing results, and record drawings. Based on its review of the information provided in Appendices J and V of the LAR, the NRC staff determines that the licensee's approach to construction quality control and documentation is consistent with engineering practice as it contains information on testing requirements and minimum testing frequencies. Therefore, the NRC staff determines that acceptance criteria (12) has been satisfied.

The LAR does not call for relocation of the existing tailings or placement of any new tailings. Therefore, the NRC staff determines that the licensee need not provide information to address acceptance criteria (13). The NRC staff recognizes that the existing tailings are placed at or below the existing grade, and that the existing radon barrier will remain in place below the mine waste and ET cover.

3.6.4 Evaluation Findings

The NRC staff has completed its evaluation of construction considerations of the LAR. This included an evaluation using the review procedures identified in Section 2.6.2 and the acceptance criteria outlined in Section 2.6.3 of the SRP (NRC, 2003).

The licensee has acceptably described applicable construction considerations by (1) providing complete engineering drawings showing all design features; (2) describing sources and quantities of borrow source material; and (3) identifying methods, procedures, and requirements for excavation and placement. Proposed compaction specifications are supported by laboratory testing. The licensee has demonstrated that sufficient capacity is available within the mine waste repository. Procedures, specifications, and requirements for riprap, soil/rock mix, and filter layers are provided and consistent with accepted engineering practice. The licensee has provided an acceptable construction schedule. Appropriate quality control provisions are in place to ensure that construction would occur as proposed in the LAR and that appropriate records will be maintained.

To clarify the upper bound on the slopes and mine waste height consistent with the LAR and the NRC staff's review, the following license condition is proposed.

> *The licensee shall conform to the final grading plan shown on engineering drawing sheet 7-07 of the LAR. Deviations from this plan that result in steeper slopes, longer slope lengths, or a higher final elevation shall be requested by license amendment and reviewed by the NRC staff.*

On the basis of the information presented in the LAR and the NRC staff's detailed evaluation of the construction considerations at UNC mill site and the license condition proposed above, the NRC staff concludes that the information related to construction considerations in the LAR is sufficient to support a decision with reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 4(c) are met. This criterion provides criteria for embankment and cover slopes. The NRC staff also determines that the licensee has demonstrated compliance with the requirements of 10 CFR Part 40, Appendix A, Criterion 4(d), which requires establishment of a self-sustaining vegetative cover or employment of a rock cover to reduce wind and water erosion to negligible levels, that the impoundment surfaces are contoured to avoid concentrated surface runoff or abrupt changes in slope gradient. The NRC staff determines that the LAR meets the regulatory requirement in 10 CFR Part 40, Appendix A, Criterion 6(1). This criterion requires that the design provide reasonable assurance to control radiological hazards be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. Finally, the NRC staff determines that Criterion 6A(1), which requires that the radon barrier be completed as expeditiously as practical after ceasing operations in accordance with a Commission-approved reclamation plan does not apply in to this review, as no additional radon barrier is proposed, the current radon barrier will remain in place, and the mine waste material is not directly regulated by the NRC.

3.7 <u>Infiltration and Hydraulic Conductivity of the Repository and Its Cover</u>

In this section of the SER, the NRC staff documents its evaluation of those parameters and processes associated with infiltration, including potential recharge into the repository and tailings and the estimated hydraulic conductivities of the cover components and the mine waste repository. Although the emphasis in NRC's NUREG-1620 is on minimizing hydraulic conductivity in order to limit radon emissions from and water infiltration into mill tailings, the emphasis for this evaluation will be on the processes associated with infiltration. This shift is due to the type of engineered cover proposed by UNC/GE, which is based on the principle of keeping water out the mill tailings and the mine waste by the process of evaporation and transpiration, i.e., evapotranspiration, or ET, and not by resistance due to the presence of low hydraulic conductivity radon barrier. In addition, the repository will place mine waste on top of the mill tailings, which will reduce the radon emissions from the tailings. The NRC staff's evaluation of the ET cover system's radon performance can be found in Section 6.1 of this SER. The hydraulic conductivity of ET cover components may increase over time; however, the performance of the cover is still anticipated to prevent excessive seepage impacts due to the properties of an ET cover. Therefore, NRC staff focused its review on the performance of the proposed ET cover with respect to the infiltration assumed to flow through the mine waste and tailings. Less focus was given to the performance of the ET cover components in limiting radon emissions in the discussion below as Section 6 of this SER evaluates that aspect in detail.

3.7.1 Regulatory Requirements

The NRC staff determines if the licensee has demonstrated that the LAR has met the requirements of 10 CFR Part 40, Appendix A, Criterion 4(d), which requires establishment of a self-sustaining vegetative cover. Places where a full vegetative cover is not likely to be self-sustaining due to climatic or other conditions, such as in semi-arid and arid regions, rock cover must be employed on slopes of the impoundment system. For ET covers, evaporation and transpiration are the main processes whereby water is removed from the upper cover soils. Without a self-sustaining vegetative cover, the transpiration on the cover would not contribute to reducing infiltration into the mine waste and tailings.

The NRC staff also determines if the licensee has demonstrated that the LAR (UNC, 2018) has met the requirements of 10 CFR Part 40, Appendix A, Criterion 5F. This criterion states that where groundwater impacts are occurring at an existing site due to seepage, action must be taken to alleviate conditions that lead to excessive seepage impacts and restore groundwater quality. In this case, NRC staff is evaluating if excess infiltration through the cover system will lead to excessive seepage impacts through the mill tailings and into the groundwater system due to additional contaminated water being released with from the tailings. Precipitation causing excess infiltration through the cover system could also have the potential to accumulate in the mine waste above the recompacted radon barrier of the original mill tailings cover.

The third regulatory requirement relates to 10 CFR Part 40, Appendix A, Criterion 6(1). This criterion requires that the design provide reasonable assurance to control radiological hazards be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.

3.7.2 Regulatory Acceptance Criteria

Section 2.7 of the SRP (NRC, 2003) provides guidance to the NRC staff on the review of disposal cell hydraulic conductivity aspects of the design. The regulations in 10 CFR Part 40, Appendix A, Criterion 6 requires construction of an earthen barrier over 11e.2 byproduct material. Typically, the earthen barrier consists of a low permeability layer to limit infiltration of water through the cover system and limit the radon flux leaving the cover to less than 20 pCi/m^2s. However, the material being placed on top of the existing surface repository is mine waste, it is not material directly regulated by the NRC. The NRC staff recognizes that the existing radon barrier will remain intact and will be covered by the mine waste and its ET cover. While the NRC staff is reviewing the LAR for consistency with the Appendix A criteria, certain aspects of these criteria are not relevant to the review as a result, as described above in Table 2. As the LAR calls for placement of mine waste and not mill tailings, the licensee is not required to place a radon barrier on top of the mine waste. The NRC staff recognizes that the licensee's proposed cover system is designed to meet the radon flux standard of 20 pCi/m^2s by relying on the overall thickness of the cover system rather than the presence of a low permeability barrier to meet the radon flux standard. As the material being placed is mine waste and no low permeability/radon barrier layer is required or planned beyond that already in place above the mill tailings, the licensee need not address all of the acceptance criteria in Section 2.7.3 of the SRP since some criteria relate to design, construction, and construction schedule of the radon barrier and its hydraulic conductivity (e.g., criteria in Section 2.7.3(3) and Section 2.7.3(4)). The existing radon barrier was approved by the NRC in 1991 (NRC, 1991). The NRC staff does not anticipate that the mine waste placement will impact the ability of the existing radon barrier to perform its intended function. To address criterion Section 2.7.3(1), a sufficient technical basis should be provided for the design hydraulic conductivity (K) values. This should be addressed in the LAR since the design hydraulic conductivity values of the upper layers of the repository affect the rate of evapotranspiration and therefore the seepage or deep percolation rate through the mine waste material and subsequently the mill tailings. The criterion in Section 2.7.3(2) states that if field testing is required, the 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.

Increased infiltration rates into and through the mine waste has the potential to create a perched condition above the recompacted existing radon barrier and the mill tailings and within the mine waste. Failure of the side-slopes or slope instability could result due to pore water pressure increasing. On the other hand, if hydraulic conductivity values of the recompacted existing radon barrier are sufficiently high so that infiltrating water does not create a perched zone within the mine spoils but rather continues to flow downward through the tailings, contaminants within that downward flowing seepage have the potential to add contaminants to the groundwater. Therefore, NRC staff reviewed information associated with the design hydraulic conductivity of the recompacted radon barrier and other component layers in addition to the range of parameters such as assumed future precipitation rates, precipitation duration, snow cover, temperature and sunshine, vegetation type, root depth, and developing soil structure. These parameters help determine the rate of ET and, ultimately, the amount of precipitation remaining to infiltrate down into and through the mine waste and tailings. Model calculations of ET will be evaluated as will the conceptual models of water flow within the repository and disposal cells from the initial precipitation to potential seepage through the mill tailings. Equally important is consideration of the full range of uncertainty associated with evaporation and transpiration processes, and that the model results are supported by other data, such as field results, lab results, and related publications.

NRC staff evaluated the technical basis of the LAR against the criterion in 10 CFR Part 40, Appendix A, Criterion 4(d). This criterion requires the establishment of a self-sustaining vegetative cover. NRC staff reviewed information in the LAR that pertains to flora in the general region of the disposal site and any anticipated changes to that vegetation due to invasive species or other factors. NRC staff also evaluated the feasibility of the cover system to host vegetation similar to the immediate surrounding area of the disposal cells, i.e., availability of the plants to obtain sufficient water and nutrients from the top cover layers as they would from the immediate surrounding area. If the licensee intends to plant and maintain a vegetation type different from the surrounding area, i.e., a separate or distinct ecology, the technical basis for the viability of this distinct ecology must be adequate.

3.7.3 Staff Review and Analysis

In this section of the SER, the NRC staff documents its findings as to whether an adequate technical basis has been presented for those parameters and processes associated with the infiltration rates, including estimated hydraulic conductivities of the cover components, through the mine waste repository and mill tailings.

Unless specifically stated otherwise, the information reviewed in this SER section is from information, data, and maps submitted by the licensee in its LAR (UNC 2018). The licensee presented the information related to the cover system design in Section 3.7 and Appendix G, Attachment G.7 including Appendixes A-C; Appendix Y; Appendix U; “Vegetation Characterization and Biointrusion Surveys” by Cedar Creek Associates (2014); and Volume II “Design Drawings” of the LAR. In addition, UNC/GE responded to NRC RAIs sent July of 2019 (NRC, 2019b). UNC/GE responses were submitted in two parts, the first in October of 2019

(UNC, 2019a) and the second in November of 2019 (UNC, 2019b). After reviewing the responses, NRC staff had subsequent clarifying questions regarding the responses. UNC/GE replied to these clarifying questions on March 2, 2020 (UNC, 2020a), March 12, 20202 (UNC, 2020b) July 8, 2020 (UNC, 2020c), and July 31, 2020 (UNC, 2020d). A supplemental submittal was transmitted to the NRC on November 18, 2019 (UNC, 2019c) including revised Appendices A, G, and H (UNC, 2019d). This occurred because of changes to the design involving the future availability of surplus sediments near the jetty area. The cover thickness increased from 4 ft (1.2 m) to 4.5 ft (1.4 m) and the analyses related to repository construction were revised to be based on the jetty excavation being the primary source for cover borrow. It is unclear to NRC staff why UNC/GE didn't complete their analysis on the suitability of using jetty soils as repository cover soils before the original license amendment was submitted in 2018. However, the NRC staff understand that the jetty soils are the primary borrow source for the ET cover system.

Appendix U, Attachment U.2 of the LAR contains the details of the licensee's intended revegetation plans for the future mine waste repository on the tailings at the mill site. These plans identify and define revegetation protocols, vegetation sampling methods, monitoring schedule and success criteria to be utilized for revegetation of the repository, and list possible post-revegetation management actions. "Vegetation Characterization and Biointrusion Surveys" by Cedar Creek Associates (2014) documented evaluation results from selected analog sites of specific parameters related to the successional communities expected to progressively inhabit the repository over the performance period. The data gathered was later used as parameter input in the UNSAT-H simulation discussed below, e.g., ground cover results were analyzed to present Leaf Area Index (LAI) for each projected community. Vegetative root density and depth were characterized through field sampling using excavated soil pits, and an animal biointrusion evaluation determined the potential for future colonization of the proposed repository based on the local fauna populations' existing habitat and the various scenarios for long-term vegetated cover and communities. Sampling of fauna, however, appears to have been limited to mammals.

Based on Appendix U of the LAR and Cedar Creek (2014), the expected ecological succession includes the reclaimed community to be dominated by fourwing saltbush and grassy/weedy species followed by a grassland community including such species as blue grama and broom snakeweed. Finally, big sagebrush is expected to invade to form the shrubland community. Succession is assumed to be as follows: reclaimed community from 0 to 50 yrs., grassland community from 25 to 100 yrs., and shrubland community from 50 to 1,000 yrs.

NRC staff included an RAI on the proposed vegetative cover in a letter to UNC/GE from July 31, 2019 (NRC, 2019b). RAI 3.8-6 asked UNC/GE to provide additional information on the effect of ant colonies on cover soil properties and on the effect of the root system of the fourwing saltbush which may extend 2 to 6 m (6.6 to 20 ft) below the surface and the root system of big sagebrush extending 1 to 4 m (3.3 to 13 ft) below the surface, specifically if soil hydraulic conductivity values will be altered or if mine spoil material will be brought to the surface. UNC/GE's response (UNC, 2019a) stated that ants and roots could transport small amounts of waste to the surface; however, that the planned mine spoils placement and new ET cover increases the distance between the surface and the more radioactive mill tailings thereby reducing existing risks associated with biointrusion. The NRC staff finds that the licensee's explanation is sufficient in addressing the impact of bioinstrusion on the cover system.

The Design Drawings in Volume II included a set of engineering drawings as part of its LAR. Of especial interest were the engineering drawings shown in Section 7 - Mine Waste Repository

Design. The NRC staff reviewed the engineering drawings and observed that the drawings were presented at a reasonable scale. The NRC staff was able to discern the location and key features of the proposed design, such as the extent of the mine waste repository, cover system components and slope, and erosion protection features.

Appendix G, Attachment G.7 of the LAR contains the details of the licensee's approach to the design of the cover system. The evapotranspiration (ET) cover over the mine waste will be 4.5-ft thick (1.4 m) thick and composed of compacted cover soil overlain by a rock/soil admixture (Figure 3 shows a similar profile but with a 4 ft cover thickness). The cover soil layer beneath this erosion protection surface layer is from the jetty area (UNC, 2019d). The surface rock/soil admixture on top will be designed to minimize erosion while providing a rooting medium for native vegetation and is designed to provide adequate storage capacity to minimize flux through the cover. All admixture profiles contain 33 percent rock to 67 percent soil by volume with the mixed soil coming from an engineer-approved borrow source and the rocks from an engineer-approved vendor or on-site stockpile meeting cover design and durability requirements. The rock size of the soil admixture layer ranges from 1.5 in (3.8 cm) diameter to 3.5 in (8.9 cm) diameter (UNC, 2019d) (prior range 1.5 in (3.8 cm) diameter to 3 in (7.6 cm) diameter (UNC, 2018)); and layer thickness range is 14 in (36 cm) to 31.5 in (80 cm) (UNC, 2019d) (prior range was 14 in (36 cm) to 27 in (69 cm) (UNC, 2018)). The reason for the admixture design change is due to the inclusion of the soil to be excavated from the jetty area with the original borrow soil. The soil from the jetty area has a maximum fines content of 96% compared to the previously approved cover soil borrow sources, which was 57%. In part as a result of this difference in fines content, the licensee revised its proposed cover system to increase the thickness of the to 4.5 feet. The thickness of the rock/soil admixture layer and cover soil layer varies depending on the location and respective slope length with the thickest admixture layer being 31.5 in (80 cm) with a rock size of 3.5 in (8.9 cm). The NRC staff's review of the ability of the cover system to minimize infiltration is provided below.

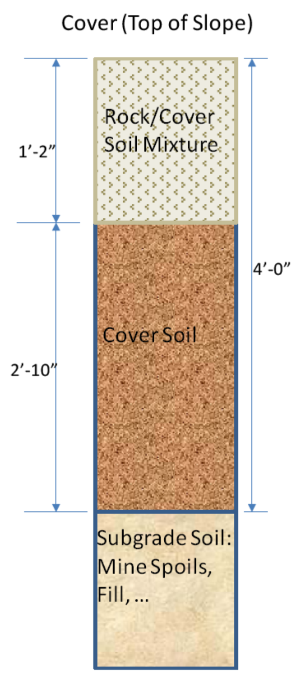

Figure 3: Figure 13 from Appendix G, Attachment G.7 of the LAR

(Source: UNC, 2020)

Section 7 in Attachment G.7 and Attachment A in Appendix Y summarized the sensitivity analyses evaluating the input parameters. Most tables summarizing model output did not include data on the soil water storage capacity or change in water storage of each layer, an important water budget component of the model runs, and which would have provided NRC staff with useful information for developing potential conceptual models of water flow within the repository system (see page 16 in UNC (2019a)). The impact of the lack of this information on the licensee's model output is described below. Using the UNSAT-H code, the licensee's sensitivity analysis evaluated the 4.5-ft-thick cover system's effectiveness for the 1,000-year performance period. The UNSAT-H modeling output (shown in Figure 1 of UNC (2019d)) also showed that for typical climatic conditions, a 2.3-ft (0.7 m) cover thickness minimized flux and that a cover thickness of 4.5 ft (1.8 m) effectively minimized flux even while applying the wettest year on record in two consecutive years. In addition, the document stated that the analyses demonstrated that the 4.5-ft cover has adequate storage capacity to withstand the worst-case scenarios expected over the 1,000-year performance period combined with some expected soil loss due to erosion. The thickness of the vegetated ET cover was obtained after model results showed that 4.5 ft provided the required storage capacity needed to minimize flux based on the application of the wettest year on record two years in a row with most of the rainwater flowing downward as infiltration.

During its review, the NRC staff sought additional clarifying information on the licensee's detailed UNSAT-H model output but was unable to obtain the detailed model output in a form that facilitated NRC review. Without the detailed model output, however, the NRC staff was not able to validate the licensee's analysis. This lack of model outputs in this area is part of the reason the NRC staff is modifying the license condition related to ground water monitoring. This is further discussed below in Section 3.7.4. In the licensee's analysis, the most sensitive parameter was stated to be the precipitation rate. The NRC staff recognizes the impact the precipitation rate can have on the analysis and finds that the licensee's approach is adequate for the purposes of modeling water flow through the ET cover system. Additional sets of sensitivity analyses were documented in Appendix G, Attachment G.7, Appendix C (UNC, 2018) showing the results of cover profiles without any vegetation for an extended period of time. The results of the analyses show that even under these conditions, a minimal amount of flux is produced and that this flux is many orders of magnitude less than the flux through the existing cover on the impoundment according to Dwyer (2017) and as seen Table 15 in Appendix Y (UNC, 2018). [Additional information as to this last point: The current cover's surface runoff system has degraded, e.g., branch swales and other runoff features have filled in with sediments, and runoff no longer completely leaves the disposal cell during heavier rainfalls. Figure 4 shows ponding on the surface of the cover in 2015.]


Figure 4: Ponding on the existing disposal cell cover at the Church Rock Site after a rainfall event in 2015.

Appendix Y (UNC, 2018) of the LAR contains the results of the licensee's analysis of the potential effect of the added weight of the mine waste on the underlying mill tailings and subsequently on the underlying groundwater. Mine waste will be disposed of in a repository designed within the footprint of the existing tailings impoundment at the mill site. Rocks and rip-rap on top of the current cover at the Church Rock site will be removed before placement of the mine waste and later reused at the surface. The original disposal cells with tailings will not be altered and the original radon barrier will also be left in place. Figure 5 shows a profile of the future repository and disposal cell in a borrow pit area (Borrow Pit #1). Placement of the mine spoils and subsequent ET cover components will place added weight, and thus stress, on the existing tailings material originally placed within the existing impoundment. Appendix Y states that there is a relatively small reduction in porosity in the tailings due to the added weight on the existing impoundment and that the coarse and fine tailings become fully saturated in some of the profiles. However, the licensee states there is no increase in flux into the underlying groundwater from the tailings and therefore no drainage impact into the underlying groundwater. Similar to the UNSAT-H simulation results performed in Appendix G, Attachment G.7, findings from these sensitivity analyses show that the new ET cover components prevent flux while the existing cover did allow percolation into the disposal cell, but no downward flux from the base of the alluvium.

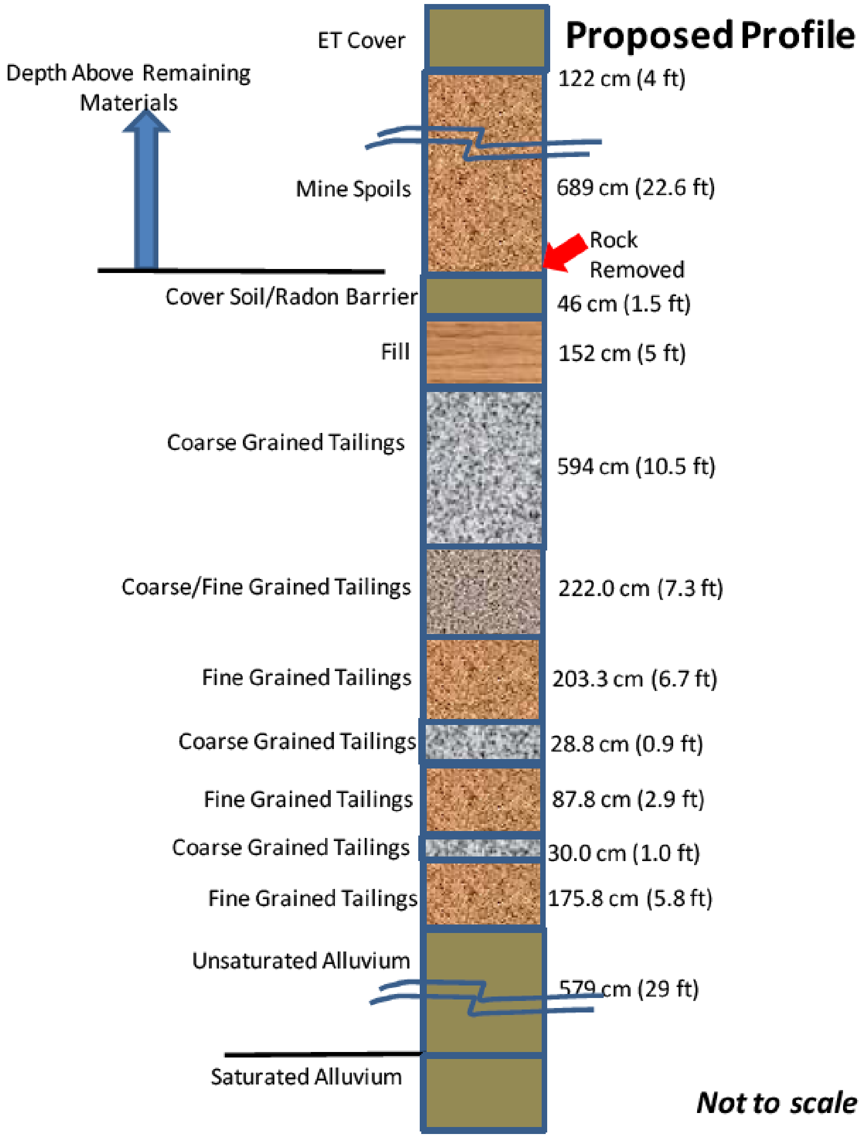

Figure 5: Proposed profile of the future repository and disposal cell in a borrow pit area.

However, the revised ET cover layers now has a total thickness of 4.5 feet (UNC, 2019d). [Source: Modified figure of Figure 10 from Appendix Y of the LAR (UNC, 2018)]

The conclusion derived from the calculations and analyses documented in the appendices and sections of the LAR and discussed above is given on page 64 in Appendix G, Attachment G.7 of the LAR (UNC,2018): “That is, no annual net percolation will pass through the vegetated cover system even in the worst case scenario.” The licensee concluded that no percolation or seepage from surface water will flow through the mine waste and mill tailings into the groundwater for hundreds of years. Such a statement requires a robust technical basis with supportive evidence to significantly reduce any associated uncertainty. The NRC staff evaluated the simulations performed by UNSAT-H and the model support provided, and the results of this evaluation are documented in the sections below.

Model support is one of the most essential technical elements of a licensee's analyses to support calculations making projections many years into the future, which cannot be validated in the traditional sense. Support for the model calculations is essential for effective decision making and can help reduce uncertainty. The LAR included an assessment of the effectiveness of undisturbed native soil profiles on or near the NECR site. Appendix G, Attachment G.7 noted that soils in semiarid and arid regions commonly have carbonate-rich horizons at some depth below the surface known as caliche layers. Caliche generally forms when minerals leach from the upper layer of the soil and accumulate in the next layer generally consisting of carbonates. At the end stage of this process thicker layers of caliche may form. Plants can contribute to the formation of caliche when plant roots take up water through transpiration, and leave behind the dissolved calcium carbonate, which precipitates to form caliche. The LAR stated that the depth of the calcium carbonate-bearing horizon is related to the depth that precipitation infiltrates before it is removed via ET. Although the depth of the caliche may indicate the limit that infiltrating will reach, literature on this topic does not show that that this has to be true, and the LAR provided no references for this statement. The licensee found increased concentrations of salts near the Church Rock site around 2 ft (61 cm) below ground surface and stated that extreme infiltration events could potentially move water deeper than this, but as the area dried this moisture would likely move back up in the profile and be removed by ET. However, no additional evidence or references were provided that would support the statement on upward movement of water through the caliche layer, e.g., moisture content data from below the cliché layer, or below 4.5 feet, could have provided additional insights. This lack of evidence or references is part of the reason the NRC staff is modifying the license condition related to ground water monitoring to include water level and water quality monitoring at the downgradient wells closest to the tailings impoundment. This is further discussed below in Section 3.7.4.

Appendix G, Attachment G.7 of the LAR also referenced and discussed a study or large-scale demonstration performed at Sandia National Laboratory in Albuquerque, NM. This project evaluated alternative covers side-by-side with prescriptive cover profiles and included six cover designs tested in this demonstration project: two baseline cover profiles (prescriptive RCRA Subtitle 'D' and Subtitle 'C' covers respectively) and four alternative cover designs (an ET Cover, two different Capillary Barrier System designs, and a cover featuring a Geosynthetic Clay Liner (GCL)) (UNC, 2018). Water was evenly applied to the plots and included simulated thunderstorms as well as melting of snow during low transpiration periods. The results showed that a well-designed ET Cover profile composed of 3.5 feet (107 cm) of native soil produced zero flux after vegetation was well established and performed as well as or better than a prescriptive cover with a resistive layer.

The NRC staff had asked UNC/GE about validation studies similar to the conceptual model of ET for the future Church Rock repository that supports the LAR's UNSAT-H modeling or simulation results. UNC/GE responded (UNC, 2020a) by referring to the previously discussed demonstration performed at Sandia National Laboratory and also to Scanlon et al. (2005). Although there were similarities at both sites to the Church Rock site, there were also key differences. The evapotranspirative covers work extremely well in these regions because of the dominance of summer precipitation (62–80%) that corresponds to periods of highest ET. This produces strong relationships between decreases in soil water storage and vegetation productivity at both sites studied and underscored the importance of vegetation in controlling the water balance in the cover systems. The Church Rock site differs from the studied sites above in that it obtains less than half of the annual precipitation in the summer months of June, July, and August (Figure 14 in Appendix G, Attachment G.7 of the LAR), and the process of evaporation outperforms the process of transpiration in UNSAT-H simulations (see Appendix C in Appendix G, Attachment G.7 of the LAR). The highest flux reported in Appendix C was less than a third of a centimeter per year without vegetation which contrasts with the reliance on transpiration in the study by Scanlon et al. (2005). As a result, the NRC staff recognizes that the cover at Church Rock is more reliant on evaporation.

The potential evapotranspiration (PET) rate used in the UNSAT-H simulations equaled 211.7 cm/yr (83.4 in/yr). Based on comparative PET maps of the United States, this value is relatively high; most show rates less than 2 meters per year. The NRC staff had asked for references or publications about the Southwest or maps showing annual potential ET values ~2 m/yr. UNC/GE responded (UNC, 2020b) by providing a comparative simulation reducing the annual PET values from 211 cm to 158 cm. The results showed that this range of annual PET rate was relatively insensitive in determining the overall water balance of the cover system (see results to the right of PET in Table 4) and since the inflow is less than the outflow that the 4.5 ft-cover was slowly drying out (NRC staff assumed that all the values in the tables were in centimeters).

Table 4: Table given in UNC (2020b)

Shows simulation results in centimeters per year for a cover with an admixture consisting of 1.5-in rock, analog soil, and shrub vegetation and with an annual PET of 211.74 cm (top table) and 158.65 cm (bottom table).

Original Annual Summary							
Year	Precip	PET	Transp	Evap	Runoff	Drain	Store
----	-------	-------	-------	-------	-------	-------	-------
Initial	storage	=					29.76
1	29.74	211.74	7.93	25.27	0.00	0.01	26.34
2	29.74	211.74	6.91	24.77	0.00	0.01	24.44
3	29.74	211.74	6.35	24.73	0.00	0.01	23.13
4	29.74	211.74	5.99	24.71	0.00	0.01	22.20
5	29.74	211.74	5.76	24.71	0.00	0.01	21.51
6	29.74	211.74	5.60	24.71	0.00	0.01	20.98
7	29.74	211.74	5.49	24.71	0.00	0.01	20.56
8	29.74	211.74	5.41	24.71	0.00	0.01	20.21
9	29.74	211.74	5.36	24.71	0.00	0.01	19.93
10	29.74	211.74	5.32	24.71	0.00	0.01	19.68
Revised Annual Summary							
Year	Precip	PET	Transp	Evap	Runoff	Drain	Store
----	-------	-------	-------	-------	-------	-------	-------
Initial	storage	=					29.76
1	29.74	158.65	6.38	25.71	0.00	0.01	27.45
2	29.74	158.65	5.87	25.36	0.00	0.01	25.99
3	29.74	158.65	5.55	25.32	0.00	0.01	24.90
4	29.74	158.65	5.33	25.30	0.00	0.01	24.05
5	29.74	158.65	5.16	25.29	0.00	0.01	23.37
6	29.74	158.65	5.04	25.28	0.00	0.01	22.82
7	29.74	158.65	4.95	25.29	0.00	0.01	22.36
8	29.74	158.65	4.88	25.28	0.00	0.01	21.97
9	29.74	158.65	4.83	25.28	0.00	0.01	21.64

10	29.74	158.65	4.78	25.28	0.00	0.01	21.36

Section 7 in Appendix G, Attachment G.7 of the LAR provided the results of sensitivity analyses with UNSAT-H. Parameters tested included hydraulic soil parameters based on the remolded values measured in the laboratory (MWH 2014) that are assumed to represent short-term conditions as well as the soil values measured in undisturbed area of the respective borrow sources in situ to assess the condition of the soils long-term. The four stages of vegetation were also evaluated in the sensitivity analyses including no vegetation, reclaimed vegetation, grassland vegetation, and shrubland vegetation. Another variable consisted of the admixture top surface consisting of 33 percent rock to 67 percent soil by volume with smaller rock mixed to a shallower depth, a medium-sized rock to a medium depth, and a larger rock mixed to a relatively deeper depth with cover soil from the same borrow source without the mixture of rock beneath. Each of these varied input parameters showed relatively small sensitivities to the outcome.

An additional sensitivity run was performed by running a precipitation cycle involving 18 average rainfall years (29.74 cm) followed by two of the wettest years on record, i.e., the precipitation rate within the model year 1906 adding up to 60.5 cm. In model year 1906, much of that moisture came as snow from January to April and October to December when the PET is relatively low and transpiration of moisture through vegetation is minimized or completely ceased. This 18 yr plus 2 yr sequence was run three times in total for the long-term simulation runs, i.e., 60 yr plus three years with no vegetation, or 63 yr. This sensitivity analysis determined that precipitation is the most important parameter for the UNSAT-H model simulations. Additional risk insight may have been gained if a variation of differing precipitation years were run besides the 18+2-year cycle. For example, a variation of slightly higher-than-average annual rainfall and drier-than-average rainfall years, or an implausible consecutive runs of higher-than-average annual rainfall years to determine what parameter values are needed to reach the threshold of net seepage into the mine waste and mill tailings. Such threshold values could potentially have been compared to other sites and provided added confidence for the model results. To address this uncertainty, the NRC staff is modifying the existing license condition related to ground water monitoring to include water level and water quality monitoring at the downgradient wells closest to the tailings impoundment. This is further discussed below in Section 3.7.4.

The five-year model runs with average precipitation rates that were documented in Appendix C of Appendix G, Attachment G.7 of the LAR is an example of sensitivity runs that provided risk insights and demonstrated that under these conditions transpiration is not an important component of cover performance since the simulations of the cover showed that it performed very well without vegetation growing on the cover surface. The NRC staff recognizes that this result is rather unexpected for an ET cover and indicates that the soil properties must be ideal for holding and storing water and allowing the evaporation process to pull that water back to the surface to be evaporated.

The documentation of sensitivity cases that may have yielded risk insights would have been comprised of model runs that include days without any evaporation or evapotranspiration and resulting change in water storage for each layer. Although the site is located in a dry climate, there are days and weeks when the weather is consistently cloudy and drizzly and evaporation would be expected to be extremely low, and there are days when the ground is covered with snow, so that evapotranspiration would be expected to be extremely low. Although UNSAT-H cannot model processes associated with snow, it can simulate ET being equal to zero and such days may allow moisture to move deeper and thereby become more difficult for ET processes to reverse the direction of the flow.

It is unclear to NRC staff why evaporation rates are so much higher than transpiration rates for most of the model runs and which parameter may be the most risk significant parameter in determining such an outcome although UNC/GE did provide one possible explanation as described in the paragraph below. The user-defined maximum soil suction value, a value that corresponds to air-dry soil, was defined as a -10^6 cm (-3.9×10^5 in) for these simulations (UNC, 2020a), although using the figure on page 4 of UNC (2020a), it would appear that the slope describing water content vs. suction would indicate a residual moisture content value of -10^5 cm or moister. Little information was provided as to how the user-defined maximum soil suction was obtained or its significance to performance, although it was stated in UNC (2020a) that an assumption of a user-defined maximum soil suction value equal to -10^6 cm was conservative. The simulations are performed without the heat function, i.e., the energy gradients are driven by elevation and suction or head. It is not clear to NRC staff if the proposed surface cover admixture with 33% rocks would affect overall temperature of the admixture layer and the vertical gradient of moisture flow since rocks may require additional energy to heat compared to the surrounding borrow sediments. To address this uncertainty, the NRC staff is modifying the license condition related to ground water monitoring. This is further discussed below in Section 3.7.4.

When heat flow is not being modeled in UNSAT-H, evaporation is calculated using the daily potential evaporation. If the actual suction head of the surface node is drier than the user-defined maximum soil suction, the simulation continues with a constant head boundary in which the suction head of the surface node is equal to the maximum head. For such conditions, the evaporation rate is less than the potential evaporation rate and is calculated as the sum of the change in storage of the surface node and the flux between the surface node and the node below it (PNNL, 2000). When the actual suction head of the surface node is wetter than the maximum suction head, evaporation will equal the potential evaporation. Actual suction heads that are moister than the user-defined maximum soil suction can be seen in Figures 22 in Appendix Y and in the figure on page 15 of UNC (2019a). These figures show soil suction values at the surface closer to a -10^3 cm (-3.9×10^2 in) and show greater soil suction below the surface, i.e., they show a downward gradient.

UNC (2020a) did have an explanation for why the evaporation rates are so much higher than transpiration rates for most of the model runs involving the existing cover system although the excerpt below is discussing the specific sensitivity case results for the existing cover at Profile B2 in a response to RAI 3.8-7(c):

> "The existing condition has a 2-ft cover profile that consists of a rock surface layer with some fine-grained sand. This cover is allowing for significant infiltration of precipitation. Conversely, drying is reduced due to the reverse capillary barrier effect of the coarse over fine-grained soil. Thus, this infiltrated water travels down through the profile into the underlying materials above the bottom fine-grained tailings. The fine-grained tailings have a very low saturated hydraulic conductivity that allows minimal drainage though it. Consequently, the large amount of water that infiltrated in years 11 and 12 is held within the soil layers above the fine-grained tailings, reaching saturation. In fact, the water level above the fine-grained tailings rises toward the surface [12 ft (3.7 m) in the case of Profile B2] and occupies much of the soil layer containing roots. This saturated or near saturated condition eliminates the ability of the plants to transpire where the roots are within soil having suction less than the anaerobic defined value of 30 cm."

Despite the nearly 12 ft (3.7 m) of saturated fill and cover layers, Figure 16 in Appendix Y shows no downward flux from the base of the alluvium for existing conditions. It appears that the water in the saturated layers above the fine-grained tailings is pulled upwards to the surface to undergo evapotranspiration based on the results of the UNSAT-H simulation. If similar simulated conditions occur near other profiles is not clear. Figure 21 representing Profile B8 shows an increase in moisture in the coarse-grained tailings but no saturated condition in the fill layer below the root zone of the existing cover. This makes sense since the fill layer has a calculated initial suction, or soil matric potential, value in the millions of negative centimeters (i.e., thousands of times drier than any other layer within the system) and takes over sixty years in the sensitivity runs to reach moisture levels comparable to other layers (see Figure 21). Unfortunately, the sensitivity runs end when the fill layer has reached a more average soil suction value, and a conceptual model of water flow after this point is unclear. Also unclear is why the fill layer in Profile B2 should become saturated as described above in a mere dozen years with an initial soil matric potential value of -2,692,958,106.4 cm, or -1,060,200,000 in, i.e., similarly dry as the fill in Profile. This lack of clarify is part of the reason the NRC staff is modifying the license condition related to ground water monitoring. This is further discussed below in Section 3.7.4.

The profile run that does allow a hypothetically small but discernable downward flux of water through the base of the alluvium is Profile B11 as simulated in the sensitivity cases. Tables A7 and A8 in Appendix Y show a drainage of approximately half a centimeter per year for the first twenty years. Figure 19 in Appendix Y presents this drainage in a more visual form where the annual flux from the base of the alluvium are positive values for both the existing disposal cell and the future repository/disposal cell. Current UNC/GE designs show less than 1.5 m (5 ft) of cover sediment at the surface, but no mine waste being placed above Profile B11, so that consolidation is minimal (0.03 m or 0.1 ft). Nevertheless, Section 7 in Appendix Y states that drainage water from anywhere below the disposal cell will be captured and held within the alluvium making that unit a potentially significant barrier to increased contaminant concentrations in the groundwater. This difference between the narrative and analysis results is part of the reason that the NRC staff is modifying the license condition related to ground water monitoring. This is further discussed below in Section 3.7.4.

UNC/GE provided responses to NRC clarification comments and questions in UNC (2020d) which pertained to the alluvium and its soil water characteristic curves (SWCCs) together with final simulated saturation values of the alluvium after the weight of the mine spoils had been added to the disposal cell. Information provided by UNC (2020d) indicated that no consolidation occurred in the alluvium because the SWCCs showed no difference between the existing cover and the proposed repository cover. Figure 1 in UNC (2020d) presented identical initial and final simulated soil water content values, 0.25, and identical soil matric potential values, -98.5 cm, showing that no parameter values changed for the alluvium near the base. The top of the alluvium does increase in water content as Figure 2 in UNC (2020d) shows. Figure 6 in Appendix Y (reproduced as Figure 6 below) is an example of a SWCC and demonstrates that changes to this curve can influence the amount of water that can be held in the soil, i.e., the water holding capacity. The initial and final saturation and suction values on the curve in Figure 1 in UNC (2020d) lie to the right of the point where a field capacity of -330 cm (-130 in) intersects the SWCC indicating that there is available water for downward flow through the alluvium. Profile B8 output results in Tables A3 and A4 show more drainage than Profiles B2 and B10; however, the drainage is minuscule (less than 0.0002 cm or 0.00008 in). The initial and final values on the curve in Figure 3 in UNC (2020d) also lie to the right of the point where a field capacity of -330 cm (-130 in) intersects the SWCC indicating that there is available water for downward flow through the alluvium and matching the data presented in Table A7 and A8.

Section 7 in Appendix Y discusses the boundary condition at the base of the alluvium being a unit gradient boundary condition and therefore “forcing drainage based on steady state conditions at the bottom node" and that it “does not necessarily mean there is actually drainage from the alluvium.” A unit gradient lower boundary condition assumes that free drainage exists in the vertical direction, i.e., downward flow due to gravity, and it implies that water that passes downward across the boundary does not return to the simulated domain. This is a standard boundary condition for unsaturated flow models besides a fixed water table or seepage boundary. Drainage water is part of the water budget of the model as seen in the tables of Appendix A of Appendix Y and should be accepted as drainage since water not bound to the soil particles will be pulled downward by gravity.

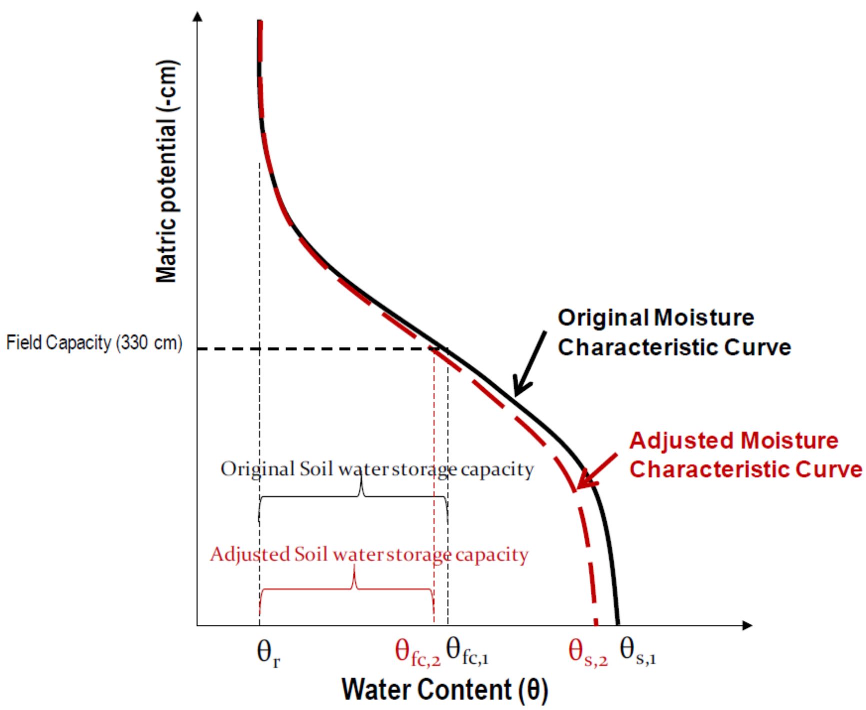

Figure 6: Hypothetical soil water characteristic curves before and after consolidation.

Although field capacity is unchanged, the retention curve has changed so that the adjusted soil water storage capacity is smaller than the before consolidation. [Source: Figure 6 from Appendix Y of the LAR (UNC, 2018)]

NUREG/CR-7028 (NRC, 2011) and NUREG/CP-0312 (NRC, 2019a) present results showing changes in hydraulic properties occurring in cover soils. In general, the saturated hydraulic conductivity and the parameters for the SWCC increased, which reflects the formation of larger pores due to pedogenic processes such as root intrusion, insect and animal intrusion, wet-dry cycling, and freeze-thaw cycling. Cracking and the formation of soil aggregates can result including macro-structures in the cover material that can potentially cause greater radon emissions and seepage of contaminants to groundwater (Fuhrmann et al., 2019). NUREG/CP-0312 (NRC, 2019a) presented information on ant colonies and the nests they build, and their existence can substantially change the soil structure. It is not clear to the NRC staff if the hydraulic properties of the analog cover soil included samples that had been altered in this fashion (Dwyer, 2014). The NRC staff observes that the Church Rock site had numerous ant colonies in the existing cover in 2015 (see Figure 7 below). Based on its experience documented in NUREG/CR-7028 and NUREG/CP-0312, the NRC staff would expect that the presence of ant colonies would change the soil structure in the proposed cover at Church Rock. Thus, the modified license condition related to ground water monitoring discussed in SER Section 3.7.4 will be used to verify the performance of the engineered cover system, including any impacts from ant colonies.

Figure 7: One ant colony in the disposal cell cover at the Church Rock Site in 2015.

NUREG/CR-7028 (NRC, 2011) provided an example of how unexpected phenomena can lead to unexpected results. As given in NUREG/CR-7028, data from an ET cover in Sacramento, CA was intended to transmit no more than 3 mm/yr (0.1 in/yr) of percolation; however, approximately 100 mm (4 in) of percolation was recorded to have been transmitted (see Figure 8 below). Water stored during the previous winter was not completely removed so that the cover had inadequate soil water storage capacity the following winters. Perennial vegetation initially established on the cover was unintentionally succeeded by annual species that had a lower wilting point potential (higher water content at the wilting point), shallower roots, and a shorter period of active transpiration, thereby allowing more water to stay in the water storage layer and eventually move downwards.

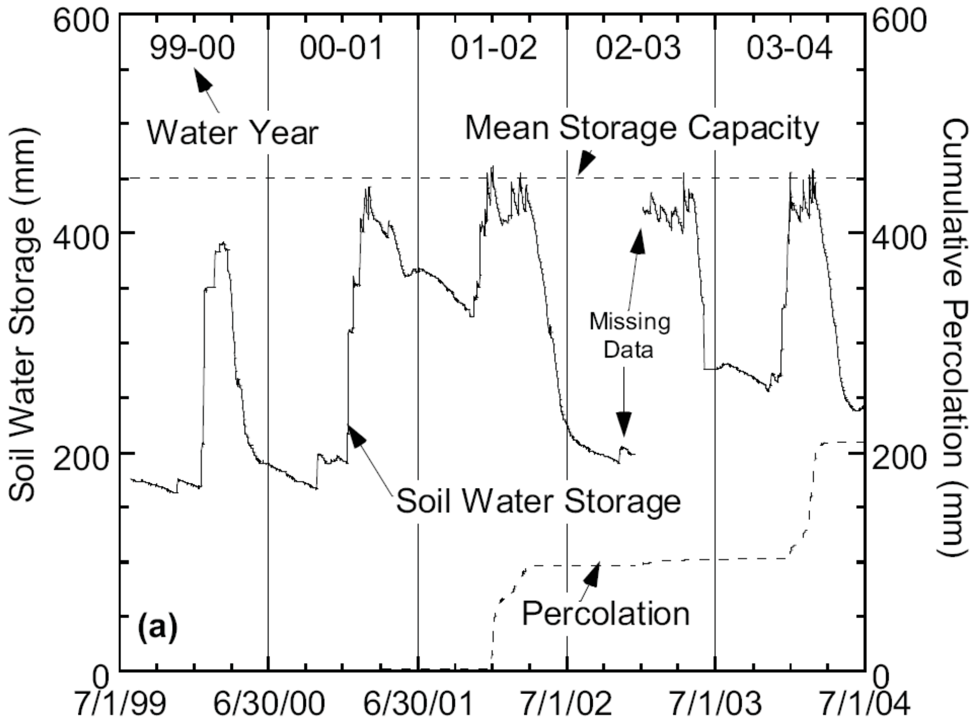

Figure 8: Storage and percolation and water contents at various depths of the ET cover

Based on the issues discussed in this section, the NRC staff concludes that the uncertainty associated with the UNSAT-H infiltration modeling results remains too large. This is not to say that the results are incorrect; future measurements or data may show that the flux predicted by the UNSAT-H simulations are correct. However, currently, the uncertainty has not been bounded and there is insufficient model support to unequivocally claim that no net seepage through the mine waste and mill tailings will ever occur for the performance period. Unforeseen, slow or fast paced detrimental events do happen in the natural world and the resulting increased parameter ranges may not have been bounded by the ranges used in the UNSAT-H models.

In 2013 (UNC, 2013), UNC/GE had responded to five “areas of potential concern” listed by NRC staff. One such concern included the potential for the formation of perched conditions within the mine waste. That is, a low permeability layer placed beneath the mine waste may potentially create a perched condition within the mine waste above the existing tailings impoundment. The concern is the possible failure of the side-slopes or slope instability due to pore water pressure increase. A recompacted radon barrier with a hydraulic conductivity value of 10^{-7} cm/s ($4x10^{-8}$ in/s) has such a potential to create a perched water zone, and due to the uncertainty of the seepage rate over centuries, the possibility of such a perched water zone being created would be difficult to exclude. It was and is NRC staff’s understanding that the upper 15 cm (6 in) of the radon barrier will to be compacted to 95 percent relative compaction per standard Proctor, at a moisture content less than the optimum water content. The optimum water content is the moisture content that corresponds to the maximum dry density in a Proctor test. The NRC staff understands that the licensee plans to re-compact the upper 6 inches of the existing radon barrier to a lower moisture content than the optimum water content. As a result of this approach, the existing radon barrier will have pore space available to absorb seepage through the mine waste. In addition, the objective of this compaction effort was to obtain a low permeable hydraulic conductivity of less than $1x10^{-7}$ cm/s (3.9×10^{-8} in/s) for the existing radon barrier. Initially, NRC staff had a concern that a low permeability value might cause the perched water zones to form sometime in the future. However, this intended hydraulic conductivity is an unsaturated hydraulic conductivity and not a saturated hydraulic conductivity. Based on Appendix G from UNC (2019d), the radon barrier material cannot achieve a saturated hydraulic conductivity of less than $1x10^{-7}$ cm/s, even under controlled laboratory conditions. What could be achieved is an unsaturated hydraulic conductivity of less than $1x10^{-7}$ cm/s, which is part of UNC/GE's design. Thus, a saturated hydraulic conductivity of greater than $1x10^{-7}$ cm/s, and closer to $3.6x10^{-5}$ cm/s (1.4×10^{-4} in/s) as given in Table 11 from Appendix Y, should be sufficient to allow water percolation to flow through at a pace sufficiently high so that no zone of saturation would develop on the surface of the radon barrier if recharge were to occur within the repository.

Consideration of perched zones within the mine waste is also discussed in Section 3.2.3 of this report.

3.7.4 Evaluation Findings

On the basis of the information presented in the LAR, the NRC staff concludes that the information provided demonstrates compliance with 10 CFR Part 40, Appendix A: Criterion 6(1), which requires that impoundment designs 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.

The staff has also completed its review of the processes and parameters, including hydraulic conductivities, associated with the infiltration rate through the mine waste repository over time. This review included an evaluation which also relied upon the review procedures in Section 2.7.2 and the acceptance criterion outlined in Section 2.7.3(1) of the NUREG-1620 SRP (NRC, 2003). The licensee is relying on the overall thickness of the cover system and mine waste to reduce or eliminate infiltration through the disposal site by acting as a water storage layer until the evapotranspiration process removes the stored water from these layers, as opposed to relying on the presence of a low permeability barrier to promote runoff and inhibit infiltrating water. The licensee is also relying on the additional mine waste thickness to reduce and meet the radon flux standard (see Chapter 6 of this report for further details). As the material being placed on the mill tailings is mine waste, and no low permeability/radon barrier layer is included near the surface in the design plans, the licensee did not need to provide additional information to address all of the acceptance criteria in Section 2.7.3 of the SRP since some criteria pertain to design, construction, and construction schedule of the radon barrier and its hydraulic conductivity (e.g., criteria in Section 2.7.3(3) and Section 2.7.3(4)), which will remain under this proposal. On the basis of the information presented in the LAR and the NRC staff's review summarized above, the NRC staff concludes that the information provided demonstrates compliance with 10 CFR Part 40, Appendix A: Criterion 6(1), which requires that impoundment designs 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. Additionally, the documents in the LAR, its references, and the NRC staff's review also have provided sufficient evidence indicating that a full vegetative cover on the repository is likely to be self-sustaining in current climatic conditions. Therefore, the NRC staff determines that the requirements of 10 CFR Part 40, Appendix A, Criterion 4(d), which requires establishment of a self-sustaining vegetative cover, is met.

The NRC staff determined that information and data provided in the LAR pertaining to processes and parameters associated with infiltrations rates through the mine waste repository and mill tailings has demonstrated that the requirements of 10 CFR Part 40, Appendix A, Criterion 5F will be met. The NRC staff is basing part of its finding on the continuation of groundwater monitoring to demonstrate the licensee's approach remains protective of groundwater. This is discussed in more detail in the following paragraphs. Criterion 5F states that where groundwater impacts are occurring at an existing site due to seepage, action must be taken to alleviate conditions that lead to excessive seepage impacts and restore groundwater quality. In the case of the proposed Church Rock repository, there were two aspect to consider for Criteria 5F that might cause excessive seepage impacts: higher infiltration rates create perched water conditions above the existing radon barrier and cause excessive pore water pressure near the cover's side slope and lead to slope instability or failure of the side-slopes, and infiltration rates through the cover system are sufficiently high to cause excessive contaminated water to seep from the tailings into the groundwater. The NRC staff has concluded (discussed at the end of Section 3.7.3 of this report) that perched conditions that might lead to slope instability or failure of the side-slopes were improbable. The planned saturated hydraulic conductivity for the radon barrier of 3.6×10^{-5} cm/s (1.4×10^{-4} in/s) should be sufficient to prevent this type of instability.

The second possibility of an excessive seepage impact involves higher than expected rates of infiltrating water combining with contaminated water from the now consolidated and therefore saturated fine-grained tailings and then recharging into the groundwater thereby significantly increasing groundwater concentrations and/or a rise in the water table, although the NRC staff considers this sequence of events unlikely since water table levels near the disposal cells with the current degraded cover have been declining. However, the processes associated with evaporating rainwater from the cover system and with transpiration of water due to plant growth is linked with significant uncertainty over the long-term. Although the range of parameters assumed in the LAR for future precipitation rates, precipitation duration, snow cover, temperature and sunshine, vegetation type, root depth, and changing hydraulic conductivities due to developing soil structures will likely bound infiltration rates so that excessive seepage impacts will not be created, it cannot be excluded due to aleatory uncertainty, e.g., future meteorological phenomena may occur to drive infiltration rates higher and/or the cover may evolve in unexpected ways. This is especially the case for model predictions that deterministically predict zero long-term flux to the groundwater as in the LAR. As previously stated, such forecasts require robust technical bases with supportive evidence to significantly reduce associated uncertainty.

Although the NRC staff considers the above scenario unlikely, it is relying on an adequate groundwater monitoring system to record any significant increase in contaminant concentrations earlier rather than later so as to consider a plan of action as dictated by the results. Since the groundwater monitoring program will need to be relied upon to detect noticeable trends of increasing contaminant concentrations within the groundwater, the placement and depth of boreholes should be verified and the frequency and depth of groundwater samples measurements should be able to intercept plumes originating from the mill tailing disposal cells and provide accurate information. The groundwater monitoring results should be properly documented and available for inspection. The NRC staff's finding is based on the revisions to license condition 30. As discussed, and explained, in more detail in Sections 5.3.4 and 5.4 of this SER, the NRC staff proposes to modify condition 30 of license SUA-1475 to include in the quarterly monitoring schedule potential seepage impacts resulting from mine waste placement. The groundwater monitoring results for certain wells located immediately downgradient of the mill tailings impoundment will be used to measure any seepage resulting from placement of the mine waste and inform any necessary follow-on analysis or activity, as appropriate.

3.8 References

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4. SURFACE WATER HYDROLOGY AND EROSION PROTECTION

In this chapter of the SER, the NRC staff documents its evaluation of portions of the LAR (UNC 2018) that address topics covered in Chapter 3, "Surface Water Hydrology and Erosion Protection," of the SRP (NRC 2003b). More specifically, this section of the SER describes the NRC staff's review of surface water hydrology and erosion protection related to long-term site stability. The NRC staff's technical evaluations and review areas include the following subsections: hydrologic description of site detailed in Section 4.1; updated estimates of flood magnitudes detailed in Section 4.2; water surface elevations, channel velocities and shear stresses in storm water flow areas detailed in Section 4.3, design of erosion protection in Section 4.4, and design of erosion protection covers in Section 4.5.

To have a better understanding of the surface water hydrology for the mill and tailing disposal area, the NRC staff reviewed the following technical documents from the licensee;

- Surface water drainage and diversion and their related appendices and attachments (ML18267A237, ML19287A009);
- Storm water control documents (ML18267A240);
- Licensee's responses to NRC's Requests for Additional Information, RAIs (ML19157A173, ML19287A007, ML19315A006, ML19322D037, ML20078K264);
- Engineering design drawings (ML18267A348), the detail of licensee's hydrologic and hydraulic models, and those modeling input parameters.

The licensee proposes modifications on the existing drainage system on and around the existing tailings disposal area. The proposed modifications are intended to divert upland runoffs and improve the protection for the tailings disposal area and mine waste repository from flooding and erosion. This includes improvements to the Pipeline Arroyo that runs near the western side of the mine waste repository. The licensee plans to construct an evapotranspirative (ET) cover on the 2 and 5 percent slopes of the mine waste repository. A small portion of the mine waste repository will have a 20 percent grade with an armored rock side slope. The design basis events for the erosion protection include the Probable Maximum Precipitation (PMP) and the Probable Maximum Flood (PMF), both of which are considered by the NRC staff in NUREG 1623 (NRC, 2002) to have very low exceedance probabilities of occurring during the 1000-year performance period.

4.1 Hydrologic Description of Site

In this section of the SER, the NRC staff documents its evaluation of the hydrologic description and flooding potential of the site. The NRC staff will focus its review on the identification of mechanisms that may result in the need for unique design features and the long-term stability of site design features in light of previous reviews and approvals. The NRC staff's review is limited to the changes proposed in the LAR; therefore, the NRC staff is not re-evaluating conditions on the south side of the existing tailings impoundment as that portion of the site will remain as it is currently constructed.

4.1.1 Regulatory Requirements

The NRC staff determines if the licensee has demonstrated compliance with the relevant aspects of 10 CFR Part 40, Appendix A.

4.1.2 Regulatory Acceptance Criteria

Unless specifically stated otherwise, the LAR was reviewed for compliance with the applicable requirements of 10 CFR 40 using the acceptance criteria presented in SRP Section 3.1, "Surface Water Hydrology and Erosion Protection" (NRC 2003b).

The acceptance criteria in SRP Section address: (1) description of the site, structures, facilities, and erosion protection design features; (2) topographic maps; and (3) level of detail presented in the LAR.

4.1.3 Staff Review and Analysis

Unless specifically stated otherwise, the information reviewed in this SER section is from information, data, and maps submitted by the licensee in Sections 4.1, 4.2, and Appendix I of the LAR (UNC 2018).

As discussed in more detail in Section 1.1 of this SER the decommissioned uranium mill and tailings disposal site are both located approximately 17 miles northeast of Gallup in McKinley County, New Mexico. The site is within the Pipeline Arroyo Watershed. The Pipeline Arroyo watershed is composed of alluvial valley and upland mesas and buttes. The region has significant slopes and high runoff potential. The Pipeline Arroyo is the major drainage feature on the Church Rock site; it runs roughly parallel to the western edge of the tailings impoundment and is offset approximately 300 ft from the tailings impoundment. The Pipeline Arroyo drains an area of approximately 18 square miles upstream of the tailings impoundment. The Pipeline Arroyo is an ephemeral channel that consists of fine sand mixed with layers of silty clay. According to the design drawings shown in Volume II of the LAR, the estimated channel depth of the Pipeline Arroyo at the site is from 25 feet to approximately 50 feet. The channel slopes of the Pipeline Arroyo are in a range from 0.18 percent to 5.3 percent.

The tailings disposal area and mine waste repository are at approximately 6,970 feet AMSL. The Pipeline Arroyo watershed outlet elevation at the property line is approximately 6,875 feet AMSL. Within the 18 square-mile area of Pipeline Arroyo watershed upstream of the existing tailings impoundment, there are no dams.

In Section 4.1 of the LAR, the licensee provides an overview of the planned changes to the surface water drainage and diversion features. Placement of mine waste in a repository constructed on roughly the northern half of the existing mill tailings impoundment will result in construction of a new cover system, improvements to the north diversion channel, improvements to the north cell drainage channel, stabilization of the Pipeline Arroyo via construction of a riprap chute, and upgrades to the east repository channel. As shown on engineering drawing 9-02, the final grading plan for the new cover system constructed over the mine waste will have a peak elevation of approximately 7,000 ft MSL and will be designed to shed water in all directions. Most of the cover system will have a slope of 5 percent or less (20H:1V); however, a small section of the cover along the northeastern portion will have a 20 percent (5H:1V) slope. The final grading plan for the proposed cover does not include any drainage swales; the existing drainage swales G, E, F, and a portion of D will be eliminated with the new design. The licensee's plans call for installation of a 4.5 ft thick cover system over the mine waste. The uppermost portion of the cover system on the 5 percent slope will be a vegetated soil/rock mixture. The 20 percent slope will be armored with rip rap. The NRC staff observes that the licensee provided narrative explanations of these changes as well as of its overall approach to surface water management at the Church Rock site in Sections 4.1 and 4.2

of the LAR. In Section 4.2.3 of the LAR, the licensee described its design for the rip rap chute in the Pipeline Arroyo and explained why it selected a 5.3 percent slope. Additionally, the NRC staff observes that Appendix I includes a detailed explanation of the changes and that Attachments I.1 through I.8 contain detailed calculations supporting the surface water design features. These attachments contain the licensee's design methodology and are the focus of the NRC staff's review.

In the LAR, the licensee presented five hydrologic models and four channel-hydraulic models to estimate various flooding conditions. The five hydrologic models are detailed in Section 4.2.3 of this SER. The four channel hydraulic models are detailed in Section 4.3.3 of this SER. The estimated flooding conditions are the design basis to modify the existing storm water control system at the site. The modifications are intended to prevent the adverse impact of flooding and erosion on the tailings disposal site and address existing concerns related to the Pipeline Arroyo and drainage channels on and around the mill tailings impoundment

As shown in Section 4.1 of Volume I and Design Drawings of Volume II of the LAR, the planned improvements of surface water control system at the mill site are summarized as follows:

1. Improvements to the North Diversion Channel (Design Drawings Sheets 9-02 and 9-05 of Volume II) and more detail shown in Section 4.3.3.3 of this SER.
2. Improvements to the drainage of the alluvial flood plain at the north of the North Cell of the tailing disposal area (Design Drawing Sheets 9-02 and 9-07) and more detail shown in Section 4.3.3.2 of this SER.
3. Improvements to the North Cell Drainage Channel (Design Drawing Sheets 9-07 and 9-08) and more detail shown in Section 4.3.3.2 of this SER.
4. Mitigation design for the Pipeline Arroyo stabilization of, and adjacent to, the repository area (Design Drawing Sheets 9-02, 9-09, 9-10, and 9-11) and more detail shown in Section 4.3.3.1 of this SER.
5. Improvements to the eroded buried rock protection area within the Pipeline Arroyo (Design Drawing Sheets 9-02), with a focus on geotechnical stability of the improvements in Section 4.3.3.4 of this SER.

The NRC staff determined that the licensee developed and submitted a sufficiently complete design that will allow for an independent evaluation to be completed. Therefore, the NRC staff finds that acceptance criteria (1) and (3) have been met.

The calculation packages provided in Attachments I.1 through I.8 contain figures related to the analysis in the specific calculation package. The NRC staff reviewed the drawings and figures and observed that they were provided at a sufficient scale and clarity to allow for an independent analysis. Additionally, the NRC staff determined that both pre-construction and post-construction conditions were shown in the drawings. Therefore, the NRC staff determined that acceptance criteria (2) and (3) have been satisfied.

4.1.4 Evaluation Findings

The NRC staff has completed its evaluation of the hydrologic description and flooding potential of the Church Rock site. This review included an evaluation using the review procedures in Section 3.1.2 and acceptance criteria outlined in Section 3.1.3 of the Standard Review Plan (NRC, 2003b).

On the basis of the information presented in the LAR and the detailed review conducted by the NRC staff of the hydrologic description and flooding potential at Church Rock, the NRC staff concludes 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 (3) the LAR with respect to surface water hydrology and erosion considerations represents a feasible plan for complying with the requirements of 10 CFR Part 40, Appendix A.

4.2 Flooding Determinations

In this section of the SER, the NRC staff documents its evaluation of the flooding potential for the Church Rock site. The NRC staff's review evaluates the licensee's selection of the precipitation potential, precipitation losses, runoff potential, and peak flow estimates for the probable maximum precipitation. Consistent with the review procedures in Section 3.2.2 of the SRP, the focus of the NRC staff's review is on the drainage channels located on and adjacent to the proposed cover system for the mine waste and the improvements planned for the Pipeline Arroyo, which runs adjacent to the existing tailings impoundment and proposed mine waste repository.

The licensee used the Hydrologic Modeling System (HEC-HMS), version 4.2.1, published in 2017 by the Hydrologic Engineering Center of the United States Army Corps of Engineers, to simulate various peak flood discharges and hydrologic conditions at the interest locations within the sites. The licensee assumed that the storm frequency to be equivalent to the flood frequency, such as a 100-year storm producing a 100-year flood.

The licensee followed the steps below to estimate the input parameter values:

(1) Selection of a design storm event;
(2) Determination of infiltration losses by Green-Ampt method;
(3) Determination of times of concentration by either the McCuen method for artificially developed catchment areas or Sabol method for natural catchment areas;
(4) Determination of temporal rainfall increments corresponding to the computed times of concentration; and
(5) Selection of rainfall-runoff conversion methods to calculate flood discharges.

Following these five steps, the licensee changed the input parameters while making the necessary adjustments in related parameters, such as ensuring that the time of concentration is consistent with the duration of the precipitation intensity. With the finalized input parameters, the licensee estimated the peak flood discharges used in the final determination of water surface profile and velocity (as evaluated in Section 4.3.3 of this SER) and rock sizes for erosion protection (as evaluated in Section 4.4.3 of this SER). Sections 4.3.2.1 through 4.3.2.5 of this SER provide additional evaluation that corresponds to the five steps listed above for determining the model input parameters.

4.2.1 Regulatory Requirements

The NRC staff determines if the licensee has demonstrated compliance with 10 CFR Part 40, Appendix A, Criterion 6(1), which requires reasonable assurance of control of radiological hazards to (i) be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years, and Criterion 12, which requires that active maintenance is not necessary to preserve isolation.

4.2.2 Regulatory Acceptance Criteria

Unless specifically stated otherwise, the LAR was reviewed for compliance with the applicable requirements of 10 CFR 40 using the acceptance criteria presented in SRP Section 3.2.3, "Flooding Determinations" (NRC 2003b).

4.2.3 Staff Review and Analysis

Unless specifically stated otherwise, the information reviewed in this SER section is from information, data, and maps submitted by the licensee in its LAR (UNC 2018). Specifically, the licensee presented its design in Section 4 of the LAR, Appendix I, and in the engineering drawings. The proximity of the Pipeline Arroyo to the tailings impoundment and mine waste repository and the upstream drainage area of approximately 18 square miles necessitates that the NRC staff consider the peak flow through the Pipeline Arroyo as a potential threat. Additionally, the NRC staff considered the performance of the existing surface water management features and the design concerns identified in 2003 (NRC, 2003a). Therefore, the NRC staff's review focuses both on flow in the Pipeline Arroyo, the proposed improvements to the Pipeline Arroyo, and surface water management features around the mine waste repository. In this Section of the SER, the NRC staff focuses on the determination of the design rainfall event, infiltration losses, time of concentration, rainfall distribution, and peak discharges. Note the NRC staff's review of the erosion control aspects of the 2 and 5 percent slopes of the ET cover system can be found in Section 4.5 of this SER.

Selection of Design Rainfall Event

As discussed in Section 4.1.1 of the LAR, the licensee designed the permanent storm water management features on and around the mine waste repository based on the probable maximum precipitation (PMP) and corresponding probable maximum flood (PMF). The Probable Maximum Precipitation (PMP) is defined by the World Meteorological Organization (WMO) as "*the greatest depth of precipitation for a given duration meteorologically possible for a design watershed or a given storm area at a particular time of year"* (WMO 2009). Operationally, when sufficient, historical extreme rainfall observations are available, the PMP is estimated based on a widely used method combining storm moisture maximization, transposition (i.e., relocating patterns of storm precipitation to other areas), and envelopment (i.e., identifying maximum storm precipitation values) (Schreiner and Riedel 1978). For highly critical infrastructures such as major dams and nuclear power plants, the PMP has been used as input to simulate the probable maximum flood (PMF) as a conservative design criterion. The PMP is the theoretical upper bound of rainfall depth that could occur under a series of adverse hydro-meteorological conditions. Note that the review procedures in Section 3.2.2 of the SRP direct the NRC staff to evaluate whether the licensee has considered a PMP event in its evaluation of flooding.

The basic approach and detailed methods used in developing operational PMP estimates have been described in numerous Hydrometeorological Reports (HMRs) published by the NWS.[1] For example, HMR 49 (Hansen et al. 1984) provides generalized all-season PMP estimates for the Colorado River and Great Basin Drainages from 10 to 5,000 mi^2 and for durations of 6–72 h. The NWS HMRs identify two types of PMP estimates: *generalized PMPs* and *individual drainage PMPs*. The PMP estimates provided in most HMRs (e.g., HMR 49) are termed "generalized estimates." In these HMRs, isolines of PMP are given on a map, allowing

[1] www.nws.noaa.gov/oh/hdsc/studies/pmp.html

determination of basin-average PMP for any drainage basin. Typically, simplifying assumptions regarding the influence of topography and orographic processes were used in lieu of a detailed analysis. Other HMRs and studies produced by NWS (e.g., HMR 41 [Schwarz 1965], HMR 46 [Schwarz 1970], and HMR 56 [Zurndorfer et al. 1986]) provide PMP estimates for individual drainage basins that are specifically adjusted for the area and physical influences of the drainage basin under consideration. The reasons for analyzing individual drainage basins include (1) generalized PMP studies were not available, (2) the watershed was larger in size than those covered by available generalized PMP studies, or (3) detailed studies indicated orographic effects would yield PMP estimates significantly different from those based on available generalized PMP charts (e.g., watersheds in the Appalachians).

Summary of licensee's information

The Northeast Church Rock License Amendment Request (LAR) provided a PMP intensity for use in the design storm event. This PMP value is intended to represent the theoretical maximum precipitation that could occur over the licensee's basin for the durations of 10 minutes to 6 hours.

The licensee's PMP information provided in Section 2.4.3 Precipitation of the LAR provides:

> An updated probable maximum precipitation (PMP) event was calculated for the analyses completed for this LAR. The PMP 1-hour precipitation value of 6.14 inches was used in the cover and stormwater design analyses. The PMP storm depths and distributions were developed using the Arizona Department of Water Resources (ADWR) PMP Evaluation Tool (ADWR, 2013). The tool provides PMP depths and distributions for three different storm types: (1) local convective storms, (2) remnant tropical storms, and (3) general frontal storms. The tool provides PMP depths for the local convective storm PMP at 1-hour intervals for storm durations between 1 hour and 6 hours. The design discharge is discussed in more detail in Section 4.1.1 and calculations are shown in Attachment I.1 of Appendix I of the LAR.

Figure 9 below shows that the location of the Church Rock site is within the region of the Arizona State PMP study.

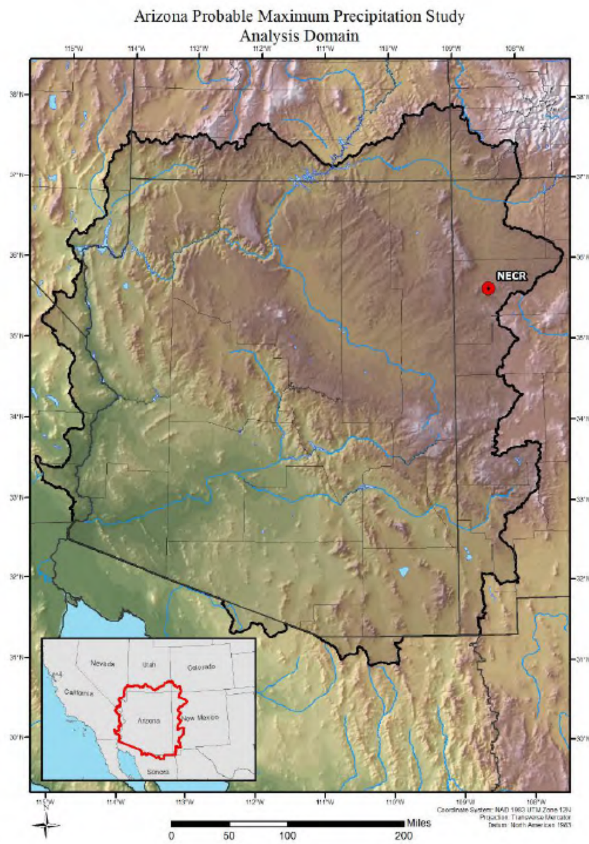

Figure 9: Church Rock location within the region of Arizona State PMP Study

NRC staff evaluation

The current version of the reclamation plan (Canonie, 1991) used a PMP value of 8.43 in its design of the erosion control features at Church Rock. The latest HMR (HMR 49) for the southwest United States was developed in 1977 and has not been reprinted since 1984. As such, much of the knowledge, data, and tools now available offer advantages over the NWS's HMR products. Some of the deficiencies related to the HMRs include the following:

- The limited number of storms analyzed;
- Lack of inclusion of storms that have occurred since the 1980s;
- Inadequate processes used to address orographic effects;
- Inconsistence data and procedures used among the HMRs; and
- Outdated procedures used to derive the PMP.

For the above reasons, the NRC staff concludes that licensee's decision to use an updated PMP is justified for the LAR (Figure 9). As stated in Attachment I.1 of the LAR, the ADWR PMP tool produces gridded PMP values using a grid spacing of 2.5 square miles at 1-hour intervals for storm durations ranging from 1 to 6 hours for the Church Rock basin. In general, the ADWR PMP study follows many procedures used in HMR development. Consistent with the HMRs and other PMP approaches, the Arizona state PMP followed a storm-based approach, by which PMP is estimated based on historical storm observations, as well as updated storm selection, updated observed storm precipitation data, storm representative dew point selection and moisture maximization, dew point climatology and moisture adjustment, and terrain adjustment.

One of the phenomena most likely to affect long-term site stability is surface water erosion. To mitigate the potential effects of surface water erosion, it is very important to select an appropriately conservative rainfall event as the design basis for the flood protection and erosion prevention designs. The licensee utilized the updated PMP event, computed by deterministic methods (rather than statistical methods). The computed PMP is based on site-specific hydrometeorological characteristics. No recurrence interval is normally assigned to the PMP. But the licensee estimated the recurrence interval to be 2 million years as presented in Section 4.2.3 of Volume I of the LAR. In Attachment I.1 of Volume I of the LAR, the licensee presented that the 6-hour 1,000-year rainfall depth (3.63 inches) is less than the 6-hour PMP depth (6.54 inches). The NRC staff considers the licensee's use of the PMP to be an acceptable design basis for a long-term site stability as it is consistent with the recommended approach in NUREG 1623 (NRC, 2002).

As indicated in the LAR, the licensee recently updated the PMP depths that were generated by the Arizona Department of Water Resources (ADWR) PMP Evaluation Tool (ML19157A173). The updated 1-hour PMP depth is 6.14 inches averaged over the total area of the Pipeline Arroyo watershed.

The ADWR PMP Evaluation Tool can be used to compute gridded PMP depths of 1-hour, 2-hour, 3-hour, 4-hour, 5-hour, and 6-hour durations for the Pipeline Arroyo watershed. The tool is also able to provide results of center-peaking temporal distribution of 6-hour PMP in 10-minute time increments. The gridded PMP depths are produced with an accuracy within a grid size of 2.5 square miles. The NRC staff reviewed the gridded PMP depths for the Pipeline Arroyo watershed and finds that the gridded PMP depths are the results of maximizing recorded large storms in the region and represent a satisfactory and acceptably conservative approach.

NRC staff used the ADWR study and the associated GIS-based PMP Evaluation Tool to evaluate the licensee's precipitation estimates for the Church Rock basin. LAR Figure 7 in Attachment I.1, "PMP storms for Durations of 1-Hour to 6-Hour PMP for the Pipeline Arroyo Watershed," provides the results of the PMP evaluation tool that is used as input to the hydrologic models. The NRC staff found that the PMP values for the Arroyo Watershed are appropriate by running the same ADWR evaluation tool. Based on the maximized storms and minimized grid size, the NRC staff concludes that use of the Evaluation Tool to update PMP depths is acceptable. The NRC staff reviewed the procedures for updating PMP values as described in the computer scripts of the tool. The NRC staff finds that the scripts follow the procedure to maximize the extreme storm. The NRC staff finds that the licensee followed the proper procedures and used the tool in an appropriate manner and considers the gridded PMP depths to be reasonable and appropriate for use as input data to PMF simulation for the 18 square miles of the Pipeline Arroyo watershed.

In addition to the PMP storm, the licensee used NOAA Atlas 14 Precipitation Data Frequency Server (NOAA, 2019) to get precipitation depths of other storm events, called frequency-based storms. The events include 2-year, 5-year, 10-year, 100-year, 200-year, 1,000-year, and 10,000-year storms. The 10,000-year storm is outside the study limit of NOAA Atlas 14. The licensee extrapolated the NOAA Atlas 14 data to generate the precipitation depths for the 10,000-year storm. The NRC staff reviewed the licensee's precipitation depths and finds that the licensee's precipitation depths are consistent with the NRC staff's confirmatory calculations. Accordingly, the NRC staff concludes that the licensee's precipitation depths of the frequency-based storms of 2-year through 10,000-year events are acceptable.

Infiltration Losses

Infiltration losses must be accounted for to estimate the amount of precipitation that contributes to runoff. Infiltration losses typically means losses into the soil. Depression storage occurs when small depressions in the topography store water and prevent further movement. The amount of precipitation falling on the watershed is referred to as the total precipitation. The amount of precipitation contributing to runoff is called effective precipitation. The effective precipitation is the total precipitation minus the infiltration and depression losses.

Summary of the licensee's information

The licensee adopted the Green-Ampt method to estimate the precipitation losses due to the infiltration into the ground. The Green-Ampt parameters include ground saturated hydraulic conductivity, wetting front suction, initial moisture content of the soil, and saturation content of the soil. The licensee assigned those parameter values to the Green-Ampt equation according to the soil database published by the United States Department of Agriculture (USDA). The licensee estimated another precipitation loss due to the depression storage on the ground surface, also referred to as surface retention. The parameters used to estimate the surface depression are initial storage and maximum storage.

NRC staff's evaluation

The NRC staff reviewed the licensee's assigned parameter values to the Green-Ampt equation and finds that those values are consistent with the data range published by the USDA. The NRC staff reviewed the licensee's assigned parameter values to the depression storage for accounting the extra of the precipitation loss. The NRC staff finds that those values are within the data range published by the Arizona Department of Water Resources (ADWR, 2007). Since the licensee's assigned parameter values are within the data range published by the USDA and ADWR, the NRC staff concludes that the parameter values are adequate.

In Attachment G.8, the licensee presents its calculation supporting the design of the rock cover for the 20 percent slope on the eastern edge of the repository. The NRC staff observes that the licensee also used the Rational Method to estimate the peak flow on the cover system. The licensee used a runoff coefficient of 1 in its calculation. The NRC staff observes that this assumption results in a conservative (high) estimate in the peak runoff for this slope. Therefore, this assumption is acceptable to the NRC staff.

Times of Concentration

In general, the time of concentration is the amount of time required for runoff to reach the outlet of a drainage basin from the most remote point in that basin. The peak runoff for a given drainage basin is inversely proportional to the time of concentration. Times of concentration and/or lag times are typically computed using empirical formulas, such as those developed by Federal agencies. Another approach is to use velocity-based formulas, which are used when more accurate estimates are needed. Such approaches rely on estimates of actual flow velocities and flow distance to determine the time of concentration of a drainage basin.

Summary of the licensee's information

The licensee used both kinds of formulas to compute the times of concentration. The licensee used the McCuen method (McCuen, 2002), which is a velocity-based formula for mandeveloped catchments and the Sabol method (Sabol, 1983), which is an empirical formula for native catchments. For the 1-hour PMP event over the Pipeline Arroyo watershed, the licensee computed the times of concentration that ranged from 0.06 hour to 1.6 hours for the existing conditions, and from 0.19 hour to 1.6 hours for the post-remedy action condition of the sites.

NRC staff's evaluation

The McCuen and Sabol methods relate the catchment characteristics, such as the main flow length, catchment slope, and the precipitation intensity to determine the times of concentration. The NRC staff recognizes that both methods used by the licensee are generally accepted in engineering practice. The NRC staff's guidance in NUREG 1623 (NRC, 2002) recognizes that licensees may choose to use different methods to estimate the time of concentration. The NRC staff reviewed the approach and finds that the assumptions used by the licensee in the calculation are consistent with the planned configuration of the mine waste repository. Therefore, the NRC staff finds the use of these methods to be appropriate for estimating times of concentration at this site.

Using a different approach to validate the licensee's times of concentration, the NRC staff performed a confirmatory calculation using the SCS TR-55 method (NRCS, 1986). The purpose of the NRC staff's calculation was to estimate times of concentration and further validate the licensee's approach. The NRC staff's calculation finds that the licensee's times of concentration estimates that ranged from 0.19 hour to 1.6 hours, depending on the catchment area, are reasonable. Therefore, the licensee's approach is acceptable to the NRC staff.

For the rock cover on the 20 percent slope, the licensee presented its design in Attachment G.8 of Appendix G of the LAR. The licensee calculated a time of concentration of 2.5 minutes for the 20 percent slope using the Brant and Oberman method. The NRC staff reviewed Attachment G.8 and the licensee's time of concentration calculations. The Brant and Oberman method is not one of the methods identified in NUREG 1623 (NRC, 2002), however the NRC staff recognizes that it is generally accepted in engineering practice. Additionally, the methodology has been used in the design of covers at other mill tailings sites. During its review, the NRC staff performed the same calculation and was able to replicate the licensee's results. Therefore, the licensee's approach and implementation is acceptable to the NRC staff.

<u>Rainfall Temporal Distributions</u>

After the PMP is determined, it is necessary to determine the rainfall intensities that correspond to shorter rainfall durations that match the time of concentration. PMP values are typically derived for a one-hour period; if the time of concentration is less than one hour, it is necessary to extrapolate the PMP data to reflect the shorter time of concentration.

The ADWR PMP Evaluation Tool (ML19157A173) provides the capability to distribute any 6-hour PMP depth in 10-minute increments. But the tool does not have functions to generate a temporal distribution for other rainfall durations less than 6 hours. To complement the lacking functions and the need for other temporal distributions for 1-hour, 2-hour, 3-hour, 4-hour, and 5-hour rainfall durations, the licensee developed an intensity-ratio method that depends on the temporal distribution of the 6-hour PMP depth generated by the ADWR PMP Evaluation Tool.

Summary of the licensee's information

As presented in Figure 10 below, the licensee's intensity-ratio method is to distribute a 1-hour peak precipitation at the middle of temporal distribution of other PMP events as the same pattern of the 1-hour peak precipitation within the 6-hour PMP event.

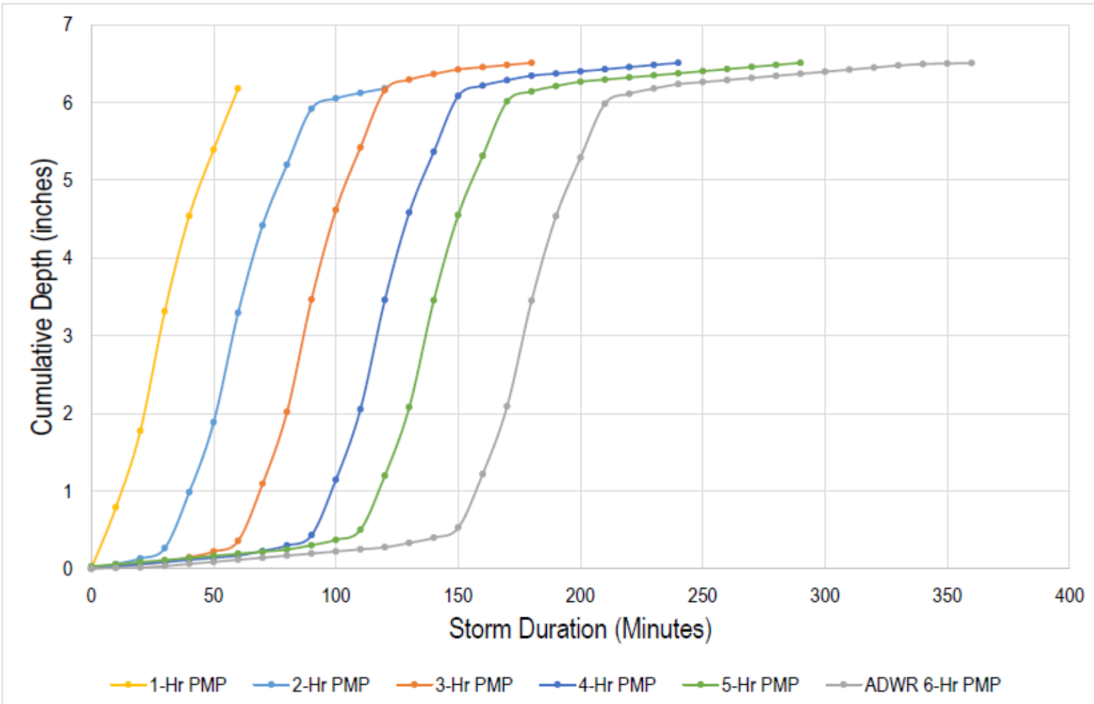

Figure 10: PMP temporal accumulations for various durations

(Reprinted from Figure 7 of Attachment I.1 of Appendix I of the LAR)

The 1-hour peak precipitation is a group of largest precipitation depths assembled at the middle of temporal distribution in any PMP duration. The residuals of the PMP depth, subtracting the 1-hour peak precipitation from the total PMP depth, are symmetrically distributed in the front and rear of the 1-hour peak precipitation within the PMP duration. For the case of 1-hour PMP event, there are no residuals of the PMP depth. The amount of the 1-hour peak precipitation and the symmetrical front and rear precipitations are linearly scaled with interpolations between the 6-hour PMP event and the 1-hour PMP event. The linear interpolations were calculated by scaling the most intense rainfall depths in the 1-hour interval of the given temporal distribution of 6-hour PMP to create 1-hour PMP temporal distribution. The temporal distributions of the created 1-hour PMP and the given 6-hour PMP were used in the interpolations to derive the 1-hour peak precipitation for the other durations of the PMP. The licensee presented 10-minute increments for accumulated PMP temporal distributions for 1-hour, 2-hour, 3-hour, 4-hour, 5-hour, and 6-hour durations as indicated in the Figure 10.

For the other storms, including 2-year, 5-year, 10-year, 100-year, 200-year, 1,000-year and 10,000-year storms, the licensee arranged a center-peaking alternative block technique to distribute the total precipitation depth in 5-minute increments. The licensee used these temporal distributions as input data to HEC-HMS surface runoff model.

To determine the peak flood flows for locations of interest within the drainage system, the license chose a 10-minute PMP rainfall increment for setting the temporal distribution of the 1-hour PMP, which is a control storm to create a maximum peak flood (See Section 4.3.2.5 of this report for detail).

NRC staff's evaluation

The NRC staff examined the computer scripts of the ADWR PMP Evaluation Tool written in the Python computer language. The NRC staff finds that the computational procedures as described in the source scripts for the rainfall temporal distribution of 6-hour PMP are reasonable because they accurately incorporate past rainfall data, distributions, and location information. To provide further confidence in the licensee's approach, the NRC staff performed simplified, confirmatory computations to check the other temporal distributions for 1-hour, 2-hour, 3-hour, and 5-hour PMP storms. The NRC staff's results generally matched the results that the licensee reached. Therefore, the NRC staff finds that the licensee's computational results are acceptable for those PMP durations less than 6 hours.

The NRC staff reviewed the licensee's rainfall intensity-duration-frequency curves for the 2-year storm up to the 10,000-year storm. The NRC staff used a spreadsheet to generate the coefficients of the rainfall intensity-duration-frequency curves for the storms from 2-year to 10,000-year events. By comparison, the NRC staff finds that the NRC staff's coefficients are consistent with the licensee's coefficients.

Based on the NRC staff's examination of the computer scripts of the ADWR PMP Evaluation Tool, the review of the temporal distributions for the PMP storm, and the 2-year up to 10,000-year storms, the NRC staff concludes that the licensee's computed rainfall temporal distributions are acceptable.

For the 20 percent rock slope on the eastern edge of the mine waste repository, the licensee presented its calculations for the rainfall intensity in Attachment G.8 of Appendix G of the LAR. Given the relatively short time of concentration on the 20 percent slope, the licensee had to extrapolate to determine the rainfall intensity. The NRC staff reviewed the licensee's approach and calculations and did not identify any computational errors. The NRC staff observes that the licensee's extrapolation approach is consistent with the guidance presented in NUREG 1623 and is acceptable to the NRC staff.

<u>Computation of PMF and Runoff Quantities</u>

The licensee used the HEC-HMS model to simulate various peak floods at different interest locations in the licensee's property for PMP, 2-year, 5-year, 10-year, 100-year, 200-year, and 1,000-year, and 10,000-year storm events. The computed various flood flows and flood conditions were used to design the surface runoff drainage system in the licensee's property.

Summary of the licensee's information

Using the HEC-HMS model, the licensee established four channel hydraulic models to estimate flood flows for multiple purposes (See Section 4.3.1). The models and their relevant storm events are shown as follows:

1. Pipeline Arroyo Existing Condition Model for 2-year and 100-year storms, and the PMP event

2. Pipeline Arroyo Post-RA Model for 2-year, 5-year, 10-year, 100-year, 200-year, 1000-year and 10,000-year storms, and the PMP event
3. Mill Site Model for 2-year and 10-year storms, and the PMP event
4. Haul Road Model for a 10-year storm

The key components in each of the licensee's four hydraulic models include sub-catchment areas, precipitations of various storms, infiltration losses, rainfall-runoff transformation, channel flow routing, and reservoir storage routing.

Based on USGS topographic data, the licensee delineated sub-catchment areas to be used in the four hydrological models. The licensee applied the synthetic Clark Unit Hydrograph method to transform effective precipitation depths to runoff hydrographs at the sub-catchment outlets. The licensee computed the time of concentration using Sabol's equation and McCuen's equation. The licensee adopted the Muskingum-Cunge method to simulate channel flows between the upstream and downstream sub-catchment outlets and used the level-pool method for simulating reservoir outflows to channels.

NRC staff's evaluation

Figure 2 of the LAR and sheet 9-01 of the engineering drawings show the existing conditions for storm water control on the existing tailings impoundment at Church Rock. In the existing design, storm water is controlled via a series of Branch Swales (A through H), the North Upstream Diversion Channel, the North Cell Drainage Channel, and the Pipeline Arroyo (with a buried rock jetty). Figure 9 of the LAR and sheet 9-02 of the engineering drawings show the planned final grading plan for the mine waste repository and the changes to the Pipeline Arroyo. The figures show that most of the mine waste repository will have either a 2 percent or a 5 percent slope; a small area on the east side of the repository will have a 5H:1V slope (20 percent slope). The revised grading plan eliminates many of the branch swales from the existing cover system (only branch swales A, B, and H remain, branch swale C will also remain, but most of the length of this branch swale will be upgraded and referred to as the East Repository Channel to accommodate additional flow). The licensee plans to construct two new drainage channels on Dilco Hill (referred to as Dilco Hill Drainage Channel A and B) on the east side of the repository. These new drainage channels are intended to control runoff from Dilco Hill. Along the west side of the existing tailings impoundment, the licensee plans to: (1) upgrade the riprap size in the runoff control ditch and (2) construct a riprap chute to convey runoff through the portion of the Pipeline Arroyo that runs past the central and southern portion of the existing tailings impoundment.

The NRC staff reviewed the sub-catchment areas and compared their delineated boundaries to the ridge lines on USGS topographic maps. Based on the NRC staff's review, the NRC staff finds that the licensee's delineated areas are reasonable and consistent with other available resources. The NRC staff find that licensee's use of the two routing methods to be acceptable for drainage design and analysis since these methods are commonly applied in hydrologic engineering practice. The NRC staff reviewed the input parameter values to the Muskingum-Cunge method and level-pool method being used in the flood routing. The NRC staff observes that the parameter values are within a reasonable range and reflect the licensee's design. Therefore, this aspect of the licensee's evaluation is acceptable to the NRC staff.

The NRC staff reviewed the licensee's assigned values of hydrologic parameters in hydrologic models, including time of concentration, Green-Ampt infiltration, and depression storage. The

NRC staff observes that the assigned parameter values are within acceptable ranges recommended by the technical document and modeling guidelines (HEC-HMS, 2000; ADWR, 2007) and are therefore acceptable. The licensee provided input data to the four hydrologic models, including sub-catchment areas, precipitation depths, temporal and areal precipitation distributions, and channel geometry.

The NRC staff created a confirmatory model based on the licensee's HEC-HMS model. To investigate their impact on the results, the NRC staff chose to use different methods to represent hydrologic processes in the HEC-HMS model. These differences in the model are shown in Table 5 below.

Table 5: Differences in NRC staff and Licensee's HEC-HMS confirmatory calculation

Components of HEC-HMS (Hydrologic Process)	Staff's selected method	Licensee's adopted method
Infiltration Losses	NRCS runoff curve	Green-Ampt equation
Rainfall-Runoff Transformation	SCS Unit Hydrograph	Clark Unit Hydrograph
Channel Routing	Kinematic Wave equation	Muskingum-Cunge method
Reservoir Routing	Not simulated since no impact on the simulation results was found.	Level-Pool method

After reviewing the NRC staff's confirmatory model and the licensee's model, the NRC staff finds that the licensee's model results are conservative.

4.2.4 Evaluation Findings

The NRC staff has completed its review of flooding potential at the Church Rock uranium mill facility and mine waste repository. This review included an evaluation using the procedures in Section 3.2.2 and the acceptance criteria outlined in Section 3.2.3 of the standard review plan (NUREG-1620).

On the basis of the information presented in the LAR and the detailed review conducted of the flooding potential for the Church Rock uranium mill facility and mine waste repository, the NRC staff concludes that the flood analyses and investigations adequately characterize the flood potential at the site and that surface water hydrology and flooding considerations represent a feasible plan for meeting the relevant requirements of 10 CFR Part 40, Appendix A.

The mill tailings and mine waste at Church Rock facility will be protected from flooding and erosion by a cover system that was designed following the guidance prepared by the NRC staff. Additionally, the licensee's plans to upgrade the Pipeline Arroyo will also help protect the site from extreme events. Flood analyses by the licensee demonstrate that this erosion protection is adequate based on (1) selection of the proper rainfall and flooding events; (2) selection of appropriate parameters for determining flood discharges; and (3) computation of flood discharges, using appropriate and/or conservative methods. While the NRC staff concludes that the flood analyses are adequate, because of the proximity of the tailings disposal cell to the Pipeline Arroyo, the 18 square mile upstream drainage area in the Pipeline Arroyo upstream of the proposed riprap chute, and the uncertainties associated with PMP related flooding at Church Rock, the NRC staff is requiring an observation period after construction of the mine waste repository. This is further discussed in Section 4.3.3.1 and 4.3.4 of this SER.

The licensee presented analyses to show that the site can be protected during extreme rain events. The erosion protection features of the design are large enough to resist flooding from the shallow depths and forces of floods occurring during a probable maximum precipitation (PMP) event in the upstream drainage area and on the cover system of the mine waste repository. Therefore, the NRC staff concludes that the erosion potential at the proposed site has been acceptably minimized, since any flooding at the site is mitigated by the erosion protection.

On the basis of the information presented in the LAR and the detailed review of the flooding potential for the Church Rock facility, the NRC staff concludes that the flood analyses contribute to meeting the following requirements of 10 CFR Part 40, Appendix A: Criterion 6(1), requiring that the design provide reasonable assurance of control of radiological hazards to (i) be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years; and Criterion 12, requiring that active maintenance is not necessary to preserve isolation.

4.3 Water Surface Profiles, Channel Velocities, and Shear Stresses

After estimating the peak flood discharges using the four hydrologic models, the licensee developed four channel hydraulic models to analyze the flow conditions (water levels, velocities, and shear stresses) in the channels. These conditions provide the basis for the required erosion protection features, including riprap size and layer thickness, which are needed to ensure erosional stability in the channels during the occurrence of the design events.

4.3.1 Regulatory Requirements

The NRC staff determines if the licensee has demonstrated compliance with 10 CFR Part 40, Appendix A, Criterion 6(1), which requires that the design be effective for a period of 200 to 1000 years, and Criterion 12, which requires that active maintenance is not necessary to preserve isolation.

4.3.2 Regulatory Acceptance Criteria

Unless specifically stated otherwise, the LAR was reviewed for compliance with the applicable requirements of 10 CFR 20 and 10 CFR 40 using the acceptance criteria presented in SRP Section 3.3.3, “Water Surface Profiles, Channel Velocities, and Shear Stresses.” (NRC 2003b).

The acceptance criteria in SRP Section 3.3.3 address: (1) flood depths, velocities, and shear stresses; (2) proper consideration and modeling of off-site flooding effects; and (3) use of acceptable models and input parameters.

4.3.3 Staff Review and Analysis

Unless specifically stated otherwise, the information reviewed in this SER section is from information, data, and maps submitted by the licensee in Attachments G.8 (20 percent side slope on cover system), I.2 (mill site and repository channel stability), I.5 (hydraulic analysis of north diversion channel), I.7 (Pipeline Arroyo Riprap chute) of the LAR (UNC 2018). The four channel hydraulic models are described next in sub-sections from 4.3.3.1 to 4.3.3.4.

4.3.3.1 Pipeline Arroyo

The licensee developed a three-dimensional flow model to simulate shear stresses and velocities in the proposed Pipeline Arroyo Riprap Chute and its outlet area. The shear stress and velocity distributions of the simulation results are the basis for the riprap rock layer design as described in the Attachment I.7 of Volume I of the LAR, entitled "Hydraulic Analysis and Riprap Sizing for the Pipeline Arroyo Riprap Chute."

Summary of the licensee's information

The LAR contains a design for replacing the rock jetty that is an existing buried riprap slope. The rock jetty is located at a channel bottom drop of the Pipeline Arroyo (Figure I.7-12 of Appendix I and Design Drawing 09-02 of Volume II of the LAR) near the northwest side of two evaporation ponds. The ponds are on the north edge of South Tailing Cell. The licensee proposed to eliminate the Pipeline Arroyo bottom drop and replace the existing rock jetty by adding a riprap chute and a sunken basin (see Figure 11 below). The licensee designed the slope of the riprap chute to be 5.3% and the sunken basin length as the chute outlet to be 65 ft with an extension of 380 ft long for the basin apron outlet (Design Drawing 09-11 of Volume II of the LAR).

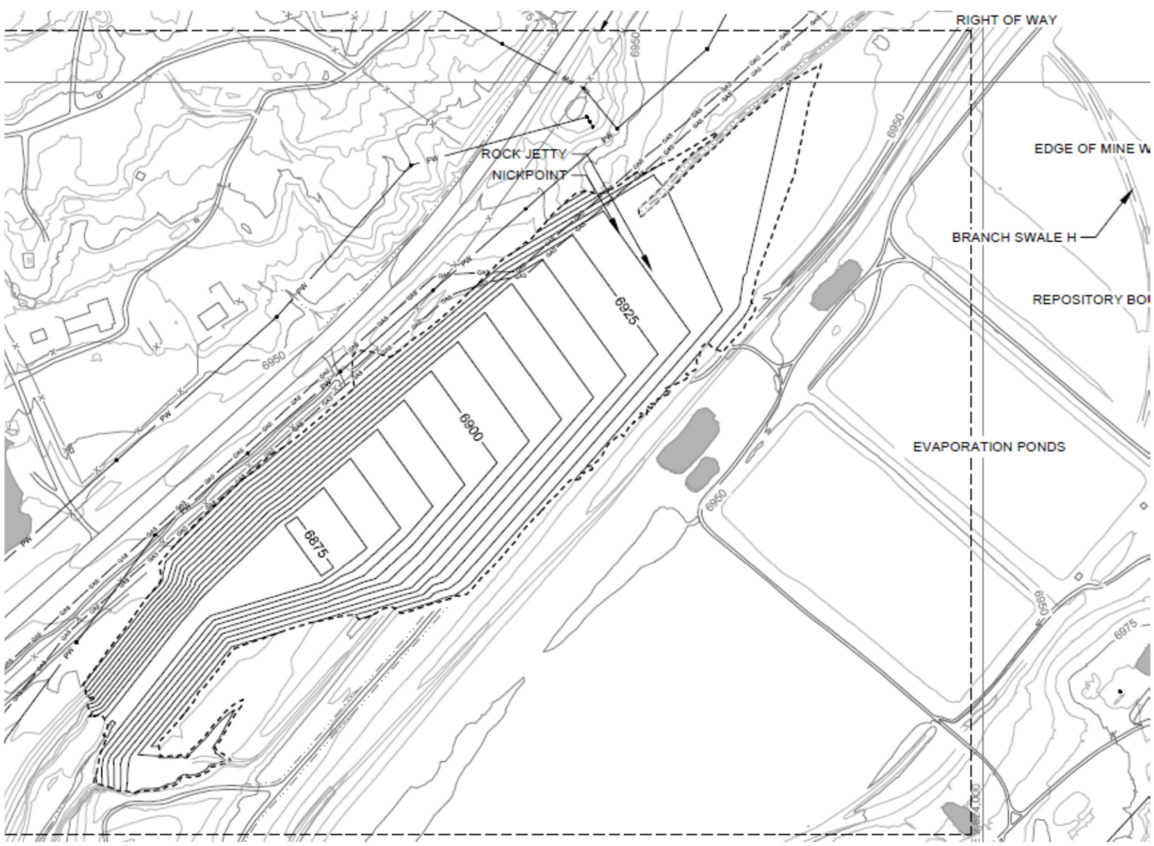

Figure 11: Location of the proposed riprap chute in the Pipeline Arroyo and the existing Branch Swale H and two evaporation ponds

(A reprint portion of Design Drawing 09-02 of Volume II of the LAR)

The licensee used a three-dimensional model to simulate steady flow conditions within the riprap rock chute and the sunken basin for multiple flood events. The simulation results indicate that the PMF produces a maximum flow speed of 27 ft/s near the right bank (northern side) of the riprap chute (Figure 3 of Supplement I.7.1 of Attachment I.7 of Appendix I, Volume I). The licensee used this flow velocity as a main velocity to design the riprap rock protection for the chute and the sunken basin. The licensee selected other velocities lower than 27 ft/s as secondary options to design riprap rock protection for low flow velocity areas.

NRC staff's evaluation

During its review, the NRC staff evaluated several different aspects of UNC's design, including: (1) the variation in the depth-average velocity along the cross section given the approximately uniform slow depth indicated on Figures 2 and 3 of Attachment I.7; (2) the channel roughness using a 12-inch height; (3) observed high flow velocities larger than 3 ft/s (Figures 2 and 3; Design Drawing 09-10) in some local areas without riprap rock protections; (4) the length of the hydraulic jump at the bottom of the riprap chute; (5) balancing of sediment transport between the inlet and outlet of the designed basin; and (6) mesh size in the 3D model. The licensee's approach to each of these aspects of the design and the NRC staff's conclusion is summarized below (the licensee's approach is summarized from ML19315A007).

1. The variation in the depth-average velocity along the cross section given the approximately uniform slow depth indicated on Figures 2 and 3 of Attachment I.7.

   The licensee stated that:

   Figure 3 of Attachment I.7 shows velocities at cross-section A-A range from about 27 to 5 feet per second. Although a straight, prismatic channel would be expected to have a more uniform velocity distribution across the section in which the velocity peak occurs at the center of the section, this riprap chute is not a straight, prismatic channel because the cross-sectional area is contracting along the left (southern) bank as flow moves down the chute as shown in Figure 1 of Attachment I.7. In this asymmetric contraction of flow, the velocity is expected to be greatest along the right (northern) side of the channel where flows have the streamline of least resistance and the velocity would be expected to stagnate along streamlines where the flow is obstructed. This asymmetry in the geometry was the reason that the 3-dimensional Computational Fluid Dynamics (Flow3D) model was used to model this structure.

   Based on the licensee's explanation, the NRC staff understands that the asymmetrical channel section is the reason for the asymmetrical flow conditions. Therefore, the NRC staff finds this aspect of the licensee's calculations to be reasonable.

2. The channel roughness using a 12-inch height

   The licensee stated that:

   The 12-inch roughness height assumed in the Flow3D hydraulic model was chosen as a reasonable representation of the portion of the D_{50} = 27-inch riprap armoring that might protrude into the flow field and contribute to the channel roughness. The roughness height specifies a boundary roughness for the boundary layer assumptions at the *channel bed in the model, and does not significantly affect the greater depth-averaged results shown in Attachment I.7 of Attachment I.*

Based on the licensee's explanation, the NRC staff concludes that the channel roughness height is adequately used in the flow simulation since the riprap rock size is considered to influence the boundary layer thickness of the channel's turbulent flow.

3. Observed high flow velocities larger than 3 ft/s (Figures 2 and 3; Design Drawing 09-10) in some local areas without riprap rock protections.

   The licensee stated that:

   Stantec updated the design drawings (9-09, 9-10, and 9-11) to extend the riprap layers downstream of the channel constriction to station 19+00. The revised drawings are included as Attachment 3 to this submittal. At this point, grading of the riprap chute ties into the existing Pipeline Arroyo channel.

   Based on the licensee's response, the NRC staff concludes that riprap rock layer will protect the downstream apron as rock will be placed in the areas of the chute with higher flow velocities. The NRC staff validated the extended riprap layer based on reviewing the licensee's submittal of the revised design Drawings 09-09 through 09-11 (ML19315A011).

4. The length of the hydraulic jump at the bottom of the riprap chute.

   The licensee stated that:

   In design drawings 9-09, 9-10, and 9-11, Stantec extended the apron length to the riprap basin to 380 feet. This is sufficient to provide erosion protection beyond the length of the hydraulic jump. The revised drawings are included as Attachment 3 to this submittal.

   The NRC staff performed a simple confirmatory calculation to verify that the licensee's hydraulic jump could be contained within the length of the riprap basin. The NRC staff's approach considered the flow velocities upstream and downstream of the riprap basin. Additionally, the NRC staff's calculation considered the geometric configuration of the riprap basin. The NRC staff's approach reached the same conclusion as the licensee – that extending the riprap basin to 380 feet is expected to be sufficient to contain the hydraulic jump. Based on its confirmatory calculation, the NRC staff finds that the licensee's evaluation is sufficient for calculating the length of the hydraulic jump. Therefore, the NRC staff finds that the extended apron length is adequate to contain the anticipated hydraulic jump length.

5. Balancing of sediment transport between the inlet and outlet of the designed basin.

   The licensee stated that:

   Stantec evaluated the sediment transport capacity upstream and downstream of the riprap chute and basin using the same methods and equations in Attachment I.4 of Appendix I, where the flow depth and shear stress are calculated based on the

Manning's Equation for the 5-year and 10-year design discharges. The upstream and downstream sections evaluated are shown……. The results show that the expected shear stresses for the 5-year and 10-year storm are greater downstream of the chute than upstream of the chute and sediment transport capacity downstream of the chute is also greater than upstream of the chute. Therefore, sedimentation is not expected on the downstream side of the riprap chute.

The NRC staff reviewed the licensee's approach in Attachment I.4 and observed that it was correctly implemented based on the licensee's design. The NRC staff observes that the calculation package is consistent with the planned cross section and slope called for in the design. Additionally, the NRC staff reviewed the approach and recognizes that the Shields approach is a widely accepted methodology (USDA, 2008). During its review, the NRC staff did not identify any arithmetic errors in the licensee's calculation. As the licensee used a widely accepted approach that was correctly implemented, the NRC staff concludes that sedimentation capacity has been acceptably described.

6. Mesh size in the Flow 3D model.

   The licensee stated that:

   An analysis of the sensitivity of the simulated velocities to the mesh size has not been performed; however, it is our judgement that decreasing the mesh size would have negligible impact on the design while requiring significantly more computation time. As an illustration of the relative resolution of the mesh size consider that the D_{50} of the riprap on the rock chute is 27-inches; so, the mesh size is already less than the median rock size (the base roughness element) on the chute. Further, the riprap design equations use average unit discharge (which we have approximated from a depth-averaged velocity) and average channel bed slope, so the refinement would provide little value from a design perspective.

   The NRC staff observes that the mesh-size can be used in the licensee's three-dimensional flow modeling since the mesh-size matches the riprap rock size and the thickness of boundary layer of channel's turbulent flow when the channel's turbulent flow is on the layer of riprap rock. Based on the licensee's response and the NRC staff's review, the NRC staff concludes that the current mesh-size is adequate as it similar to the riprap rock size.

For a comparison to the licensee's modeling approach, the NRC staff performed a confirmatory calculation. The NRC staff used a one-dimensional HEC-RAS configuration for steady flow simulations. The purpose of the NRC staff's approach was to provide further assurance in the licensee's calculated flow velocity in the riprap chute. In developing its calculation, NRC staff used the licensee's revised design drawings (Design Drawings 09-10 and 09-11, ML19315A011) to develop channel geometry. Consequently, the NRC staff's channel geometry is consistent with the configurations of the licensee's riprap chute, downstream basin and the basin outlet channel. In its calculation, the NRC staff arrived a maximum flow velocity of approximately 27 ft/s in the riprap chute, which is consistent with the results of the licensee's analysis. Based on the comparisons of the licensee's analysis and the NRC staff's confirmatory calculation, the NRC staff finds that the licensee's approach is sufficient for calculating the flow velocity in the riprap chute. Additionally, the NRC staff determined that the flow velocity, 27 ft/s, is adequate and can be used to calculate the riprap rock protection in the riprap chute and outlet basin.

The licensee stated it has followed the guidance in NUREG-1623 in designing the riprap chute. The NRC staff observes that the guidance is intended for situations where there are no particularly difficult erosion considerations. Past correspondence with UNC on earlier versions of reclamation plans discuss the challenges with the Pipeline Arroyo and its proximity to the tailings impoundment at Church Rock (NRC, 1988; NRC, 1989; NRC, 1990; and NRC,1991a). While the reclamation plan and modifications to it have received NRC approval in amendments 10 (NRC, 1991b), 17 (NRC, 1993), 24 (NRC, 1996a), and 25 (NRC, 1996b) to license SUA-1475, the Pipeline Arroyo remains a challenging aspect of the Church Rock site. Given the challenging aspects of the Church Rock site identified above and the specific aspects of the Pipeline Arroyo discussed below, the NRC staff is concerned that this is a site with particularly difficult erosion considerations that falls outside the scope of the guidance in NUREG-1623. The first challenging aspect relates to the riprap chute. The riprap chute in the Pipeline Arroyo is an engineering feature that, to the NRC staff's knowledge has not been constructed in a similar size at other uranium mill tailings sites. The second challenging aspect relates to the impact forces in the area of the hydraulic jump at the bottom of the rip rap chute. The proximity of the tailings disposal cell to the Pipeline Arroyo, the 18 square mile upstream drainage area in the Pipeline Arroyo upstream of the proposed riprap chute, and the near surface soil conditions and situating the riprap chute on the alluvium layer within the Pipeline Arroyo all relate to the NRC staff's concerns. Performance concerns with the riprap jetty in the Pipeline Arroyo have been documented (NRC, 2003a). These composited aspects of the site and performance to date make the integrity of the riprap chute, and potential need for maintenance more uncertain in the long term. The NRC staff therefore cannot conclude with reasonable assurance that the proposed design will provide control of radiological hazards for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. As discussed in more detail in SER Section 4.3.3.4, the NRC staff is therefore imposing a license condition requiring an observation period prior to license termination to verify that the design is function as intended. Additionally, the observation period will allow for an informed decision related to the anticipated life span of the design and any long-term surveillance, maintenance, and funding needs for the revised approach to site stability, in light of past performance and significant uncertainties discussed above. The license condition allows the licensee to demonstrate compliance using a performance-based approach. The condition can be found in the evaluation findings section below (SER Section 4.3.4).

4.3.3.2 Upper Pipeline Arroyo Area

In Volume I of the LAR, Attachment I.6, "Upper Pipeline Arroyo Hydraulic Model," the licensee addressed two-dimensional channel hydraulic simulations to estimate the flood flow profiles, velocities, and shear stresses in the North Cell Drainage Channel and its adjacent flood plain, the Northern Alluvial Area. The simulation is based on the Hydrologic Engineering Center's River Analysis System (HEC-RAS 2-D) model published by the United States Army Corps of Engineers. The HEC-RAS 2-D model can simulate depth average flow velocities within a flood area.

Summary of the licensee's information

The North Cell Drainage Channel and Northern Alluvial Area (see upper right corner of Figure 12 of this SER) are adjacent to the northern boundary of the north cell of the Tailing Disposal Area (TDA). The channel and its alluvial flood plain discharge flood flows into the upstream reach of the Pipeline Arroyo. The North Cell Drainage Channel runs east to west through the Northern Alluvial Area. In the LAR, the licensee presented an elevation increase of the channel embankment to confine an estimated PMF flow in the channel. To determine the increase of the embankment height, the licensee used the simulation results of HEC-RAS 2-D model. The licensee used aerial survey data to create the geometric data as input parameters to the model that included channel configuration, flood plain extent, and their adjacent terrain. The channel design and its embankment improvement are presented on the Design Drawings 9-02 and 9-07 in the Volume II of the LAR.

Regarding the flow boundary conditions of the two-dimensional flow simulation, the licensee assigned inflow hydrographs at two upstream locations and specified an energy slope at the outlet of the downstream reach of the Pipeline Arroyo. The licensee specified the effective precipitation over the simulation area to exclude the precipitation loss due to infiltrations in the soil. The simulation is for unsteady flow conditions.

The simulation results indicate that the PMF flow remains in the North Cell Drainage Channel with the proposed embankment improvement (Figures 7 of Attachment I.6 of Appendix I of Volume I). Also, the results indicate that the improved channel embankment reduces the shear stress on the channel bed area (Figures 5a and 5b of Attachment I.6 of Appendix I of Volume I). The simulation results state that the flow velocity is reduced with the embankment improvement. The licensee concluded that the simulated PMF flow and other lesser flows remain in the improved channel and the flows do not overtop the improved right embankment (looking downstream) of the channel.

NRC staff's evaluation

The NRC staff reviewed the licensee's two-dimensional model, including the assigned boundary values, input parameters, and the output data. The NRC staff finds that the assigned hydrographs at the two upstream locations are consistent with the hydrological modeling results (HEC-HMS modeling results). The NRC staff finds that the specified energy slope and the channel slope at the simulation outlet are consistent. The NRC staff finds that the hydraulic parameter values assigned to the model are within a reasonable range as recommended by the design manual of the HEC-RAS 2-D model. The NRC staff finds that the licensee's aerial survey data with an accuracy within 1-foot horizontal and 0.5-feet vertical is reasonable to represent the channel geometry and the adjacent areas of the North Cell Drainage Channel. Subsequently, the NRC staff considers that using the survey data is adequate to develop the two-dimensional flow model. Based on the NRC staff's review on the modeling boundary values, input parameters, and output data, the NRC staff finds that the licensee's computed PMF flows do not overtop the embankments of the channel, and the shear stresses are reduced on the channel bed and its adjacent areas.

4.3.3.3 North Diversion Channel

In the LAR, Attachment I.5, "Hydraulic Analysis of the North Diversion Channel," the licensee addressed one-dimensional channel hydraulic simulations to estimate the existing flow capacity in the channel and check potential overbank flows. The one-dimensional flow simulation is based on the Hydrologic Engineering Center's River Analysis System (HEC-RAS 1-D) model published by the United States Army Corps of Engineers.

Summary of the licensee's information

The North Diversion Channel originates at the outlet of Basin 41 (Figure I.1-1J of Attachment A to Attachment I.1 of Appendix I of Volume I of the LAR). The downstream reach of the North Diversion Channel runs north along the east boundary of the property and ends at an alluvial flood plain (see right edge portion of Figure 12 of this SER). The channel collects surface runoff from the upstream basins, including Basins 32, through 38, and 41 of the Mill Site Repository Area. The licensee plans to remove the aggregated sediment in a portion of the upstream channel and improve the left embankment (looking downstream) of the channel (Design Drawing 9-05 of Volume II of the LAR).

The licensee simulated the PMF profile for the channel using the HEC-RAS 1-D model. The simulation is for a steady peak flow condition in the channel. The simulation results indicate that the PMF profile remains throughout all reaches of the North Diversion Channel (Figures 2 through 26 of Attachment I.5 of Appendix I of Volume I of the LAR). The licensee adjusted flow friction coefficients to reflect the worst-case hydraulic channel condition. The licensee concluded that the simulated PMF flows in the worst hydraulic condition do not overtop the improved left embankment (looking downstream) of the channel (Figures 27 of Attachment I.5).

NRC staff's evaluation

The NRC staff used the licensee's aerial survey data saved on a Compact Disc (ML19157A173) to develop the channel geometry and establish a confirmatory hydraulic calculation for the North Diversion Channel. The purpose of the NRC staff's calculation was to provide further assurance in the licensee's calculated flow velocity in the North Diversion Channel. The NRC staff used a one-dimensional configuration in the HEC-RAS software. The NRC staff assumed a steady flow simulation. By using HEC-RAS in this manner, the NRC staff was able to gain insights on the water surface profile that would result from a PMP event. In its calculation, the NRC staff used the same parameters for the North Diversion Channel that the licensee used in its analysis. The NRC staff's results for the maximum flow velocity and flow depth in the North Diversion Channel reached similar results to what was presented in the licensee's analysis. The NRC staff's confirmatory calculation provides additional support and confidence in the licensee's approach as the two separately prepared calculations resulted in similar values for the flow depth and velocity in the North Diversion Channel. Based on the comparison between the licensee's approach and the NRC staff's approach, the NRC staff determined that the licensee has adequately computed PMF flows. Additionally, the NRC staff finds that the licensee has demonstrated that the computed PMF elevations at multiple locations do not overtop the embankments of the channel. Therefore, the NRC staff finds the licensee's approach acceptable for determining the flow depth and velocity in the North Diversion Channel.

4.3.3.4 Stability of Riprap Chute in Pipeline Arroyo

Stability of Stiff Stream Banks

The NRC staff reviewed the Pipeline Arroyo with the Field Photographs 3, 4 and 5 of Appendix B of Attachment I.8 of Volume I of the LAR (ML18267A275) and visited the site on June 11, 2019. Based on the photographs and the site observation, the NRC staff considers that the stiff slopes of stream banks are unstable, and the existing channel is an erosional pathway. The slope failures and the streambed erosions appear inevitable. The licensee provided riprap chute design to prevent the bank slopes from failure and protect the streambed from erosion. The key portion of the licensee's explanation is below (ML20078K264).

Summary of licensee's information

Please refer to Drawings 9-9 and 9-10 and Photos I.7.3 and I.7.4 from Appendix I. Within the limits of the riprap chute, the design side slopes range from 5:1 (horizontal: vertical) to 2.5:1. Given that these slopes are generally mild from a slope stability standpoint (i.e., the slope angle is much less than the soil friction angle), a formal geotechnical stability study is not considered necessary. From an erosional stability perspective, the design includes the requirement to armor the slopes with riprap, which will protect the slopes from surface water erosion. ….. In the design of the riprap chute, the potential for settlement of the foundation was considered by the geotechnical team. The geotechnical team's review identified that the loads on the foundation soils will generally decrease (not increase), due to excavation depths prior to rock placement with the installation of the riprap chute because there will be a net cut of existing soils. Based on this finding, a bearing capacity analysis was determined to be unnecessary. In addition, foundation preparation and compaction requirements for the soil subgrade have been incorporated to limit any areas of localized settlement. An advantage of a riprap chute is that the structure can withstand modest settlement of the foundation without impacting the performance of the chute.

NRC staff's evaluation

The NRC staff recognizes that side slopes of the riprap chute were designed to change the vertical channel side slope to be between 0.2 (5 feet horizontal to 1 foot vertical) and 0.4 (2.5 feet horizontal to 1 foot vertical), which is less than 0.5 (2 ft horizontal to 1 ft vertical), Based on the designed side slopes being shallow and the relatively short slope lengths within the riprap chute a detailed of the slope stability study for the riprap chute is not needed and the NRC staff finds that the side slope design is adequate.

The NRC staff recognizes that the excavation in the riprap chute area can provide some extra bearing capacity to support the channel bed and the expected settlement of the channel bed is modest. The NRC staff finds that it is not necessary to analyze the bearing capacity due to the licensee providing soil compaction and the excavation depths prior to placing rock layer on the channel bed.

Stability of the Proposed Riprap Chute with Hydraulic Jump

The licensee presented the alluvium profile at the proposed riprap chute area in the Pipeline Arroyo as indicated in Figures 2, 3, and 4 of Attachment I.8 of Appendix I of Volume I of the LAR, Geotechnical Evaluation Report Church Rock Mill Site Jetty, with an average subgrade thickness of the alluvium below the ground surface of approximately 100 ft. The alluvium layer and its thickness may therefore not support a constricted flow at the downstream end of a hydraulic jump in the riprap chute for the long term, although the top alluvium layer at a 3 to 5 ft depth will be replaced by compacted soil and rock filters.

Over the long term, the licensee has not established whether the alluvium is sustainable to support an impact force resulting from a hydraulic jump in the riprap chute. Since the alluvium materials are silt-clayey and not structurally and concretely integrated, it is uncertain whether the alluvium is capable of sustaining the large impact force acting on the embankments of the constricted flow section with an adequate factor of safety when the hydraulic jump occurs at the outlet basin of the riprap chute. The NRC staff performed an independent assessment and recognizes there is uncertainty with the forces acting on the riprap in a hydraulic jump. The NRC staff considers that the erosion protection features will likely require active maintenance over the performance period because of the unique aspects of the site. The NRC staff further concludes that the licensee has not demonstrated that hydraulic design features can sustain the impact forces resulting from hydraulic jumps at the narrow outlet channel near the end of the riprap chute. The bottom width of the riprap chute is narrowed down from approximately 350 ft to 50 ft. This chute design creates a flow contraction at the junction of the hydraulic jump and the narrow channel outflow. This contraction force could potentially to cause downstream channel failure and result in damage to the riprap chute and surrounding area, including the existing tailings. Although rom the contraction flood forces that are very large and have low probabilities of occurrence over the performance period, the staff cannot find reasonable assurance of adequate protection on the downstream narrow channel supported with alluvium. Further, given the uncertainty associated with the calculation of forces on the rip rap chute in the area of the hydraulic jump, it is unlikely that additional analyses would provide the NRC staff with reasonable assurance. Instead, the NRC staff proposes to approve the proposed modifications subject to a license condition requiring an observation period prior to termination of the license. This license condition will allow the NRC staff to observe the actual performance of the rip rap chute and make a risk-informed, performance-based decision on any modifications or maintenance needs for the post-termination performance period. The proposed license condition is included as License Condition 34C in Section 4.3.4 of this SER.

4.3.3.5 Drainage channels adjacent to mine waste repository

In the LAR, Attachments I.2, and I.4 of Appendix I to Volume I of the LAR describe the channel capacity, erosion stability, and sediment transport competency in the local drainage channels. The evaluated local drainage channels include East Repository Channel, North Cell Drainage Channel, Runoff Control Ditch, Branch Swale H, and Dilco Hill Channels A and B. The suitability of the erosion protection and channel capacity for the local channels is evaluated based on the Manning Equation and allowable shear stress equation, except for the North Cell Drainage Channel. The licensee used a two-dimensional hydraulic model to simulate PMF flow conditions for the North Cell Drainage Channel. For the local drainage capacity and erosion protection, the licensee used a PMF event as a design basis. For the sediment transport competency, the licensee used 2-year and 10-year flood events as design bases.

The licensee’s description and the NRC staff evaluation relevant to the channel capacity, erosion protection, and sediment transport, follow.

Summary of the licensee’s information

The licensee proposed the lower East Repository Channel and two branches, Dilco Hill Channels A and B, to convey surface runoff from the Church Rock Mill Site Repository and Dilco Hill areas to the existing North Cell Drainage Channel (see Figure 12 below).

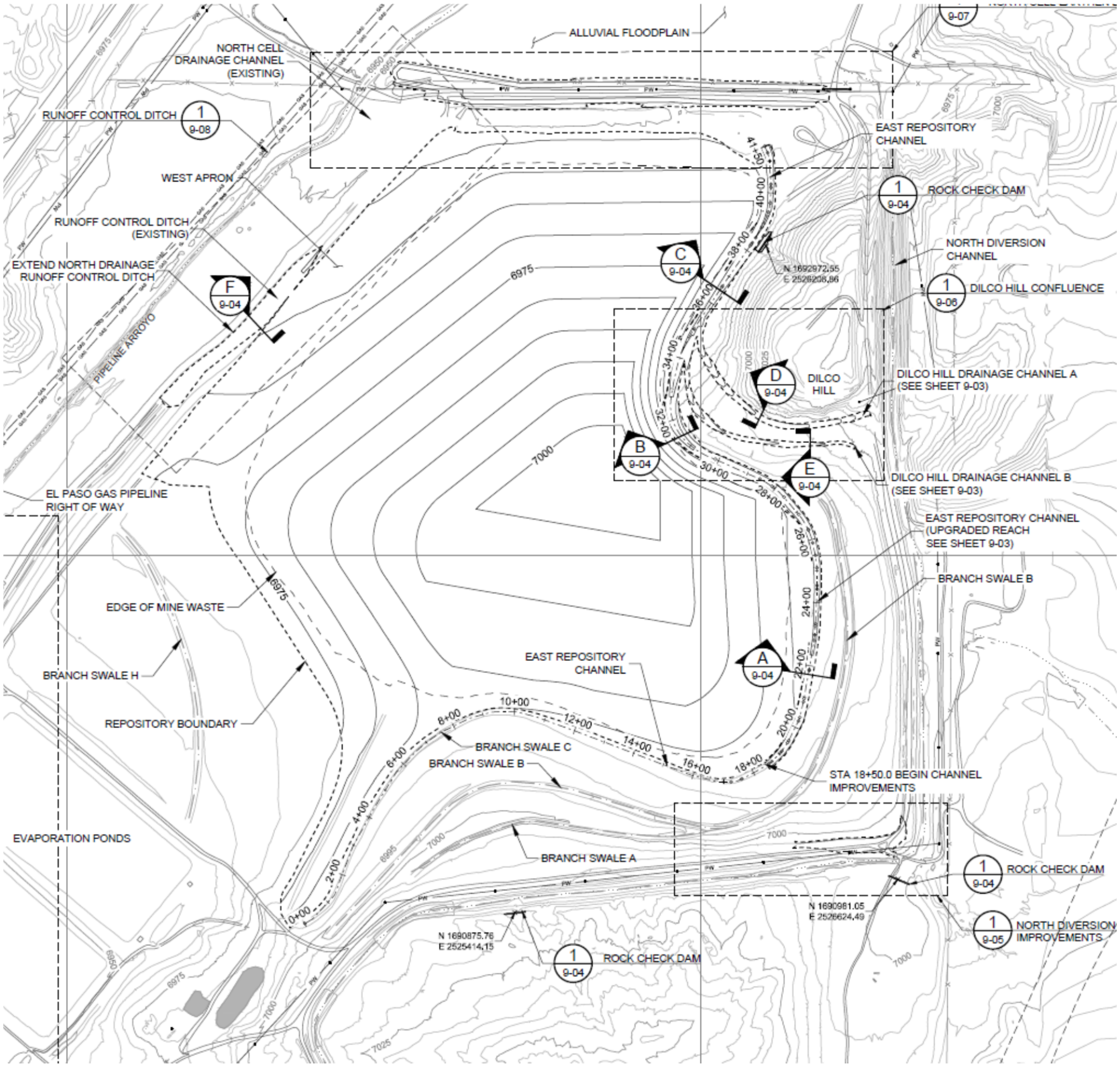

Figure 12: Layout of drainage system in the proposed repository area of the mill site

(A reprint portion of Design Drawing 09-02 of Volume II of the LAR)

The Repository area will be overlaid by a proposed mine waste layer and a cover layer as part of the Removal Action (RA) plan. The proposed lower East Repository Channel will follow the existing path of the upper reach of the North Cell Drainage Channel. The licensee presented the channel alignment, channel profiles, and typical channel cross sections in the Design Drawings 9-02 through 9-06 (Volume II Design Drawings of the LAR, ML18267A348) for the lower East Repository Channel and the two Dilco Hill Channels A and B. The Design Drawing 9-02 also shows the locations of Branch Swale H, which has no outlet (see middle left edge of Figure 12), and Runoff Control Ditch, which connects to a natural drainage downstream along the north-west edge of the mill site repository area.

The licensee applied the Manning Equation and the Shield Curve to quantify the sediment competency of the local channels. For sediment transport, the design of the lower East Repository Channel is to increase the sediment transport competency in the channel by modifying existing channel geometry. The design of the two Dilco Hill Channels A and B, which are two sediment interception channels, is to reduce sediment delivery into the lower East Repository Channel by breaking overland flow lengths on the Dilco Hill slope and by intercepting sediment on the slope. Further, to intercept sediment transport from Dilco Hill, the licensee proposed a check dam downstream of Dilco Hill as a sediment control point.

To prevent overbank flows with a 6-inch freeboard, the licensee designed the channel capacities to convey PMF flows using the Manning Equation. For the channel protection from erosion for a PMF event, the licensee used a shear stress method to design riprap rock sizes in the top layer of channel lining. The calculated channel flow capacities and riprap rock sizes were provided in Attachments I.2 of Appendix I to Volume I of the LAR.

Concerning sediment transport competency, the licensee applied the Manning Equation to compute the maximum flow depths of two peak flows related to 2-year and 10-year storms. The calculated sediment transport competency is detailed in Attachments I.4 of Appendix I to Volume I of the LAR. A maximum flow depth is associated with a maximum shear stress on the channel bed. The licensee adopted a force balance equation for a uniform flow depth to compute the maximum shear stress individually for a 2-year and a 10-year storm. With the computed maximum shear stress, the licensee applied the Shield Curve to determine the different largest size of the movable sediment on the channel bed for 2-year and 10-year storms. The licensee stated that an increase of the computed largest size of the movable sediment for the post-RA condition is the index of increasing the sediment transport competency in the design channel.

Based on the increased largest size of movable sediment, the licensee concluded that the channel design provides enough competency of the lower East Repository Channel to convey the upstream sediment delivered from the two Dilco Hill Channels A and B.

NRC staff's evaluation

The NRC staff reviewed the licensee's Design Drawings on Sheets 9-2 through 9-6 for the lower East Repository Channel and the Dilco Hill Channels A and B. Examining the licensee's drawings and the computational data, the NRC staff finds that the licensee used channel geometrical data that is consistent with drawings for the computations to determine the largest size of the movable sediment transport for each of 2-year and 10-year storms. The NRC staff further finds that the licensee used the same channel geometry to determine the channel capacity and the riprap size for erosion protection for a PMF event. Based on the NRC staff's evaluation the computational results, the NRC staff finds that the licensee correctly implemented the design in its evaluation of the local drainage capacity. Thus, the local drainage design is acceptable.

The NRC staff finds that the licensee's methodology to determine the largest size of movable sediment is reasonable because the licensee applied the Manning Equation and Shields Curve, which is commonly used in sediment transport computations (USDA, 2008). The NRC staff reviewed the licensee's computational results shown in Attachment A, Calculation Worksheet, of Attachment I.4 of Appendix I to Volume I of the LAR. The NRC staff compared the licensee's computed largest size of the movable sediment and the NRC staff's confirmatory estimate. The purpose of the NRC staff's estimate was to verify that the licensee had correctly implemented the Shields methodology. In developing its calculation, the NRC staff used the same channel geometry that was identified in the LAR. Additionally, the NRC staff used the same methodology used by the licensee. Through its confirmatory calculation, the NRC staff arrived at similar results to the licensee. Based upon the evaluation above and by separately validating the licensee's approach in its own calculation, the NRC staff concludes that sediment transport has been adequately incorporated into the channel design.

Based on the NRC staff's review, the NRC staff determines that the lower East Repository Channel and Dilco Hill Channels A and B are adequately designed. The NRC staff concludes that the lower East Repository Channel provides enough sediment transport competency and that the Dilco Hill Channels A and B reduce sediment delivery into their downstream areas for 2-year and 10-year storms.

The NRC staff finds that the Branch Swale H is not suitably evaluated at this time since the Branch Swale H has no outlet. The NRC staff will evaluate the Branch Swale H when the evaporation ponds, which are part of the licensee's current CAP, are eliminated, and the swale outlet will be restored, as further described in License Condition 34B proposed in Section 4.3.4 of this SER. This purpose of the license condition is to have the NRC staff verify that the extension of Branch Swale H can still convey the flows from its contributing drainage area with the design approved in the 1991 reclamation plan.

The licensee evaluated the channel flow depths, velocities, and shear stresses for the drainage features on the mine waste repository in Attachment I.2 of the LAR. The licensee used the flow rates calculated in Attachment I.1 (NRC staff's review documented in Section 3.2 of this SER) and a series of equations for open channel flow hydraulics to calculate the depth, velocity, and shear stresses in the channels. For the rock lined channels (East Repository Channel, Runoff Control Ditch, Dilco Hill Channel A and B, and Branch Swale H, the licensee followed the guidance in NUREG 1623 in calculating the shear stresses in the channels. The NRC staff reviewed the licensee's calculations and performed its own, independent analysis in Microsoft Excel to verify the licensee's results. In its evaluation, the NRC staff used the channel geometries shown in the engineering drawings. The NRC staff also used the same parameters and engineering methodology for open channel flow that the licensee used in its calculation, consistent with NUREG-1623. Specifically, the NRC staff used Manning's equation in its analysis. In its independent analysis, the NRC staff derived values for flow depths, velocities, and shear stresses similar to those in the LAR. By reaching similar results as the licensee in its own calculation following NRC guidance, the NRC staff has additional assurance of the adequacy of the licensee's values, and with the evaluation above, concludes that the licensee has acceptably calculated the flow depth, velocity, and shear stresses in the channels. For the vegetation lined North Cell Drainage Channel, the licensee followed the Temple method (Temple et al., 1987) in evaluating allowable soil velocities and vegetation stresses. The licensee estimated a peak channel velocity of 1.9 ft/s in the North Cell Drainage Channel. This flow velocity is less than the suggested permissible flow velocity (between 2.5 and 3 ft/sec) in a vegetated channel in NUREG 1623. The NRC staff reviewed the licensee's calculations and validated the approach in its independent confirmatory calculations. Similar to the approach described above, the NRC staff used the design geometry for the North Cell drainage channel in its evaluation. Additionally, the NRC staff used the Manning equation to calculate the flow velocity in this channel. In its evaluation, the NRC staff reached a similar value for the peak velocity as the licensee and finds that the licensee's evaluation is acceptable. Therefore, the NRC staff finds that the licensee's estimated peak velocity of 1.9 ft/s can be sufficiently contained in the vegetative lined North Cell drainage channel. In its review, the NRC staff observed that the licensee followed a reasonable approach and that input parameters used reflect the known conditions at the Church Rock site. The NRC staff's independent analysis provided further validation that the licensee's approach was technically sound as the NRC staff's approach was based on accepted engineering practices and the proposed configuration of the site. Therefore, the licensee's approach is acceptable to the NRC staff.

In Attachment I.5 of the LAR, the licensee presented its analysis of the hydraulic capacity of the North Diversion channel (NDC). The NDC runs along the eastern site of the mine waste repository and conveys runoff from areas upgradient of the repository to a flood plain located to the north. The licensee plans to install two check dams to control flow and sediment entering the NDC but does not plan any additional changes to the channel configuration (dimensions or lining). The licensee's calculations state that the NDC can convey the PMF to the flood plan north of the mine waste repository. The NRC staff reviewed the licensee's approach and assumptions used in its calculations. The NRC staff observes that the licensee followed an approach that was based on widely accepted open channel flow methodology. Additionally, the NRC staff recognized that the licensee used input parameters and channel geometry that reflect the planned configuration of the mine waste repository conditions at the site. In its review of the licensee's calculations, the NRC staff did not identify any arithmetic errors. Therefore, the licensee's approach is acceptable to the NRC staff.

4.3.3.6 Cover System Top and Side Slopes

As discussed in Section 3.2.3 of this SER, engineering drawings 7-04 through 7-08 show the grading plan for the final surfaces of the repository. These drawings show that most of the mine waste repository will have either a 2 percent or a 5 percent top slope; a small area on the east side of the repository will have a 5H:1V side slope (20 percent slope). The NRC staff's review of the erosion protection aspects of the ET cover planned for the 2 percent and 5 percent slopes is located in Section 4.5 of this SER. The remainder of this section is focused on the 20 percent side slope of the mine waste repository.

The licensee's analysis supporting the rock sizing for the 20 percent side slope is presented in Attachment G.8 of Appendix G of the LAR. The licensee used the rational method to estimate the unit with discharge for the 20 percent side slope, which is consistent with the recommended approach in NUREG 1623 (NRC, 2002). In its evaluation, the NRC staff reviewed the licensee's assumptions, methodology, and implementation of the rational method. The NRC staff determined that the cover system geometry used in the licensee's approach matches the planned configuration of the 20 percent slope on the mine waste repository. Additionally, the NRC staff concludes that the licensee correctly implemented the appropriate methodology consistent with the NRC's guidance in NUREG 1623. The NRC staff did not identify any arithmetic mistakes in its review. Therefore, the NRC staff determines that the licensee's approach in calculating the flow velocities and shear stresses on the 20 percent slope is acceptable.

4.3.4 Evaluation Findings

The NRC staff has completed its review of the flooding and surface water routing calculations related to the Church Rock Mine Waste Repository. This review included an evaluation using the review procedures in Section 3.3.2 and the acceptance criteria outlined in Section 3.3.3 of the Standard Review Plan.

On the basis of the information presented in the LAR and the detailed review conducted of the flooding and surface water routing calculations for the Church Rock mine waste repository, the NRC staff concludes that the velocities resulting from surface water runoff have been acceptably computed. The mill tailings and mine waste will be protected by flooding and erosion by a series of channels around the perimeter of the repository. With the exception of riprap chute in the Pipeline Arroyo, the analyses presented by the licensee demonstrate that adequate protection is provided by: (1) selection of proper models to assess rainfall and flooding events; (2) selection of appropriate parameters for models for determining flood forces; and (3) computation of flood forces using appropriate and/or conservative methods.

In Section 4.1.2.4 of Volume I of the LAR, and in Section I.4.2 of Appendix I of Volume I of the LAR, the licensee stated that the existing Branch Swale H has no outlet. In the future, the licensee plans to connect the swale to the reach of the downstream South Diversion Channel through the existing evaporation ponds. The existing two evaporation ponds will be removed at that time. The licensee assumes that the future Branch Swale H outlet will be restored as reflected in the current NRC-approved reclamation design (Canonie, 1991; NRC ADAMS ML17121A552) and the downstream South Diversion Channel will be completed prior to license termination. The NRC staff finds that the assumption of restoring Swale H connected with the South Diversion Channel per the approved reclamation design in 1991 by the NRC is not based on the currently updated hydrologic condition and the currently estimated PMF event. Consequently, according to the licensee's plan as summarized above and the currently updated PMF event and site condition, the NRC staff proposes that Condition 34B be included in license SUA-1475. This condition will require verification by the NRC that the extension of Branch Swale H can still convey the flow from its contributing drainage area within the design approved in the 1991 reclamation plan.

> License Condition 34B:
> The impact of future restoration for the Branch Swale H outlet on the local drainage system in the areas adjacent to the two evaporation ponds must be verified when the ponds are removed. The removal of the ponds provides extension space for the Branch Swale H to create its downstream outlet. The licensee shall provide the design of the Branch Swale H extension to the NRC staff for written verification that it is capable of conveying the flow from its contributing drainage area of the mine waste repository within the design approved in the 1991 reclamation plan.

The NRC staff recognizes that the licensee provided the updates of Design Drawing sheets 9-09 through 9-11 of Section 9 of Volume II of the LAR (ML19315A011) to indicate riprap rock would be extended for preventing the downstream area of the basin outlet from erosion. The licensee stated that monitoring an area downstream of the outlet basin in the Pipeline Arroyo be performed to identify possible instabilities with the potential to migrate back toward the riprap basin due to downstream channel bank erosion. Considering the NRC staff's concerns noted in this SER Section 4.3.3.1, the NRC staff proposes license condition 34C in license SUA-1475. The NRC staff would impose this condition to require the licensee to document the as-built performance of the cover system and riprap chute in the Pipeline Arroyo to demonstrate that they have been constructed correctly and perform as expected. Additionally, this condition will allow for an informed decision about long term maintenance and funding needs to be made at license termination.

License Condition 34C

The licensee shall monitor the combined mine waste repository/mill waste impoundment for a minimum of 5 years after relocation of the mine waste and construction of the riprap chute is complete. The purpose of this observation period is to verify the performance of the site features, with a focus on the riprap chute constructed to convey flow through the Pipeline Arroyo.

During the observation period, the licensee shall:

1. Document any observed movement of riprap in the riprap chute.

2. Verify that the 20 percent side slope on the eastern portion of the mine waste repository is functioning as intended.

3. Observe the perimeter drainage channels for evidence of sedimentation.

4. Observe the slopes of the mine waste repository for signs of depressions or grade reversals.

5. Submit an annual report documenting items 1-4 above. This can be submitted with one of the semiannual reports required by 10 CFR 40.65

Prior to license termination, the licensee shall:

1. Repair any observed damage.

2. Determine if any design changes are necessary to provide control of radiological hazards for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.

3. Use the information gained during the observation period to identify any long-term maintenance needs and funding requirements. Any funding requirements will be integrated into the long-term care fee required by Criterion 12.

Finally, the staff proposes modifying License Condition 34 to reflect the modifications to the reclamation plan to accommodate the placement of the mine waste and the LAR. The following sentence would be added to License Condition 34.

The licensee shall implement the revisions to the reclamation plan submitted by the licensee on September 24, 2018 and modified by the submittals on May 16, 2019; June 6, 2019; June 28, 2019; November 18, 2019; September 5, 2019; October 7, 2019; October 14, 2019; November 11, 2019; November 1, 2019; December 4, 2019; February 2, 2020; March 30, 2020; June 4, 2020; and July 8, 2020.

Based on the NRC staff's review and the license conditions described above, the NRC staff has reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 6(1) and Criterion 12 have been met.

The NRC staff concludes that the analyses and models used by the licensee in the LAR and the license conditions discussed above contribute to meeting the following requirements of 10 CFR Part 40, Appendix A: Criterion 6(1), requiring the design to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.; and Criterion 12, requiring that active ongoing maintenance is not necessary to preserve isolation of the tailings.

4.4 Design of Erosion Protection

The ability of a riprap layer to resist the anticipated velocities and shear forces associated with surface water flows is related to the size and weight of the stones used to make up the riprap. Typically, riprap layers consist of a mass of well-graded rocks which vary in size. Because of this variation in size, the design criteria are usually specified as the median stone size, D_{50}, where the subscript denotes the percentage of material that contains stones of less weight. For example, a rock layer with a minimum D_{50} of 6 inches could contain rocks ranging in size from 1 inch to 9 inches. However, at least 50 percent of the weight of the rocks in the layer will be provided by rocks that are larger than 6 inches.

4.4.1 Regulatory Requirements

The NRC staff determines if the licensee has demonstrated that the LAR has met the requirements of 10 CFR Part 40, Appendix A, Criterion 4(c), which requires that embankments and cover slopes be relatively flat after stabilization to minimize erosion potential and to provide conservative factors of safety that ensure long-term stability, are met. The NRC staff determines if the requirements of 10 CFR Part 40, Appendix A, Criterion 4(d) are met. This regulation requires that the rock cover reduces wind and water erosion to negligible levels, including factors such as the shape, size, composition, and gradation of the rock particles. The NRC staff determines if the requirements of 10 CFR Part 40, Appendix A, Criterion 4(f) are met. This regulation requires that the design promote deposition, where feasible. The NRC staff determines if the LAR provides reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 6(1) have been satisfied. This criterion requires that the design provide reasonable assurance to control radiological hazards be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. Finally, the NRC staff determines if the LAR meets the requirements of 10 CFR Part 40, Appendix A, Criterion 12 is met. This regulation requires that active maintenance is not necessary to preserve isolation.

4.4.2 Regulatory Acceptance Criteria

Unless specifically stated otherwise, the LAR was reviewed for compliance with the applicable requirements of 10 CFR 20 and 10 CFR 40 using the acceptance criteria presented in SRP Section 3.4.3, "Design of Erosion Protection" (NRC 2003b).

The review procedures in SRP Section 3.4.2 direct the NRC staff to evaluate the banks of natural channels, top and side slopes, apron/toe of the slope, diversion channels, sedimentation, rock durability, and construction considerations. The acceptance criteria in SRP Section 3.4.3 address: (1) approach proposed for on-site maintenance; (2) demonstration of a site-specific need for active maintenance; and (3) providing funding for active maintenance by increasing the financial assurance amount.

4.4.3 Staff Review and Analysis

Unless specifically stated otherwise, the information reviewed in this SER section is from information, data, and maps submitted by the licensee in Attachments G.7, G.8, I.2, I.7, and I.8 of its LAR (UNC 2018). In this section of the SER, the NRC staff's review focuses on sizing of the erosion protection features proposed in the LAR.

Pipeline Arroyo (adjacent drainage channels)

The licensee's approach is described in Attachment I.7 of the LAR. To determine the rock size to resist the anticipated flow velocities and shear stresses within the riprap chute, the licensee used the Abt-Johnson method. The depth averaged velocity and flow depth from the licensee's CFD model were used as inputs in the Abt-Johnson formula. The NRC staff recognizes that use of the Abt-Johnson method for sizing rock is consistent with the guidance in NUREG-1623. The NRC staff reviewed the licensee's approach and performed its own independent calculations to validate that the licensee correctly implemented the Abt-Johnson method. In its analysis, the NRC staff used the geometric configuration of the riprap chute shown on the engineering drawings. The NRC staff also used the inputs from the CFD model, where appropriate as not all of the inputs from the licensee's CFD model are necessary to include in the NRC staff's confirmatory calculation. The NRC staff used a simplified analytical technique to estimate the anticipated flow velocities and shear stresses in the riprap chute. The NRC staff then used those values from its calculation in the Abt-Johnson methodology to estimate the D_{50} value in the riprap chute. The NRC staff's calculation for the flow depth and velocities in the riprap chute was not designed or capable of producing the same result as the licensee's model. Rather, the NRC staff's calculation was intended to validate that the licensee's overall combination of its CFD model used in conjunction with the Abt-Johnson method reached a reasonable result. Within the riprap chute, the licensee determined that a D_{50} of 27 inches for the bottom portion and part way up the side slopes is the minimum rock size to safely convey the flow from the PMF. In its confirmatory analysis, the NRC staff arrived at a similar rock diameter. In addition to the evaluation above, reaching a similar result via a different analytical method in its independent calculations provides the NRC staff with additional assurance that the licensee has used a valid approach. The NRC staff recognizes that either the licensee's CFD and Abt-Johnson approach or the NRC staff's approach of using a simplified analytical method would be consistent with the guidance in NUREG 1623. Therefore, based on its review, the NRC finds the D_{50} size in the riprap chute to be acceptable. As shown on engineering drawing 9-11, the rip rap layer in the chute will be 54 inches thick. This is consistent with the NRC staff's recommendation in NUREG 1623 that the thickness of the riprap layer be twice the D_{50}. Additionally, the riprap will be installed approximately 380 ft downstream of the end of the riprap chute. As shown on engineering drawing 9-11, the licensee also proposes to install a dual layer filter layer beneath the riprap. The NRC staff observes that the licensee followed the approach to evaluating a filter layer that is described in NUREG 1623. The NRC staff reviewed the licensee's approach and did not identify computational errors. Therefore, the licensee's approach to the selection of the rock size and filter layer in the riprap chute is acceptable to the NRC staff.

Drainage channels on mine waste repository

The licensee evaluated the channel flow depths, velocities, and shear stresses for the drainage features on the mine waste repository in Attachment I.2 of the LAR. The drainage features evaluated in Attachment I.2 include: the east repository channel, Dilco Hill Channel A, Dilco Hill Channel B, Branch Swale H, and the Runoff Control Ditch. The licensee used the flow rates calculated in Attachment I.1 (NRC staff's review of these flow rates is documented in Section 4.2 of this SER) and a series of equations for open channel flow hydraulics to calculate the depth, velocity, and shear stresses, and ultimately the required rock size in these channels. For the rock lined channels, the licensee followed the guidance in NUREG 1623 (Johnson method) in calculating the required minimum riprap sizing in the channels. The minimum required riprap size ranges from a D_{50} of 1.5 inches in the upper reaches of the east repository channel to a minimum D_{50} of 9 inches in the lower portions of the east repository channel. The licensee's minimum D_{50} values are provided in Table 6 of Attachment I.2. The NRC staff reviewed the licensee's calculations and developed its own, confirmatory calculations using Microsoft Excel. In its verification calculations, the NRC staff used the same channel geometries and Johnson method that the licensee used. In this situation, the NRC staff's analysis was intended to verify that the licensee had correctly implemented the Johnson method described in NUREG 1623. Developing its own spreadsheet evaluation provided the NRC staff with a method to validate that the licensee's approach in more detail than following the licensee's calculations presented in Attachment I.2. The NRC staff's analysis resulted in similar minimum required rock sizes that the licensee's analysis showed. As the NRC staff's calculation reached a similar result, the NRC staff finds that the licensee has correctly implemented the Johnson method in calculating the necessary rock sizes. Therefore, the NRC staff finds that the licensee's rock sizing for these channels (the east repository channel, Dilco Hill Channel A, Dilco Hill Channel B, Branch Swale H, and the Runoff Control Ditch) is acceptable.

For the vegetation lined North Cell Drainage Channel, the licensee followed the Temple method (Temple et al., 1987) in evaluating allowable soil velocities and vegetation stresses. The licensee estimated a peak channel velocity of 1.9 ft/s in the North Cell Drainage Channel. This flow velocity is less than the suggested permissible flow velocity (between 2.5 and 3 ft/sec) in a vegetated channel in NUREG 1623. The NRC staff reviewed the licensee's calculations and finds the approach to be reasonable. The NRC staff observed that the licensee's approach is consistent with the guidance in NUREG 1623. Additionally, the licensee used input parameters that are consistent with the conditions at the Church Rock site. Therefore, the licensee's approach is acceptable to the NRC staff.

In Attachment I.5 of the LAR, the licensee presented its analysis of the hydraulic capacity of the North Diversion channel (NDC). The licensee plans to install two check dams to control flow and sediment entering the NDC but does not plan any additional changes to the channel configuration (dimensions or lining). The licensee's calculations show that the NDC can convey the PMF to the flood plan north of the mine waste repository. The NRC staff observes that the licensee followed an approach that was based on widely accepted open channel flow methodology. Additionally, the NRC staff recognized that the licensee used input parameters and channel geometry that reflect the planned configuration of the mine waste repository conditions at the site. In its review of the licensee's calculations, the NRC staff did not identify any arithmetic errors. Therefore, the licensee's approach is acceptable to the NRC staff.

With respect to sedimentation, the licensee evaluated sediment transport capacity in the lower portions of the east repository channel in Attachment I.4 of Appendix I of the LAR. The licensee's analysis showed that the changes made to the channel geometry and planned construction of the two channels on Dilco Hill will minimize sedimentation issues within the east repository channel. The licensee evaluated sedimentation in the north diversion channel in supplement I.5-1 of Attachment I.5 of Appendix I of the LAR. The licensee's analyses in Attachments I.4 and I.5 document that sedimentation is not anticipated to be an issue in the east repository channel or the north diversion channel. The NRC staff reviewed the licensee's approach to evaluating sedimentation in the east repository channel and the north diversion channel. In both analyses, the licensee followed reasonable approaches using input parameters that reflected the planned post construction configuration of the site. Additionally, the licensee used a widely accepted approach in estimating sedimentation. During its review, the NRC staff reviewed the implementation of the licensee's approach and did not identify any errors. Therefore, the licensee's approached are acceptable to the NRC staff.

Top and side slopes

The licensee proposed a rocky soil cover for the 2 percent and 5 percent slopes of mine waste repository. The erosion protection aspects of this portion of the design are reviewed in Section 4.5.3 of this SER.

The licensee's analysis supporting the rock sizing for the 20 percent side slope is presented in Attachment G.8 of Appendix G of the LAR. For sizing the rock on this portion of the cover system, the licensee used the Abt-Johnson method. This method is recommended in NUREG 1623 and is acceptable to the NRC staff. The licensee calculated that rock with a D_{50} of 1.5 inches will provide adequate protection on the 20 percent side slope. The NRC staff performed an independent verification and reached a similar result for the necessary rock size on the 20 percent side slope. In its evaluation, the NRC staff reviewed the licensee's assumptions, methodology, and implementation of the rational method. The NRC staff determined that the cover system geometry used in the licensee's approach matched the planned configuration of the 20 percent slope on the mine waste repository. Additionally, the NRC staff was able to verify that the licensee correctly implemented the appropriate methodology as described in NUREG 1623. The NRC staff did not identify any arithmetic mistakes in its review. Therefore, the NRC staff determines that the licensee's approach in calculating the flow velocities and shear stresses on the 20 percent slope is acceptable.

Apron

Appendix D of NUREG 1623 discusses riprap sizing at the toe of embankment slopes. In reviewing the licensee's design drawings and calculations, the NRC staff observes that the cover system for the mine waste either transitions to a riprap lined channel or to the existing erosion protection cover. This is shown on engineering drawings 7-08 to 7-10. As the mine waste cover terminates into a channel with larger riprap, or into the existing cover with equivalently sized riprap, the licensee stated construction of a riprap apron at the termination of the cover system is not necessary. The NRC staff reviewed the construction details and finds that the licensee's explanation is sufficient as it describes that the cover system ties into an engineered channel that has been designed to withstand the anticipated flows. Therefore, the potential for erosion at the toe of the cover system has been minimized.

Rock Durability

The previous sections of this SER evaluated the ability of the proposed erosion control aspects of the design to withstand flooding events reasonably expected to occur within 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. In this portion of the SER, the NRC staff evaluates rock durability to determine if there is reasonable assurance that the rock itself will be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.

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

To assure that the rock used in the erosion protection design remains effective for 200 to 1,000 years, potential rock sources must be tested to identify acceptable sources of riprap. As discussed in Appendix H of the LAR, the licensee has identified two potential quarries that could be used to provide riprap for this project. The quarries and rock type identified at each quarry are: (1) Tampico Pit, limestone; and (2) Page Pit, granite. According to the licensee, the Tampico and Page pits are located near Gallup, NM (approximately 20 miles west of the Church Rock site). The licensee followed the guidance in NUREG 1623 in evaluating the off-site borrow areas for the rock. Based on the results of the durability evaluation, the licensee stated that rock from the Page pit would meet NRC guidance without oversizing. Rock from this source scored 81, using the methodology contained in the NRC guidance. According to the licensee, the Tampico pit would require oversizing of approximately 5 percent of the D_{50} to be consistent with NRC guidance. The NRC staff reviewed the information in Appendix H and Attachment H.1 and observes that the licensee's approach is consistent with the NRC staff's guidance in NUREG 1623. Additionally, the NRC staff observes that the licensee has correctly followed the oversizing approach outlined in NUREG 1623. Therefore, the NRC staff finds that the licensee's calculation approach is adequate for the purposes of determining the rock size.

Attachment I.8 contains information on petrographic analysis of the offsite rock sources, as well as a petrographic analysis of the sandstone materials that would be removed during excavation for the riprap chute. The licensee stated that the on-site sandstone is not recommended for use as erosion protection riprap. The licensee also discussed the results of the petrographic analysis for the Tampico Pit limestone and the Page pit granite. According to the licensee, both sources are adequate for use for erosion protection purposes from a petrographic standpoint. The NRC staff reviewed the information provided by the licensee in Attachment I.8, Appendix D. The NRC staff observes that the petrographic analysis was performed by a geologist with experience in petrographic analysis, which is consistent with the guidance in NUREG 1623. Based on its review of the information in Attachment I.8 and its understanding of the geology in the Tampico pit and Page pit, the NRC staff finds that the licensee's interpretation of the results of the petrographic analysis is adequate for the purposes of identifying appropriate erosion protection rock.

Testing and Inspection of Erosion Protection

The licensee presented a set of technical specifications for construction of the mine waste repository in Appendix J of the LAR. Additionally, the licensee provided a construction quality control plan in Appendix V of the LAR. Together, these documents describe the licensee's approach for ensuring that the construction activities are consistent with the proposed design. In the construction quality control plan (Appendix V, Table V.1), the licensee does not propose a set frequency for evaluating durability testing of the rock; however, the technical specifications (specification 02273, pages 5 and 6) call for durability testing prior to production and again when ¼, ½, and ¾ of the total produced volume of rock. The NRC staff recognizes that the guidance in NUREG-1623 suggests that rock durability is based on several samples. As the LAR calls for durability testing at several stages, the licensee's approach is consistent with NRC guidance and acceptable to the NRC staff.

In reviewing the technical specifications (Riprap, 02273 and Earthwork, 02200), the NRC staff was able to validate that gradation testing is required for the work. Both specifications include appropriate ASTM standards (ASTM D422 for particle size analysis of soil in 02200 and ASTM D5519). For the larger riprap pieces, the licensee plans to use photo-gradation techniques to verify the material is correctly sized. In specification 02273, gradation testing if required every 500 linear feet of channel length and once per 3,000 cubic yards of material. The NRC staff observes that identification of testing frequencies is consistent with the guidance in NUREG-1623. The licensee's approach is acceptable to the NRC staff.

The NRC staff observes that procedures for placement of riprap are described in specification 02273. The specification calls for placement of riprap to the lines and grades shown on the drawings, in a manner that provides for a minimum of voids. The NRC staff recognizes that hand placement of riprap will be allowed. The NRC staff observes that this approach is consistent with the guidance in NUREG 1623 and is therefore acceptable to the NRC staff.

In reviewing specification 02273, the NRC staff was able to verify a methodology for a testing program to assure that the soil and riprap layers are constructed to the thicknesses identified on the drawings. The licensee will perform field surveys to verify that the thickness requirements were met for the soil and riprap layers. This approach is acceptable to the NRC staff to ensure consistency between the designed and as-built soil and riprap layers.

Wind Erosion

The licensee evaluated wind erosion of the proposed cover system in Section 4.4.2 of Attachment G.7 of the LAR. The licensee used a methodology called 'Wind Erosion Prediction System' (WEPS), which was developed by the U.S. Department of Agriculture (USDA, 2010). The licensee estimated that wind erosion is approximately 0.2 tons per acre per year at the Church Rock site for the proposed cover system. The NRC staff reviewed the licensee's approach and observes that it was based on the site and wind conditions present at Church Rock. The NRC staff observes that the licensee did not assume the presence of any vegetation on the cover system. The NRC staff recognizes that this is a conservative assumption as the proposed cover system is an ET cover with vegetation. Based on its review, the NRC staff accepts the licensee's approach and finds that wind erosion will be kept to a negligible level.

4.4.4 Evaluation Findings

The NRC staff has completed its evaluation of design of the erosion protection at the Church Rock mill tailings impoundment and mine waste repository. This review included an evaluation using the review procedures in Section 3.4.2 and the acceptance criteria outlined in Section 3.4.3 of the SRP (NRC, 2003b).

On the basis of the information presented in the LAR the NRC staff's detailed evaluation of the design of the erosion protection features, the NRC staff concludes that the design is acceptable. The mill tailings and mine waste will be protected from flooding and erosion by drainage features and a cover system consisting of a rock soil matrix. The NRC staff concludes that the erosion protection design is adequate as the licensee used appropriate methods for determining the erosion protection features needed to resist the erosive forces generated by the design discharge, and (2) selection of the rock type for the riprap on the 20 percent side slope and in the drainage channels will be durable and capable of providing the necessary level of protection for a long period of time. Further, the NRC staff considers that the riprap will be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years for the following reasons: (1) the rock proposed was evaluate using rock quality procedures identified in NUREG 1623 and is not expected to deteriorate significantly over the performance period; (2) rock fragments are dense, resistant to abrasion, and free from cracks, seams, and other defects; and (3) during construction, the rock will be placed in accordance with appropriate engineering and testing practices, minimizing the potential for damage, dispersion, and segregation of the rock

On the basis of its review of the designs for the Church Rock uranium mill and mine waste repository, the NRC staff concludes that the hydraulic designs contribute to meeting the requirements of 10 CFR Part 40, Appendix A: (1) Criterion 4(c), requiring embankments and cover slopes to be relatively flat after stabilization to minimize erosion potential and to provide conservative factors of safety that ensure long term stability; (2) Criterion 4(d), requiring that the rock cover reduces wind and water erosion to negligible levels, including consideration of such factors as the shape, size, composition, and gradation of the rock particles; (3) Criterion 4(f), requiring the design to promote deposition, where feasible; (4) Criterion 6(1), requiring the design provide reasonable assurance to control radiological hazards be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years; and (5) Criterion 12, requiring that active on-going maintenance is not necessary to preserve isolation.

4.5 Design of Erosion Protection Covers

In this section of the SER, the NRC staff focuses its review on the proposed cover system for the top slopes of the mine waste repository, which would be above the mill tailings. In the LAR, the licensee proposes a vegetated rock-soil matrix for the 2 percent and 5 percent slopes, underlain by a soil layer. The licensee's intent is to have the cover system function as an ET cover to limit the infiltration of water into the mine waste, and ultimately the mill waste.

4.5.1 Regulatory Requirements

The NRC staff determines if the licensee has demonstrated that the LAR has met the requirements of 10 CFR Part 40, Appendix A, Criterion 4(b), which requires siting and design such that topographic features provide good wind protection. The NRC staff also determines if the requirements of 10 CFR Part 40, Appendix A, Criterion 4(c), which requires that embankments and cover slopes be relatively flat after stabilization to minimize erosion potential and to provide conservative factors of safety that ensure long-term stability, are met. The NRC staff determines if the LAR provides reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 6(1) have been satisfied. This criterion requires that the design provide reasonable assurance to control radiological hazards be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. Finally, the NRC staff determines if the LAR meets the requirements of 10 CFR Part 40, Appendix A, Criterion 12 is met. This regulation requires that active maintenance is not necessary to preserve isolation.

4.5.2 Regulatory Acceptance Criteria

Unless specifically stated otherwise, the LAR was reviewed for compliance with the applicable requirements in 10 CFR 40 using the acceptance criteria presented in SRP Section 3.5.3 (NRC

2003b). The acceptance criteria in SRP Section 3.5.3 address: (1) approach to active maintenance at the site; (2) demonstration of the need for active maintenance; and (3) funding mechanism for active maintenance. The review procedures in SRP Section 3.5.2 direct the NRC staff to evaluate (1) the design flow rate that reflects consideration of settlement, soil removal, degradation of vegetation, trees; (2) correct value of Manning's n corresponding to the vegetative cover is used; (3) determination of allowable shear stresses and velocities when the cover is in a degraded state (no vegetation or after a fire, drought, or other conditions that may result from no active maintenance); and (4) a check of the licensee's calculations.

4.5.3 Staff Review and Analysis

Unless specifically stated otherwise, the information reviewed in this SER section is from information, data, and maps submitted by the licensee in its LAR (UNC 2018). The licensee presented the information related to the ET cover system for the 2 and 5 percent slops of the mine waste repository in Attachment G.7 of Appendix G of the LAR.

The licensee's approach to designing the ET cover system consisted of two calculations. The licensee's first step was to identify the appropriate rock/soil admixture. The licensee's approach in Attachment G.7 included identifying the minimum size of rock necessary to resist movement from erosional forces and the depth the rock would need to be placed. Once the rock/soil admixture was identified, the licensee compared evaluated the long-term stability of the slope following the guidance for a rocky soil cover in Appendix A of NUREG 1623.

The NRC staff reviewed the licensee's approach for designing the rock/soil admixture on the 2 and 5 percent slopes. In the absence of NRC specific guidance on ET covers, the licensee followed an approach outlined in the document entitled "Closing Small Tribal Landfills and Open Dumps" (EPA, 2011). Briefly, the licensee's approach considered the PMP event, used the time of concentration to calculate the anticipated rainfall intensity, calculated the incipient particle size, and the depth of scouring. Consistent with the guidance in SRP section 3.5.2, the licensee used a reasonable value for Manning's coefficient. The NRC staff did not identify any arithmetic mistakes during its review. Note that the NRC staff's evaluation of the cover design's ability to provide sufficient resistance to infiltration can be found in Section 3.7.3 of this SER.

The NRC staff also reviewed the licensee's approach to evaluating the long-term erosional stability of the 2 and 5 percent slopes. As discussed above, the licensee followed the approach outlined in Section 2.4 of Appendix A of NUREG 1623. The licensee used the approach in NUREG 1623 to identify the various slope lengths required to maintain stability for the rock and admixture depth combinations. During its review, the NRC staff was able to validate the licensee's calculations. In its review, the NRC staff verified the input parameters selected by the licensee, confirmed the slope geometries, and verified the arithmetic in the licensee's approach. In its evaluation of long-term erosional stability, the licensee assumed a rocky soil slope with no vegetation. The NRC staff recognizes this is a conservative approach as the presence of vegetation will provide additional resistance to erosion. The NRC staff recognizes that this approach is consistent with the guidance in Section 3.5.2 of the SRP. As the licensee followed NRC guidance in NUREG 1623 and the NRC staff validated the implementation of the licensee's approach, this aspect of the licensee's design is acceptable to the NRC staff.

For the 2 percent slope, the licensee's calculations identified rock with a D_{50} of 1.5 inches should be mixed with soil at a ratio of 33 percent rock to 67 percent soil to a depth of 14 inches. For the 5 percent slope, the licensee's D_{50} and soil depth varied depending on the length of the slope. For the lower slopes, the rock will have a D_{50} of 3.5 inches and an admixture depth of 31.5 inches. For the upper slopes, the rock will have a D_{50} of 2 inches and an admixture depth of 18 inches. For all scenarios on the 5 percent slopes, the admixtures will be 33 percent rock and 67 percent soil.

The licensee is not planning for and has not requested approval of active maintenance in the LAR. As the licensee has not proposed active maintenance, acceptance criteria (1), (2), and (3) are not relevant to this review. While the licensee does not propose active maintenance, the NRC staff is imposing a license condition to require an observation period after completion of construction to monitor the performance of the cover system and demonstrate that it will function as intended. This is further discussed in Sections 4.3.3.1 and 4.3.4 of this SER.

4.5.4 Evaluation Findings

The NRC staff has completed its evaluation of erosion protection covers at the Church Rock impoundment and mine waste repository. This review included an evaluation using the review procedures in Section 3.5.2 and the acceptance criteria outlined in Section 3.5.3 of this SRP.

The mill tailings and mine waste will be protected from flooding and erosion by an engineered soil cover consisting of a rock soil matrix on the 2 percent and 5 percent slopes. The NRC staff considers that a satisfactory cover will provide adequate protection against erosion and dispersion by natural forces over the long term. In addition to the adequacy of the flood analyses discussed in SRP sections 3.2 and 3.3, the NRC staff concludes that adequate cover designs are provided by: (1) use of appropriate methods for determining cover slopes needed to resist the forces produced by the design discharge and (2) selection of a cover that will be capable of providing the necessary erosion protection for a long period of time. Further, as discussed in Section 4.4.3 of this SER, the NRC staff considers that the riprap component of the rock soil matrix will be durable over the performance period for the following reasons: (1) the rock proposed was evaluate using rock quality procedures identified in NUREG 1623 and is not expected to deteriorate significantly over the performance period; (2) rock fragments are dense, resistant to abrasion, and free from cracks, seams, and other defects; and (3) during construction, the rock layers will be placed in accordance with appropriate engineering and testing practices, minimizing the potential for damage, dispersion, and segregation of the rock.

On the basis of the information presented in the LAR and the detailed review of erosion protection covers for the Church Rock mill tailings impoundment and mine waste repository, the NRC staff concludes that the cover design contributes to meeting the following requirements of 10 CFR Part 40, Appendix A: Criterion 4(b), requiring that siting and design such that topographic features provide good wind protection; Criterion 4(c), requiring that embankments and cover slopes are relatively flat after stabilization to minimize erosion potential and to provide conservative factors of safety; Criterion 6(1), requiring that the design provide reasonable assurance to control radiological hazards be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years; and Criterion 12, requiring that active ongoing maintenance is not necessary to preserve isolation.

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5. PROTECTING WATER RESOURCES

5.1 Regulatory Requirements

10 CFR Part 40, Appendix A, Criterion 5, Criteria 5A-5D and new Criterion 13 incorporate the basic ground-water protection standards imposed by the Environmental Protection Agency in 40 CFR Part 192, Subparts D and E (48 FR 45926; October 7, 1983), which apply during operations and prior to license termination and site closure. Ground-water monitoring to comply with these standards is required by Criterion 7A."

5.2 Regulatory Acceptance Criteria

The NRC staff must determine if the LAR has met the conditions stated in 10 CFR Part 40, Appendix A, Criterion 7, which requires a groundwater monitoring program to ensure the ground-water protection standards established under Criterion 5A(1) of 10 CFR Part 40, Appendix A are met at the licensed site. The LAR was reviewed for compliance with the applicable requirements of 10 CFR 40 using the acceptance criteria described in SRP Section 4.0, "Protecting Water Resources" (NRC 2003). The acceptance criteria associated with groundwater compliance monitoring program in this SRP Section on which NRC staff focused include: (1) the characterization of hydrogeologic units impacted by the mill tailings; (2) the groundwater monitoring network, including number of monitor wells and their locations with respect to each of the hydrogeologic units; and (3) the adequacy of current monitoring network to provide needed data for evaluating any impact by the proposed disposal of mine waste in the tailings impoundment.

5.3 Staff Review and Analysis

As there is an already NRC approved groundwater monitoring program for the current mill tailings impoundment, NRC staff reviewed those aspects of the program impacted by the LAR, such as consolidation of mill tailings that may impact the site groundwater. In addition, NRC staff also reviewed historical reports related to site hydrogeology, mill tailings reclamation, and groundwater monitoring to facilitate the evaluation of the current monitoring network, in light of the proposed changes.

5.3.1 Groundwater Compliance

The Stantec license amendment request (LAR) did not include information for Section 4, "Protection Water Resources" as outlined in NUREG-1620 (NRC, 2003). The reason provided for not including the information references the conclusions presented in the Consolidation and Groundwater Report (Dwyer, 2018). Dwyer (2018) states in Section 7.0 that the loading by placement of mine spoils in the mill tailings impoundment would not result in an increase of contaminated water from the tailings material to the groundwater beneath the proposed repository, and, therefore; there are no groundwater quality impacts that could occur because of the disposal of mine spoils from NECR. The LAR further stated that the checklist items in Section 4.0, NUREG-1620 (NRC, 2003) pertain to "the groundwater corrective action program and not a change in conditions resulting from the construction of the repository. Therefore, Section 4.0 is not applicable to the request for source material license amendment." Section 4.6 in the LAR further stated that the "groundwater protection standards defined in license amendment No. 52 (NRC, 2015) would still apply to the site."

Based on the review plan for Section 4, Protection Water Resources (NRC NUREG-1620), NRC staff's review of information concerning the protection of groundwater resources is coordinated with the evaluation of the site stratigraphy, structural and tectonic information, which are provided in Section 2.5, Section 2.7, and Section 4.6, with more detailed information available in other site historical documents. During its review, NRC staff was primarily concerned with the potential impacts of the disposal of mine spoils at the mill tailings impoundment on the groundwater compliance with existing protection standards already established at the site, including the ongoing groundwater CAP. Failure of the ET cover to perform as designed may result in mobilizing the chemical and radiological constituents of concern in the mill tailings materials to the underlying groundwater. In this scenario, recharge migrates through the ET Cover and interacts with the existing mill tailings, and the hazardous constituents in the mill tailings could be released and transported with the recharge. In addition, consolidation of the existing mill tailings materials caused by the placement of the ET Cover and mine spoils over the current impoundment could result in release of contaminated water from the existing mill tailings. Dwyer (2018) conducted its analysis to address this consolidation issue related to the mill tailings at the site. In the analysis, some assumptions, such as constant coefficient of permeability during consolidation of fine-grained tailings, were not justified or supported. NRC staff found that the conclusions of the analysis that groundwater will not be impacted were inconclusive because certain assumptions and input parameters were not supported. Given current information, the NRC staff anticipates that the mill tailings and groundwater would not be impacted by the disposition of mine spoils at the current impoundment, but with unacceptably large uncertainties. As discussed in SER Section 5.3.4, the existing groundwater monitoring network will remain in place to validate the licensee's analysis and NRC staff's conclusion.

As identified in 10 CFR Part 40, Appendix A, Criterion 7A, the Applicant is also required to establish a comprehensive compliance monitoring program to monitor the site groundwater for the duration of the compliance period. The specific objectives of this compliance monitoring are to verify the effectiveness of ET Cover design, or specifically any groundwater recharge through the tailings, and potential impact of the mine wastes on the compliance with the current site groundwater protection standards. The current groundwater monitoring program for the mill tailings impoundment consists of a monitoring network or wells (including compliance and exposure wells) located in the SW alluvium, Zone 1 and Zone 3, with specified chemical constituents for analysis and monitoring schedules. Although the applicant stated that the current groundwater protection program is still valid without providing details, the NRC staff performed an independent evaluation of the current groundwater monitoring program's ability to monitor potential near-term impact on the mill tailings and groundwater through the placement of the mine spoils. The NRC staff's concern is that the current groundwater flow conditions may be potentially impacted by additional water released from consolidation of the mill tailings resulting from placement of the mine waste. The extent of impact on groundwater flow may depend on the footprint of mine spoils with respect to the mill tailings, configuration of contact of tailings with the alluvium, and Gallup sandstones of Zone 1 and Zone 3 among other factors. Impact on the groundwater by seepage from the tailings, for example, may change the groundwater flow direction. This may result in the current compliance wells being less effective.

Based on the NRC staff's understanding of ET cover performance and the associated minimization of water percolation, the proposed ET cover represents a potential significant improvement from the current cover at the site regarding water percolation among others, but the long-term performance or effectiveness of the proposed ET cover needs to be evaluated/demonstrated through continuing to monitor site groundwater. An effective groundwater monitoring network for each of the zones are critical in collecting water level and quality measurements for long-term performance of the ET cover and potential further consolidation of the tailings at the site. As discussed in SER Section 5.3.4, the existing groundwater monitoring network will remain in place to verify performance of the ET cover.

5.3.2 Mill Tailings Impacted Hydrogeologic Units

Mill tailings disposal began in May 1977 and continued through May 1982 at the UNC Church Rock site. An estimated 820 million gallons of tailings liquid was deposited in three separate unlined disposal cells, namely the North Cell, Central Cell, and the South Cell. After loss to evaporation and during the breach in 1978, only approximately 350 million gallons were available for pore retention and infiltration. Most of the mill tailings in the North Cell are on top of the alluvium except along the eastern side of the cell where Zone 3 is in direct contact with the tailings (Figure 2-3, Canonie 1987).

In the Central Cell the mill tailings are in direct contact with the underlying alluvium, Zone 1 and Zone 3 of the Gallup Sandstone through Borrow Pit No. 2, although Borrow Pit No. 1 is directly exposed only to alluvium and Zone 3. The Central Cell along with the two hydraulically connected borrow pits are sources of seepage to the alluvium, Zone 1 and Zone 3 geohydrologic units at the site. The South Cell is underlain only by a thick sequence of alluvium.

The hydrogeologic unit Zone 3 consists of fine- to coarse-grained quartzose sandstone with a continuous, thin (two to seven feet) coal and shale seam in the lower part. In the tailings disposal area, the thickness of Zone 3 rages from 70 to 90 feet. Zone 3 has an average permeability of 10^{-3} cm/sec, which is approximately one order of magnitude less than the alluvium. Zone 3, an artificial flow system created by the recharge of the discharged mine water through the alluvium, is impacted by tailings seepage migrating from the North Cell and, to a lesser extent, Borrow Pits Nos. 1 and 2 in the Central Cell.

The hydrogeologic unit Zone 1 consists of fine to medium -grained massive sandstone with thin beds of carbonaceous shale and coal. The thickness of this unit is constant in the tailings disposal area, varying from 80 to 90 feet. Note that the average permeability of Zone 1 is almost one order of magnitude lower than zone 3 (at 10^{-4} cm/sec).

The SW Alluvium unit consists of sand, gravel, silt and clay, with organic matter deposited in interfingering layers. The thickness of the alluvium varies from absence in the northeastern and eastern portions of the tailings disposal area to approximately 150 feet in the central tailings area. The average permeability of the alluvium is in the range of 10^{-2} cm/sec, approximately between 2 to 3 order of magnitude higher than Zone 3 and Zone 1, respectively.

The seepage from the tailings observed to date created a mound on top of a largely artificial groundwater system due to mine water discharge. This artificial groundwater system includes three hydrogeologic units that are all hydraulically connected to the mill tailings either naturally by subcrop of Upper Gallup Sandstone and alluvium below the tailings or by borrow pits. The seepage mound formed from the mill tailings cells has resulted in localized seepage migrating primarily to the south in the alluvium, and east and northeast of downdip of the Upper Gallup Sandstone member Zone 1 and Zone 3, respectively.

5.3.3 Evaluation of Consolidation of Mill Tailings and Release of Water

NRC staff conducted a review of the physical conditions, including the spatial distribution, thickness and moisture among others of mill tailings in the impoundment. These data were collected during a geotechnical investigation conducted by the applicant for the ET cover design (MWH, 2014). It was found that the vertical profile of mill tailings generally consists of one single layer of tailings, or more layers with alternating layers between coarse-grained and fine-grained tailings of various thickness. The bottom of layer, generally a fine-grained tailings is underlain by alluvium material or Gallup sandstone depending locations within the mill tailing impoundment. The fine-grained tailings have relatively high moisture content, at or close to saturated condition at some locations and very low saturated hydraulic conductivities, while the coarse-grained tailings are relatively dry compared to the fine-grained material, with several orders of magnitude higher saturated hydraulic conductivities than the fine-grained tailings.

The placement of mine spoils and ET cover on the impoundment will result in the mill tailings being compressed or consolidated, especially the saturated fine-grained tailings materials. Water will be mostly drained from the fine-grained tailings as the porosity of mill tailings decreases during the consolidation process. The applicant performed a consolidation analysis involving relatively fine-grained soils based on Terzaghi's theory of 1-Dimensional consolidation. The NRC staff's evaluation of settlement is presented in detail in Section 3.3 of this SER. In summary, the NRC staff recognizes the use of Terzaghi's theory simplifies the analysis and that the results should be viewed in the context of the assumptions involved and uncertainties. The NRC staff finds that the licensee's evaluation is appropriate for the purposes of estimating the consolidation of the fine-grained tailings as it represents a conservative approach to estimating consolidation.

Based on the estimated respective ET Cover and mine spoils weight at each location, the applicant calculated the settlement and amount of water drained from representative vertical tailings profiles collected in the North Cell (boring B2) and Central Cell (boring B8 and B10 in Borrow Pit 1, and boring B11 in Borrow Pit 2). The calculated settlement in the fine-grained tailings varies from 0.18 ft in boring B2 in the North Cell, 0.93 ft in boring B10 with 25.5 ft thick of tailings, 0.1 ft in boring B11 with 11.5 ft thick of tailings to 0.65 ft in boring B8 with 18.5 ft thick of tailings of borrow pits of Central Cell. As shown the amount of settlement depends on both the loads and thickness of fine-grained-tailings material, these selected borings are representative of an overall physical conditions of mill tailings over the areas of the tailings impoundment based on the information presented in the reclamation plan and data obtained during the pre-cover design investigation. The fine-grained tailings are absent, or relatively thin and dry in the North Cell depending on the specific location, whereas the thickest fine-grained tailings at, or close to saturation, are located in the borrow pit area of the Central Cell. The applicant performed a water balance calculation based on the estimated amount of settlement and saturation condition in each of the selected boring profiles. The result shows that if water drained from fine-grained tailings layers migrates into adjacent tailings layer (most coarse-grained tailings with less saturation), the consolidation of mill tailings would not result in fully saturated tailings in most of the selected boring profiles, except boring B8 (located in Borrow Pit No. 1). The applicant concluded that there would be no water drained from the mill tailings to impact underlying groundwater.

As discussed in more detail in SER Section 3.3, the NRC staff concludes that the applicant's analysis of settlement appears reasonable, and the amount of water drained from the fine-grained tailings appears to be limited given the small areas of Borrow Pit 1 and 2 with the most of fine-grained tailings subject to the most consolidation at the site. However, NRC staff does have some concern about applicant's statement that water drained from tailings would not impact groundwater because of the uncertainty in the assumptions used in the analysis over the long term (see generally Section 3.7 of this SER). NRC staff also concludes that if water released from the tailings as a result of consolidation does migrate down to the saturated hydrogeologic units, the impact on the groundwater flow and quality will likely be minimal due to a limited amount of water drained. The NRC staff recognizes that potential seepage impacts are unlikely, but they are possible given identified uncertainty. Therefore, the NRC staff proposes to modify condition 30 in license SUA-1475 to include additional ground water monitoring near the tailings impoundment. Data obtained from the wells will document any significant increase in contaminant concentrations to inform a plan of action as dictated by the results. The condition is presented in SER Section 5.4.

5.3.4 Groundwater Monitoring Network

The groundwater monitoring network at the UNC Church Rock mill tailings impoundment is designed to monitor and evaluate the impacts of seepage from mill tailings stored in the North Cell, Central Cell including Borrow Pits Nos. 1 and 2, and the South Cell. These monitoring wells are also used to support past and current groundwater remediation at the site. The groundwater monitoring network has been evolved significantly over time in response to the progress made in groundwater remediation and changes in hydraulic characteristics (e.g., saturated thickness) of the impacted hydrogeologic units since initial installation in the 1980's (e.g., Canonie Environmental, 1989; Hatch, 2019). As described in the NRC materials license (License Number SUA-1475, Amendment No. 54), the monitoring wells in the current groundwater monitoring network are required for both quarterly groundwater sampling and water level measurement.

The monitoring wells listed below are located near the mill tailings cells in the three hydrogeologic zones:

In Zone 1, the monitoring wells immediately downgradient of the Central Cell to the Northeast include Wells 614, 515A, 604 and EPA 5;

In Zone 3, the monitoring wells immediately downgradient of the North Cell to the East include Wells 701, 702, 703, and 613; and

In the SW Alluvium, the monitoring wells adjacent to the mill tailings cells include Wells 509-D, EPA 23, 807, 803, 805, 808, 802, 632 and 801. Well 509-D is located next to the Central cell to the West along Pipeline Arroyo, with the rest of wells listed above located further downgradient in the alluvium.

Based on their locations with respect to the mill tailings, hydraulic gradients in the three hydrogeologic units (Zone 1, Zone 3 and the SW Alluvium), and historical groundwater monitoring performance, NRC staff concludes that the existing monitoring wells at the site are appropriately located to assess potential impact on the groundwater by the proposed mine waste disposal and performance of the ET cover. As discussed in the previous SER section, the NRC staff proposes to modify condition 30 of license SUA-1475 to include in the quarterly monitoring schedule potential seepage impacts resulting from mine waste placement. If water drained from the tailings does reach the saturated units contrary to the applicant's analysis because of uncertainty, the magnitude of rise in groundwater elevation is expected to be far less than some of the historically higher levels that have been observed in the current monitoring wells. Given that the groundwater elevations have been decreasing significantly in recent years mostly due to remedial groundwater extraction and significant reduction of seepage from the tailings, the resulting groundwater elevation caused by water released from mill tailings will be below those past higher levels.

5.4 Evaluation Findings

The applicant stated in the LAR that disposal of NECR mine spoils in the UNC Church Rock mill tailings impoundment would not result in water drained from the mill tailings to the hydrogeologic units beneath the proposed repository, and therefore there are no groundwater impacts at the site (Dwyer, 2018). The applicant did not provide details to demonstrate that the current groundwater monitoring network at the site is adequate to assess groundwater impact if it occurs. However, as discussed above in the NRC staff's analysis, the NRC staff finds that the existing well locations are adequate to assess potential impacts resulting from mine waste placement. Based on the review of relevant sections of the LAR, and other site information related to the site hydrogeology and groundwater monitoring, the NRC staff finds that the existing groundwater monitoring program will remain compliant with Criteria 7A of 10 CFR Part 40, Appendix A.

Based on the review and analysis above, the NRC staff concludes the following related to ground water and consolidation:

1) The amount of settlement of fine-grained mill tailings and water released during the consolidation process as a result of the addition of mine wastes at the existing tailing impoundment appears limited based on the one-dimensional settlement analysis. As the field investigation shows that the fine -grained tailings are largely saturated while most of the coarse-grained tailings are unsaturated, there is not a significant amount of fine - grained mill tailings of relatively dry distributed in the North Cell, and the thickest of fine-grained tailings are found at or close to saturation only in a small area around former Borrow Pit Nos. 1 and 2 of the Central Cell. The mill tailings impoundment is situated above the local groundwater table. The largest potential source of seepage would be from those fine-grained tailings in the two borrow pits area, which will not likely have a large impact on the site groundwater because the area around the Borrow Pit Nos. 1 and 2 is small relative to the size of the tailings impoundment. Although the NRC staff may not fully agree with certain assumptions used in the modeling analysis and interpretation of the results, the consolidation analysis provides rough approximation with a large uncertainty. The NRC staff will require the existing groundwater monitoring network to remain in-place to help validate the licensee's analysis.

2) As the largest source of contributing seepage to Zone 1, mill tailings liquid in Borrow Pit No. 2 was neutralized during reclamation (Canonie Environmental, 1989). The neutralization significantly reduced the level of toxicity of tailings liquid, and therefore its impact on the groundwater was significantly reduced as it seeped into the saturated hydrogeologic Zone 1. Results of historic groundwater monitoring have shown that the seepage-impacted groundwater in Zone 1 has not traveled far downgradient from the eastern property boundary, perhaps because Zone 1 is less permeable than the Zone 3 and SW Alluvium. Monitoring wells EPA 5, EPA 7, 614, 515-A, and 604 are located immediately downgradient of the mill tailings impoundment in Zone 1. As they are downgradient, they are appropriately located to detect seepage in this situation.

3) The current groundwater monitoring network includes monitoring in all three hydrogeologic units: SW Alluvium, Zone 1 and Zone 3. Given that groundwater beneath the tailings may flow into any of the hydrogeologic unit due to hydraulic connection at the impoundment, the monitoring wells are strategically located immediately down gradient of the mill tailings in each of the three hydrogeologic zones at the site. The current groundwater monitoring network would therefore promptly detect any change in any or each hydrogeologic units as it occurs.

However, as discussed previously (Section 3.7.4 of this report and reflected in the discussion earlier in this SER section), increase of contaminant concentrations in groundwater and/or a rise in the water table could result from excessive infiltration through the ET cover and consolidation of the existing tailings. Infiltrating water at higher than expected rates may significantly displace the contaminated water from the now consolidated and saturated fine-grained tailings and into the groundwater in the saturated zones at the site. Although the NRC staff considers this sequence of events unlikely, it cannot be dismissed due to large uncertainties associated with parameters assumed in the LAR for future climate, vegetation and soil structures among other variables.

It is therefore required that quarterly measurements of water levels and water quality sampling results from the following monitoring wells, EPA 5, 614, 515A, and 604 in Zone 1, EPA 23, 509D, 802, 803, 807, and 808 in SW Alluvium, and 613, 701, and 702 in Zone 3 be used to measure any seepage resulting from the placement of the mine waste. These wells are located immediately downgradient of the mill tailings impoundment in each Zone. Wells that go dry should also continue to be checked for the reemergence of water on a quarterly basis. The findings should be included in the annual site monitoring report.

License condition 30, NRC materials License Number SUA-1475, Amendment No. 54 would be revised to reflect the NRC staff's finding regarding the ongoing need for groundwater monitoring in the table below.

30. The licensee shall implement a compliance monitoring program containing the following:

Portion of Site	Well	Quarterly Sampling	Quarterly Water level monitoring only
Zone 1	**EPA 5**	**X**	
	EPA 7	X	
	614	**X**	
	515-A	**X**	
	604	**X**	
Zone 3	4	X	
	8		X
	9		X
	13	X	
	501A		X
	EPA 2	X	
	613	**X**	
	702	**X**	
	701	**X**	
	505A		X

	517	X	
	706		X
	714		X
	707		X
	EPA 14	X	
	708	X	
	717	X	
	712		X
	713		X
	420	X	
	504-B	X	
	711	X	
	719	X	
	0142	X	
	0143		X
	402		X
	412		X
	424		X
	502A		X
	504A		X
	710		X
	446		X
	627	X	
SW Alluvium	**EPA 23**	**X**	
	807	**X**	
	803	**X**	
	808	**X**	
	805		X
	801	X	
	802	**X**	
	632	X	
	GW1	X	
	GW2	X	
	GW3	X	
	25	X	
	28	X	
	624	X	
	509-D	**X**	

Quarterly sampling shall include: chloride, ammonia, nitrate, sulfate, manganese, calcium, magnesium, sodium, bicarbonate, potassium, field-pH, TDS and water level, arsenic, beryllium, cadmium, chloroform, lead, lead-210, nickel, combined radium-226 and radium-228, selenium, thorium-230, uranium, gross alpha and vanadium.

The water level measurements and sampling results from the wells that are in **bold** (EPA 5, EPA 23, 509D, 515A, 604, 613, 614, 701, 702, 802, 803, 807, and 808) in the table above are utilized to validate the licensee’s assumptions related to seepage resulting from placement of the mine waste. Wells that go dry shall continue to be checked for the reemergence of water on a quarterly basis.

Notwithstanding the above, the licensee is only required to sample EPA wells after receipt of written authorization by the landowner to enter that area for the purpose of sampling ground water from those specified wells. The licensee shall make every reasonable effort to obtain such authorization. If authorization is not obtained, the licensee shall inform the NRC, promptly.

5.5 References

Canonie Environmental (Canonie), 1991. Tailing Reclamation Plan as Approved by NRC, March 1, 1991 (MI17121A552).

Canonie Environmental, 1989. Remedial Design, Church Rock site, Gallup, New Mexico.

Dwyer Engineering, LLC, 2018. Consolidation and Groundwater Evaluation Report, Northeast Church Rock Site Closure, ADAMS Accession No. ML18267A276 (Appendix Y).

Hatch, 2019. Annual review Report 2018, Groundwater Corrective action, Church Rock Site, Gallup, New Mexico. ADAMS Accession No. ML 19037A415.

US NRC, 2003. 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, NUREG-1620

6. RADIATION PROTECTION

In this chapter of the SER, the NRC staff documents it's evaluation of portions of the licensee's "Application for Amendment of USNRC Source Material License SUA-1475," or license amendment request (LAR), (UNC 2018) that address topics covered in Chapter 5, "Radiation Protection," of the SRP (NRC 2003). These topics include: (1) the proposed radiation protection design for the Mine Waste Repository cover; (2) the cleanup and disposal of contaminated soil; and (3) the proposed radiation safety controls and monitoring during reclamation and decommissioning activities.

6.1 Disposal Cell Cover Radon and Gamma Attenuation and Radioactivity Content

In this section of the SER, the NRC staff documents its evaluation of the Mine Waste Repository evapotranspiration (ET) cover design.

6.1.1 Regulatory Requirements

As described in detail in Chapter 1 of this SER, the NRC staff determined that the UNC Mine Site mine waste that the licensee proposes to emplace at the Church Rock Mill Site tailings disposal area is not source, byproduct, or special nuclear material regulated by the NRC. For this reason, the NRC staff determined that the requirements in 10 CFR 40, including 10 CFR 40 Appendix A that pertain to mill tailings do not apply to UNC Mine Site mine waste. Instead, the proposed UNC Mine Site mine waste and the new evapotranspirative cover would be additional cover material over the existing mill tailings disposal area and the requirement in 10 CFR 40, Appendix A, Criterion 6(5), applies to these materials as they would to any mill tailings cover. Criterion 6(5) states, "Near surface cover materials (i.e., within the top three meters) may not include waste or rock that contains elevated levels of radium; soils used for near surface cover must be essentially the same, as far as radioactivity is concerned, as that of surrounding surface soils. This is to ensure that surface radon exhalation is not significantly above background because of the cover material itself." Because UNC Mine Site mine waste contains uranium and radium in concentrations well above concentrations in surrounding surface soils, criterion 6(5) would normally preclude utilization of UNC Mine Site mine waste as additional cover material.

The Introduction to Appendix A provides that:

> "licensees or applicants may propose alternatives to the specific requirements in this appendix. The alternative proposals may take into account local or regional conditions, including geology, topography, hydrology, and meteorology. The Commission may find that the proposed alternatives meet the Commission's requirements if the alternatives will achieve a level of stabilization and containment of the site concerned, and a level of protection for public health, safety and the environment from radiological and nonradiological hazards associated with the site, which is equivalent to, to the extent practicable, or more stringent than the level which would be achieved by the requirements of this appendix and the standards promulgated by the Environmental Protection Agency in 40 CFR part 192, subparts D and E."

In the evaluation in this SER Section, the NRC staff evaluates whether the emplacement of UNC Mine Site mine waste and an additional evapotranspirative cover, though a proposed alternative to 10 CFR 40, Appendix A, criterion 6(5), nevertheless provides stabilization and containment of the UNC Mill Site tailings disposal area, and a level of protection for public health, safety and the environment from radiological hazards associated with the site, which is equivalent to, to the extent practicable, or more stringent than 10 CFR 40, Appendix A, criterion 6(5) and the standards promulgated by the Environmental Protection Agency in 40 CFR part 192, subparts D and E. As explained in detail in the following sections, to determine whether the proposed cover design features provide a level of radiological protection equivalent to or more stringent than 10 CFR 40, Appendix A, criterion 6(5), the NRC staff evaluated whether the licensee's proposal meets 10 CFR 40 Appendix A criteria 6(1), 6(2), and 6(3), and whether the mine waste material, as well as the ET cover that would be placed atop it, provide adequate protection of public health per Part 40 Appendix A.

Staff notes that this evaluation of the Mine Waste Cover is in addition to the previously approved design and emplacement of a radon barrier over the mill tailings that the licensee states it will leave intact while emplacing the mine waste.

6.1.2 Regulatory Acceptance Criteria

Unless specifically stated otherwise, the LAR was reviewed for compliance with the applicable requirements of 10 CFR 20 and 10 CFR 40 using the acceptance criteria presented in SRP Section 5.1, "Disposal Cell Cover Radon and Gamma Attenuation and Radioactivity Content" (NRC 2003).

The acceptance criteria in SRP Section 5.1.3 address whether: (1) the method used by the licensee to calculate radon flux or minimum cover thickness is based on the one-dimensional, steady-state gas diffusion theory and appropriate input values; (2) input values of the material parameters lead to a reasonably conservative estimate of the long-term radon flux; (3) material parameters are consistent with construction specifications and expected long-term conditions; (4) the long-term attenuating capability of cover materials is justified using acceptable results of relevant tests or conservative estimates; (5) estimates of contaminated materials thickness are determined utilizing a sufficient number of data or by use of the default value; (6) if not measured, the estimated porosity of cover soils and tailings materials is based on the method in Regulatory Guide 3.64; (7) soil moisture values represent long-term moisture retention capacities; (8) Ra-226 activity has been measured in the tailings and other large volume sources of contaminated materials using acceptable procedures; (9) the emanation coefficient is obtained by either the equilibration method or the prediction method, or is set to a reasonably conservative value of 0.35; (10) the radon diffusion coefficient of the cover soil is determined from direct measurements or from a calculation based on Regulatory Guide 3.64; and (11) the cover gamma level and radioactivity content will be correctly determined and documented.

6.1.3 Staff Review and Analysis

Unless specifically stated otherwise, the information reviewed in this SER section is from information, data, and maps submitted by the licensee in its LAR (UNC 2018).

The licensee described its cover design for the proposed Mine Waste Repository in its LAR, Appendix G, "Mine Waste Repository Design," Attachment G.5, "Repository Design and Construction," and Attachment G.7, "Cover System Design Report (Dwyer Engineering)" (UNC 2018). The licensee proposed that it remove a nominal 15-cm-thick (6-in-thick) layer of erosion barrier (i.e., top layer) atop the existing tailings disposal area (TDA), thereby exposing the underlying radon barrier. The licensee explained the top 15 cm (6 in) of exposed radon barrier will then be compacted to meet a hydraulic conductivity of no more than 10^{-7} cm/s. The compacted radon barrier will be the foundation for the Mine Waste Repository.

The NRC staff evaluated how removal of a nominal 15-cm-thick (6-in-thick) layer of erosion barrier would affect performance of the existing TDA cover while it is being prepared as a foundation for the Mine Waste Repository. The licensee stated in Section 3.11.2.2.1 of its Environmental Report (UNC 2018) that a 1996 measurement of radon flux from the existing TDA cover was 5.7 pCi/m^2·s, which is about 30% of the regulatory limit in Criterion 6(1). Using the equations in NUREG/CR-3533 (NRC 1984), the NRC staff estimated that the amount of radon attenuation contributed by up to 30 cm (12 in) of erosion barrier is less than 1 pCi/m^2·s, or less than 5% of the Criterion 6(1) limit. The NRC staff determined that this small amount of radon attenuation contributed by the erosion barrier means that there will be no significant worker or public radiation risk associated with preparing a foundation for the proposed Mine Waste Repository, as radiation levels should be essentially unchanged.

The licensee proposes that approximately 800,000 cubic meters (1,000,000 cubic yards) of mine waste would be emplaced in the Mine Waste Repository. The mine waste would then be capped with a 4.5 ft (137-cm) thick evapotranspiration (ET) cover. Details 2, 3, 4, and 5 on sheet 7-09 of the engineering drawings show the various cover system cross sections. The lower portion of the cover system consists of soil and ranges in thickness from 22.5 inches to 40 inches. The remaining thickness of the top layer would be a uniform mixture of cover soil (67 percent by volume) with rock (33 percent by volume). The top layer is designed to mitigate erosion by creating an armored surface with rock large enough to resist the erosive forces created during a PMP event.

In the following SER subsections, the NRC staff documents its evaluation of whether the Mine Waste Repository cover design meets the requirements in 10 CFR 20 and 10 CFR 40, including the provision in 10 CFR Part 40, Appendix A for alternatives.

6.1.3.1 Radon Attenuation

The NRC staff evaluated the licensee's use of a web-based calculator to estimate radon-222 flux from the proposed ET cover. The licensee used a calculator available at a website maintained by the World Information Service on Energy (WISE) Uranium Project (http://www.wise-uranium.org/ctc.html). On its help page (http://www.wise-uranium.org/ctch.html), WISE states that its calculator "is a clone of the RAECOM code (Radiation Attenuation Effectiveness and Cover Optimization with Moisture Effects), as described in [Rogers 1984]. It performs one-dimensional, steady-state radon diffusion calculations for a multi-layer system." In the WISE calculator, if a diffusion coefficient is not provided by the user for one or more layers, the calculator estimates the diffusion coefficient for those layers from porosity and moisture data using the method by Rogers (1991).

The NRC staff evaluated the licensee's approach by independently calculating radon fluxes using the methodologies described in NUREG/CR-3533 (NRC 1984) and Rogers (1991). The NRC staff used a Microsoft Excel spreadsheet to perform the calculations (NRC 2019). Using the same input data used by the licensee, the NRC staff calculated a radon flux through the ET cover of 15 pCi/m^2·s, as compared to a radon flux of 13.73 pCi/m^2·s estimated by the licensee. Because these results are similar, the NRC staff determined that the licensee's values are reasonable. Because the licensee's method is consistent with Regulatory Guide 3.64 and NUREG/CR-3533, the NRC staff determined that the licensee's calculation meets SRP acceptance criterion 5.1.3.1(1), which states that the one-dimensional, steady-state gas diffusion theory for calculating radon flux is used (NRC 2003).

For purposes of evaluating the net flux of radon-222 through the proposed ET cover, the licensee assumed the background concentration of radon-222 is zero. The NRC staff determined this is consistent with SRP acceptance criterion 5.1.3.1(2), which states that the radon concentration above the top of the cover is either set to a conservative value of zero or a measured background value.

The licensee used the following site-specific parameter values in its radon flux calculations: (1) design thicknesses of the mine waste and two layers of the ET cover; (2) long-term average moisture content of the mine waste and two ET cover layers; (3) average radium-226 concentration in the mine waste; and (4) porosity of the mine waste and two ET cover layers. All other parameters used in the WISE calculator, including diffusion coefficients, are calculated from these site-specific parameter values. In the following paragraphs, the NRC staff documents its evaluation of the licensee's site-specific parameter values and determines whether they are either: (1) consistent with reference values described in Regulatory Guide 3.64 or; (2) conservative, based on an adequate number of samples, measured with appropriate quality assurance, and representative of long-term conditions.

Mine waste thickness

In its calculation, the licensee assumed a mine waste thickness of 500 cm (16.4 ft). The NRC staff determined that the mine waste thickness assumption meets SRP acceptance criterion 5.1.3.1(4), which states that the estimated thickness of the source is used, or alternatively, the default value of 500 cm (16.4 ft) is used. The NRC staff further notes that the mine waste and ET cover thicknesses should significantly exceed the thickness of radon attenuation soil cover and the erosion protection layer (up to 46 cm) that will be reused from the existing tailings pile such that exposures to direct radiation and radon flux originating from NRC licensed materials would be significantly diminished from the original tailings pile design levels.

Mine waste and cover soil long-term moisture content

The licensee assumed a mine waste moisture content of 6 percent, which is a reference value for tailings in Regulatory Guide 3.64, Table 1, “Cover Design Parameters, Symbols, and References Values.” Regulatory Guide 3.64 states, “The use of reference values for tailings parameters is acceptable because radon flux and cover thickness calculations are more sensitive to cover parameters than to tailings parameters” (NRC 1989). The licensee estimated moisture content from multiple samples of the mine waste and cover materials and calculated a moisture content under wilting conditions, or soil suction values of 15 bars. This is acceptable because Regulatory Guide 3.64, Section 1.1.3, states, “The NRC staff will accept the moisture content at which permanent wilting occurs as a reasonable value of the long-term moisture content.” The NRC staff determined that these assumptions meet SRP acceptance criterion 5.1.3.1(6), which states that one acceptable method for estimating long-term soil moisture is the capillary moisture test (15-bar suction) corresponding to the moisture content at which permanent wilting of plants occurs.

Mine waste radium-226 concentration

The licensee stated it calculated the radium-226 concentration in mine waste using a volume-weighted average of 90th-percentile radium-226 concentrations from each of thirteen different areas in the NECR Mine Site mine waste stockpile. The licensee provided summary statistics of radium-226 concentrations in mine waste and soil in each of the thirteen areas in LAR Attachment G.7, "Cover System Design Report," Table 17, "Radium-226 Concentrations in Mine Spoils (provided by Stantec)." As shown in licensee's proposed Radiation Protection Plan (LAR Appendix L, Health and Safety Plan, Attachment L-1, "Radiation Protection Plan," Attachment 5, "NECR Mine Site Uranium Ore Dust Isotopic Analysis"), the licensee based its average radium-226 concentration used in the evaluation of the cover materials on 375 surface and subsurface sample results in thirteen different areas in the mine waste stockpile.

To evaluate the summary statistics the licensee provided in Table 17, the NRC staff compared them to averages the NRC staff calculated using individual sample analysis results previously provided by the licensee in its Pre-Design Studies (MWH 2014). Specifically, the NRC staff examined radium--226 sample results summarized by the licensee in Pre-Design Studies Report, Appendix A2, "Analytical Data Removal Site Evaluation MWH, 2007A," Table 3.15, "Summary of Surface Soil Analytical Results, Preliminary COPCs Removal Site Evaluation 2007," and additional tables contained in an Appendix A2 section titled "Soil Analytical Summary Tables, Subsurface Supplemental Removal Site Evaluation Phase 1 2008." For example, the NRC staff finds that the average concentration of radium-226 in subsurface sample results reported for area NECR-1 (Area 8 in Table 17), which represents the largest volume of mine waste among all the areas, is about 30 pCi/g radium--226, as compared to the 90th percentile value of 28.7 pCi/g reported in Table 17. On the basis that individual sample results support the summary statistics in Table 17, the NRC staff determines the Table 17 results are reasonable. For these reasons, the NRC staff determines that the licensee's estimate of radium-226 concentrations meets SRP acceptance criterion 5.1.3.1(7), which states that the values for radium-226 concentration are measured directly.

The NRC staff also evaluated whether radium-226 in mine waste is in secular equilibrium with its parent radionuclides (uranium and thorium). The NRC staff determined that the data in LAR Appendix L, Health and Safety Plan, Attachment L-1, "Radiation Protection Plan," Attachment 5, "NECR Mine Site Uranium Ore Dust Isotopic Analysis," demonstrate that radium-226 and its longer-lived parent radionuclides are in secular equilibrium based upon the source of the material. Therefore, the NRC staff determined the concentration of radium-226 will remain stable over a 1,000-year performance period and there is no need to consider ingrowth or decay of radium-226 during the performance period that would be caused by any disequilibrium between radium-226 and its uranium and thorium parent radionuclides (e.g., thorium-230).

Mine waste and cover soil porosity

The licensee's estimates of cover material and mine waste porosity are based on measurements of saturated volumetric moisture content shown in LAR Table 11, "Borrow Cover Soil Laboratory Measured Soil Properties," Table 12, "Adjusted Borrow Soil Laboratory Measured Soil Properties for 33% Rock by Volume," and Table 15, "Mine Spoils Measured Soil Hydraulic Properties" (UNC 2018). The NRC staff evaluated whether the values are conservative; based on an adequate number of samples; measured with appropriate quality assurance; and representative of long-term conditions. The NRC staff determined the cover soil porosity values are appropriate because they are based on the average saturated volumetric moisture content measured in five different bulk soil samples. Modeling has a moderate response to this parameter given the proposed depth of material and the range of porosities provided. Modeling only the upper range of measured porosity in cover materials results in a 19 pCi/m^2·s Rn flux rate which complies with the Appendix A, Criterion 6(1) limit. Staff notes that the 20 pCi/m^2·s limit is applicable to the average across the entire disposal cell/repository and using upper range values only provides an estimate of the upper range of the average.

As communicated by the licensee in response to RAI 6.1-1 (ADAMS Accession No. ML19157A165 [pkg]), the value utilized for the mine waste (a single measurement) is based on sampling of the mine spoils performed in 2011 after being remolded to the specified placement density in the repository. While the Rn flux modeling does appear slightly sensitive to variations in source porosity, the optimal modeling porosity occurs at a value of 0.3 and results in a 13% increase over that obtained using the measured value, in the modeled Rn flux which is significantly less than the Appendix A, Criterion 6(1) limit of 20 pCi/m^2·s.

Staff determined that the porosity for the mine waste and cover material is appropriately based on measured values. The NRC staff determined that the site-specific parameter values meet SRP acceptance criterion 5.1.3.1(3), which states that material parameters in radon flux should be reasonably conservative, considering the uncertainty of the values.

Mine waste and cover soil dry bulk mass density

The licensee estimated dry bulk mass densities of the mine waste and two ET cover layers using an estimate of the porosity and specific gravity of these layers using Equation 3 from Regulatory Guide 3.64.   In response to RAI 6.1-2 (ADAMS Accession No. ML19157A165 [pkg]), the licensee explained that the dry bulk density of alluvium soil, and thus porosity, are largely unaffected by freeze-thaw events and that the input parameters to the Rn flux model utilized are not known to have any significant change when subjected to freeze/thaw cycles. The licensee utilized measured values for most parameters at the perceived long-term density of the soil, which NRC staff considers appropriate. Staff also noted that the licensee did consider freeze/thaw cycles for some parameters as described in Section 6.7 of NECR Cover System Design Report. However, the licensee did not explicitly consider the lowering of dry bulk mass densities by freeze thaw cycles, as explained in SRP acceptance criterion 5.1.3.1(5), which states that dry bulk densities of cover soils and tailings are determined using Standard or Modified Proctor Test data, with due consideration of the impact of freeze-thaw events on assumed cover density and porosity. Regardless, staff find the calculated bulk density values adequate because the licensee utilized the reference specific gravity of soil value established in Regulatory 3.64 for cover materials and the only other variable affecting dry bulk density is the porosity of the materials which was evaluated in the prior section of this SER and found adequate.

Mine waste radon emanation fraction

The licensee assumed a radon emanation fraction of 0.35, which is a reference value for this parameter in Regulatory Guide 3.64. Regulatory Guide 3.64 states, “The use of reference values for tailings parameters is acceptable because radon flux and cover thickness calculations are more sensitive to cover parameters than to tailings parameters.” (NRC 1989). The NRC staff determined that this assumption meets SRP acceptance criterion 5.1.3.1(8), which states that the emanation coefficient may be either a reasonably conservative value of 0.35 or determined using specified alternative methods.

Mine waste and cover soil radon diffusion coefficients

The licensee calculated radon diffusion coefficients using an updated method by Rogers (1991). The NRC staff determined that this assumption meets SRP acceptance criterion 5.1.3.1(9), which states that a diffusion coefficient calculated using long-term moisture saturation and porosity is acceptable.

Soil cover thickness

Based upon the evaluations described and evaluated above, the soil cover thickness proposed for the Mine Waste Repository would result in an average radon-222 flux of less than 13.72 pCi/m^2·s. The NRC staff determined that this assumption meets SRP acceptance criterion 5.1.3.1(10), which states that a cover thickness is acceptable if it reduces long-term radon flux to a level that meets 10 CFR 40, Appendix A, Criterion 6(1).

6.1.3.2 Gamma Attenuation

In LAR Appendix G, "Mine Waste Repository Design, Section G.12.4, "Repository Cover Gamma Exposure Rate Measurement," the licensee stated, "A direct gamma radiation survey will be performed following placement of the ET cover to verify that the direct gamma exposure attains the required ambient background levels." The licensee explained that it will compare the results of the survey completed after placement of the ET cover to the survey conducted following removal of the 15-cm (6-inch) erosion protection layer on the existing TDA. The licensee will perform measurements at the same 102 locations as the radon flux measurement locations. The final gamma survey will consist of a one-minute static gamma measurement at each location over the Mine Waste Repository area using a 2" x 2" sodium iodide (NaI(Tl)) scintillation detector. The licensee will include the results of the individual direct gamma exposure rate measurements in the as-built report for the Mine Waste Repository. The NRC staff determined that this approach meets SRP acceptance criterion 5.1.3.2, which evaluates whether the licensee proposed an acceptable method to demonstrate the cover will reduce gamma radiation from byproduct material to local soil background levels based upon the tools and approach proposed.

6.1.3.3 Cover Radioactivity Content

The NRC staff evaluated the licensee's descriptions of radioactive material in the proposed cover soils. Criterion 6(5) of 10 CFR 40, Appendix A, states near surface cover materials (i.e., within the top three meters) may not include waste or rock that contains elevated levels of radium. In LAR Appendix H, "Borrow Areas," Section H.4.1.1, "Borrow Area Investigations," the licensee stated radiologic testing was completed on each borrow area, which indicate that radium-226 concentrations are between 0.8 and 1.7 pCi/g (MWH 2014). The NRC-approved Tailings Reclamation Plan (UNC 1991) indicates the background concentration of radium-226 in soil is 1 pCi/g radium-226. In LAR Section 2.9.1, "Approved Reclamation Plan," the licensee also explained that during reclamation, the mean of the background measurements was 0.78 ± 0.53 pCi/g. The NRC staff determined that the testing results for the proposed borrow areas are within the range of background.

The mine waste which will be added to the TDA is known to contain Ra-226, in secular equilibrium with its uranium and thorium decay chain parent and progeny, in exceedance of background. For the purposes of this evaluation, the mine waste is considered cover material over the tailings disposal area (versus as 11e.2 byproduct material). But such cover material does not meet SRP acceptance criterion 5.1.3.3, which states the licensee will demonstrate an appropriate procedure to determine the cover material contains levels of radioactivity essentially the same as surrounding soil. However, as explained in Section 6.1.1 of this SER, the licensee has proposed this alternative pursuant to Appendix A to 10 CFR Part 40 (which, the staff notes, is part of a connected EPA-directed removal action), and the NRC concludes that the design of the cover materials would limit Rn flux to meet the 10 CFR Part 40, Appendix A, Criterion 6(1) limit of 20 pCi/m^2·s.

6.1.4 Evaluation Findings

The NRC staff has completed its evaluation of the disposal cell cover radiation control at UNC Mill Site. This evaluation included an evaluation using the review procedures in Section 5.1.2, and the acceptance criteria outlined in Section 5.1.3 of the SRP (NRC 2003).

On the basis of the information presented in the application and in the NRC staff's detailed evaluation of the site characterization for the uranium mill facility, the NRC staff concludes that the Mine Waste Repository radon and gamma attenuation and radioactivity content are in compliance with 10 CFR Part 40, Appendix A, Criterion 6(1), which requires placement of an earthen cover over tailings and wastes at the end of the milling operations while providing assurance of control of radiological hazards for 1,000 years, to the extent reasonably achievable (but no less than 200 years); and which limits releases of radon-222 from uranium byproduct materials to the atmosphere so as not to exceed an average rate of 20 picocuries per square meter per second (pCi/m^2-s); Criterion 6(2), which requires demonstration of the effectiveness of the final radon barrier prior to emplacement of erosion protection measures or other features; and Criterion 6(3), which requires that radon exhalation is not significantly above background because of the cover material.

While Criterion 6(5) is not met with this action (I.e., the mine waste within the top three meters of cover does contain Ra-226 concentrations exceeding background), the NRC staff find this acceptable because the cover design provides an acceptable alternative that was established to ensure that Rn flux does not exceed the 10 CFR Part 40, Appendix A, Criterion 6(1) limit of 20 pCi/m^2·s.

6.2 Final Status Survey

In this section of the SER, the NRC staff documents its evaluation of the licensee's plans for performing radiological surveys upon completion of the removal action (i.e., final status surveys) to demonstrate that residual radiological contamination at the UNC Mill Site is within acceptable limits. The NRC staff notes that the UNC Mine Site is not within the NRC-licensed area. Therefore, the NRC staff did not evaluate those portions of the licensee's proposed final status survey plan that apply to the UNC Mine Site, nor any other areas outside the UNC Mill Site licensed area. The sufficiency of these actions was and will be evaluated by EPA pursuant to their authority.

6.2.1 Regulatory Requirements

The NRC staff determines if the licensee has acceptable plans to survey affected areas within the licensed area following closure of the Mine Waste Repository, in accordance with the requirements of 10 CFR 40, Appendix A: Criterion 6(6), which requires that any portion of a licensed uranium mill site not designed to control radon releases contain a concentration of radium in land, averaged over areas of 100 square meters, which, as a result of byproduct material, does not exceed the background levels by more than (i) 5 pCi/g of Ra-226 averaged over the first 15 cm 16 in.] below the surface, and (ii) 15 pCi/g of Ra-226 averaged over 15-cm-thick layers more than 15 cm below the surface.

The NRC staff has determined that the radium benchmark approach described in Criterion 6(6) does not apply to this action. The Criterion 6(6) benchmark dose standard, from which allowable concentrations of uranium and thorium in soil would be calculated, is not applicable to the UNC Mill Site because its decommissioning plan was approved before June 11, 1999. UNC submitted a mill decommissioning plan on December 29, 1988, which was later revised on April 10, 1990. A mill decommissioning completion report was submitted to NRC on April 13, 1993 (UNC 1993).

In addition, the NRC staff determines whether the proposed reclamation plan demonstrates compliance with 10 CFR Part 40, Appendix A, Criterion 6(7), which requires prevention of threats to human health and the environment from non-radiological hazards associated with the wastes.

The NRC staff determines if the reclamation plan specifies the location of records of information important to the decommissioning as required by 10 CFR 40.36(f) and meets the criteria of 10 CFR 40.42(g)(4) and (5). The NRC staff also determines if the reclamation plan sufficiently demonstrates that the proposed decommissioning activities will result in compliance with 10 CFR 40.42(j)(2) requirements to conduct a radiation survey and if the plan complies with the 10 CFR 40.42(k)(1) and (2) requirements that source material be properly disposed of and reasonable effort be made to eliminate residual radioactive contamination.

6.2.2 Regulatory Acceptance Criteria

Unless specifically stated otherwise, the LAR was reviewed for compliance with the applicable requirements of 10 CFR 20 and 10 CFR 40 using the acceptance criteria presented in SRP Section 5.2, "Decommissioning Plan for Land and Structures" (NRC 2003).

The acceptance criteria in SRP Section 5.2.3 address ten topics that are applicable to cleanup and disposal of 11e.(2) byproduct material waste outside a tailings impoundment at a mill tailings site. However, the proposed emplacement of mine waste in the Mine Waste Repository atop the licensee's existing TDA does not require the licensee to revisit all aspects of its approved decommissioning plan, as described in detail in Table 2. The acceptance criteria in SRP Section 5.2.3 that are relevant to the LAR pertain to: (1) plans to identify mine waste to be placed in the Mine Waste Repository; (2) soil background radiological values; (3) acceptable concentrations of residual radioactive material in soils outside the TDA following emplacement of mine waste and completion of the Mine Waste Repository ET cover; (4) environmental monitoring quality assurance and control; (5) final status survey procedures; and (6) records retention.

6.2.3 Staff Review and Analysis

Unless specifically stated otherwise, the information reviewed in this SER section is from information, data, and maps submitted by the licensee in its LAR (UNC 2018).

6.2.3.1 Identification of Mine Waste

The licensee explained that the waste it proposes to emplace in the Mine Waste Repository is located outside the UNC Mill Site licensed area at the 51-ha (125-ac) NECR Mine Site located about 1600 m (5000 ft) northwest of the UNC Mill Site licensed area. According to the licensee, a prior Removal Site Evaluation (RSE) and Pre-Design Study (PDS) determined that radium-226 concentrations in surface soils range from background up to 875 pCi/g. Subsurface soil concentrations of radium-226 range from background up to 438 pCi/g to a depth of about 6 m (20 feet) (UNC 2018).

The portion of mine waste that will be placed in the Mine Waste Repository at the UNC Mill Site will have concentrations of radium-226 and uranium that fall between lower and upper concentration bounds. In LAR Section 1.4, "Proposed Action," the licensee explained that mine waste entering the Mine Waste Repository includes soils above bedrock with measured activity concentrations above 2.24 pCi/g radium-226 and 230 mg/kg uranium. Mine waste that contains 200 pCi/g or more of Ra-226 and/or 500 mg/kg or more of total uranium will be segregated from lower activity mine waste and transported to an off-site, licensed and controlled disposal or reprocessing facility (i.e., it will not be disposed at the UNC Mill site). The licensee identifies soils above the upper concentration bound as Principal Threat Waste (PTW). The licensee's estimate of the volume of PTW is 15,000 cubic meters (19,000 cubic yards), or about 2 percent of the estimated total volume of mine waste.

The NRC staff determined that the licensee has described the mine waste in adequate detail to meet SRP acceptance criterion 5.2.3(1), which states that the licensee's plans are substantiated by characterization data and site history and describes procedures to identify and place soils that exceed applicable standards.

6.2.3.2 Background Concentrations of Radionuclides in Soil

The licensee stated that average background concentrations of radionuclides in surrounding soil, which were measured during a sampling event August 17, 2006, are 1 pCi/g radium--226 and 1.1 mg/kg total uranium. The licensee provided summary statistics for background concentrations of radionuclides in its ER Table 3.11-1, "Statistical Summary of Chemical and Radiological Background Concentrations – Mine Site." In Appendix T, "Cleanup Verification Plan," Attachment T.2, "Final Status Survey Plan," Section 4.2, "Background Reference Area," the licensee explained its background measurement values are based on 25 samples collected in August 2006 from nodes of a triangular grid in a 4-acre area upwind and upslope from the mining activities. The NRC staff determined that these samples are not likely to be affected by site activities and are geologically and chemically similar to the contaminated areas. The NRC staff determined this meets SRP acceptance criterion 5.2.2(2), which states the soil background values are proposed with supporting data.

6.2.3.3 Soil Cleanup Levels

In Appendix T, "Cleanup Verification Plan," Attachment T.2, "Final Status Survey Plan," the licensee explained the acceptable residual contamination at the UNC Mill Site is based on Criterion 6(6), which requires that any portion of a licensed uranium mill site not designed to control radon releases, contain a concentration of radium in land, averaged over areas of 100 square meters, which, as a result of byproduct material, does not exceed the background levels by more than (i) 5 pCi/g of Ra-226 averaged over the first 15 cm [6 in.] below the surface, and (ii) 15 pCi/g of Ra-226 averaged over 15-cm-thick layers more than 15 cm below the surface. As explained in SER Section 6.2.1, "Regulatory Requirements," the licensee is not required to use the benchmark dose approach described in Criterion 6(6) to derive limits for radionuclides other than radium-226. Therefore, the NRC staff determined the licensee does not need to meet SRP acceptance criterion 5.2.2(3), which states uranium and thorium expected to remain in soil meets limits derived using the radium benchmark approach in Criterion 6(6).

6.2.3.4 Instrumentation and Procedures

In Appendix T, “Cleanup Verification Plan,” Attachment T.2, “Final Status Survey Plan,” Section 4.6, “Gamma Radiation Surveys,” the licensee explained that direct gamma radiation surveys will be used to detect radium-226 in soils. The licensee will use a 2” x 2” sodium iodide (NaI) scintillation detector (such as a Eberline SPA-3 and Ludlum 44-10) connected to a scaler/rate meter (such as a Ludlum 2221 or Ludlum 2241) to detect gamma radiation. This is similar to the survey equipment used for the Removal Site Evaluation (RSE), Interim Removal Action (IRA), and Pre-Design Studies (PDS). The detector, shielded or unshielded depending on the potential for interference from contaminated areas nearby, will be held 12 inches above ground level. The licensee will use correlations between the instrument response and surface soil radium-226 concentrations to convert gamma measurements to radium-226 concentrations in soil. The NRC staff determined that this type of correlation between measurements of gamma radiation above the surface and concentrations of radium-226 in soil, as described in 40 CFR 192(b)(1) – guidance for implementation of protection standards for uranium and thorium mill tailings -- is the same type described in SRP acceptance criterion 5.2.2.(4). Therefore, the NRC staff determined this meets SRP acceptance criterion 5.2.2(4), which states the licensee used the same or very similar instrumentation and procedures for background analyses, radium-gamma correlation, and verification data.

6.2.3.5 Quality Assurance and Control

The licensee provided its Quality Assurance Project Plan (QAPP) in LAR, Appendix T, “Cleanup Verification Plan,” Attachment T.3, “Quality Assurance Project Plan.” The licensee also included in Attachment T.3 its contractor laboratory QAPP. The NRC staff determined that the contents of the QAPP are consistent with the regulatory positions in Regulatory Guide 4.15, Revision 2 (NRC 2007). The NRC staff determined this meets SRP acceptance criterion 5.2.2(5), which states the licensee has provided a detailed quality assurance and quality control plan for all aspects of decommissioning.

6.2.3.6 Final Status Survey

The UNC Mill Site area outside the TDA was previously released by NRC for unrestricted use in 1995 (NRC 1995). The survey procedures presented by the licensee for the Mine Waste Repository address Mill Site areas that could become contaminated as a result of Mine Waste Repository construction.

The licensee provided its Final Status Survey (FSS) plan in LAR, Appendix T, “Cleanup Verification Plan,” Attachment T.2, “Final Status Survey Plan.” The licensee used the guidance available in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (USEPA 2000) to design the FSS plan. The NRC staff evaluated portions of the FSS plan that address licensed areas at the UNC Mill Site. The FSS plan describes 17 total FSS areas at the UNC Mine and Mill Sites that exceed the remedial action level identified by the licensee. The survey areas inside the existing NRC-licensed UNC Mill Site include three contiguous areas, as shown in Figures 3 and 5 of the FSSP: (1) the FSS Area 4 Decontamination Area, which is a single Class 1 survey unit SU-04-01; (2) small portions of FSS Area 7, which are haul roads between the UNC Mine Site and UNC Mill Site, which is a single Class 2 survey unit SU-07-01; and (3) FSS Area 8, which comprises the UNC Mill Site equipment yard, which is divided into two Class 2 survey units SU-08-01 and SU-08-02.

The licensee explained that it used a method described in MARSSIM Section 5.5.2.2 (NRC 2000), the Wilcoxon Rank Sum non-parametric statistical test, to determine that the number of samples required per survey area at the UNC Mill Site to achieve the desired Type I and Type II error rates. In FSSP Table 2, “Parameters for Number of Data Point Calculation for WRS Test,” the licensee showed the parameter values it used to calculate that it should obtain 7 samples from each background area and survey unit. In FSSP Table 3, “Grid Length Calculation Parameters,” the licensee showed the parameter values it used to calculate a grid length of 24 m (80 ft) in Mill Site Class 1 survey units, and 41 m (135 feet) in Mill Site Class 2 survey units. The NRC staff found the licensee’s input parameters were reasonable and consistent with available data, and the calculations of the number of sample points and grid size were performed correctly per the applicable MARSSIM methodologies.

In FSSP Table 4, “$DCGL_{emc}$ Calculation Parameters,” the licensee showed the parameter values it used to calculate the elevated measurement comparison for derived concentration guideline level ($DCGL_{emc}$). For the UNC Mill Site, the licensee calculated site remedial action levels (i.e., $DCGL_{emc}$ plus background) of 9.06 pCi/g radium-226 in Class 1 survey units and 6.45 pCi/g radium-226 in Class 2 survey units. The licensee also established investigation levels for direct measurement, soil samples, and surface scans at the same concentrations as the remedial action levels. The NRC staff found the licensee’s input parameters were reasonable and the calculations of $DCGL_{emc}$ were performed correctly per MARSSIM.

The NRC staff considered the review procedures in SRP section 5.2.2(7) in evaluating the licensee’s proposed FSSP and determined that the MARSSIM methodology adopted by the licensee meets SRP acceptance criterion 5.2.2(6), which states that final status survey procedures are adequate to demonstrate compliance with soil cleanup standards.

6.2.3.7 Records

In LAR Table 1.5-1, “LAR Sections and Supporting Information – NUREG-1620 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,” the licensee incorrectly stated that under Section 5.2, item 7., that decommissioning records retention is not applicable to this LAR. However, 10 CFR 20.1501(b) requires records from surveys describing the location and amount of subsurface residual radioactivity identified at the site must be kept with records important for decommissioning and retained in accordance with 10 CFR 40.36(f). 10 CFR 40.36(f) requires each person licensed under Part 40 to keep records of information important to the decommissioning of a facility in an identified location until the site is released for unrestricted use, or until the license is terminated.

Notwithstanding the licensee’s statement in Table 1.5-1, in Appendix T, ‘Cleanup Verification Plan,” Attachment T.2, “Final Status Survey Plan,” Section 9.0, “Report of FSS Findings,” the licensee stated survey procedures and sampling results will be documented in an FSS report following the general guidance in MARSSIM. The FSS report will become an integral part of the remedial action (RA) report. The licensee described the types of information that will be included in the FSS report, including site map; tables of radionuclide concentrations in each sample from each survey unit; summary statistics; graphical displays of data; and results of statistical tests. The NRC staff determined that this report, which will be a public record of the action, is sufficient to meet the record identification and retention requirements of 10 CFR 20.1501(b) and 10 CFR 40.36(f). The NRC staff determined this meets SRP acceptance criterion 5.2.2(7), which states the reclamation plan indicates the location of records important to decommissioning procedures for protection of health and safety.

6.2.3.8 Control of Non-radiological hazards

The licensee provided a Health and Safety Plan in LAR Appendix L. Section L.8, "Project/Site Hazards and Their Control," describes both radiological and non-radiological hazards, including uranium and its decay products, arsenic, silica, diesel fuel, and respirable dust. The licensee described the use of personal protective equipment and a medical surveillance program that will prevent and detect worker exposure to non-radiological hazards. The NRC staff determined this meets SRP acceptance criterion 5.2.2(9), which states the reclamation plan describes the control of non-radiological hazards associated with the wastes as required by 10 CFR 40, Appendix A, Criterion 6(7).

6.2.4 Evaluation Findings

On the basis of the information presented in the reclamation plan and the detailed review conducted of proposed decommissioning activities for the UNC Mill Site, the NRC staff concludes that the information is acceptable and is in compliance with 10 CFR Part 40, Appendix A, Criterion 6(6), which requires that any portion of a licensed uranium mill site not designed to control radon releases, contain a concentration of radium in land, averaged over areas of 100 square meters, which, as a result of byproduct material, does not exceed the background levels by more than (i) 5 pCi/g of Ra-226 averaged over the first 15 cm 16 in.] below the surface, and (ii) 15 pCi/g of Ra-226 averaged over 15-cm-thick layers more than 15 cm below the surface. In addition, the licensee's proposed reclamation plan demonstrates compliance with 10 CFR Part 40, Appendix A, Criterion 6(7), which requires prevention of threats to human health and the environment from non-radiological hazards associated with the wastes.

The decommissioning plan specifies the location of records of information important to the decommissioning as required by 10 CFR 40.36(f) and meets the criteria of 10 CFR 40.42(g)(4) and (5). The plan sufficiently demonstrates that the proposed decommissioning activities will result in compliance with 10 CFR 40.42(g)(2) requirements to conduct a radiation survey. The NRC finds that the decommissioning plan complies with the 10 CFR 40.42(k)(1) and (2) requirements that source material be properly disposed of and reasonable effort be made to eliminate residual radioactive contamination.

6.3 Radiation Safety Controls and Monitoring

6.3.1 Regulatory Requirements

The NRC staff determines if the licensee has met 10 CFR 20.1101, regarding an acceptable radiation protection plan; 10 CFR 40, Appendix A, Criterion 8, which requires control measures to limit dust emissions; and 10 CFR 40.42(g)(4)(iii), which requires methods that ensure protection of workers and the environment from radiation hazards.

6.3.2 Regulatory Acceptance Criteria

Unless specifically stated otherwise, the NRC staff reviewed the LAR for consistency with the requirements of 10 CFR 20 and 10 CFR 40 using the acceptance criteria presented in SRP Section 5.3, "Radiation Safety Controls and Monitoring" (NRC 2003). While the mine waste is not NRC regulated material, the licensee submitted a supplemental radiation protection plan for dealing with the mine waste. As such, staff performed this review to ensure that the plan was accurate and appropriate for the materials and hazards that will be encountered consistent with the regulatory requirements identified above. Should the licensee encounter byproduct material during this work (I.e., mill tailings), the previously approved radiation protection plan and license conditions would be in effect when working with that material.

The acceptance criteria in SRP Section 5.3.3 address: (1) radiation hazards present at the site; (2) changes to the existing radiation protection plan; (3) dust control measures; (4) proposed changes, if any, to the bioassay program; (5) workplace airborne radiological monitoring; (6) contamination control; (7) environmental monitoring; and (8) documentation of monitored occupational dose.

As noted in the SRP, the radiation safety controls and monitoring for site worker, public, and environmental protection during reclamation and decommissioning will be acceptable if they meet the criteria.

6.3.3 Staff Review and Analysis

Unless specifically stated otherwise, the information reviewed in this SER section is from information, data, and maps submitted by the licensee in its LAR (UNC 2018). In 1991, UNC submitted the UNC Church Rock Tailings Reclamation Plan (UNC 1991, ML17121A552). Section 7.5, "Radiation Protection Program" addressed Radiation Protection as implemented at the site. In the licensee's 2018 LAR, including Appendix L, "Health and Safety Plan," the licensee described radiological hazards anticipated during construction of the proposed Mine Waste Repository. The NRC staff focused its review on the more recent submittal as it would apply to the NRC licensed site during mine waste repository construction (i.e., the UNC Mill Site), and the NRC already reviewed and approved the radiation protection program currently in force at the site. The NRC staff did not evaluate hazards and proposed activities that will occur outside the licensed area at the adjacent UNC Mine Site or transport between the two areas.

The LAR described radiation safety controls in Section 2.9, "Radiological Monitoring," Section 4.10, "Radiation Safety," and Appendix L, "Health and Safety Plan." Attachment L-1, "Radiation Protection Plan," most directly addresses the radiation hazards the licensee expects to encounter. In Table L.8-1, "Occupational Health Exposure and Toxicological Properties for Contaminants of Occupational Health Concern" of Appendix L, the NRC staff noted the listing of uranium, radium-226, thorium-230, uranium-238, and radon progeny in the identification of contaminants of concern. In response to RAI 6.3-3, the licensee indicated it would also evaluate exposures from polonium-210 and lead-210 (long-lived Rn progeny). In Attachment L-1, the licensee stated that uranium ore presents both internal hazards from alpha emitting radionuclides (natural uranium, radium-226, thorium-230, polonium-210, and radon-222 progeny) as well as external hazards (primarily from lead-214 and bismuth-214). Attachment L-1 described how the licensee plans to control areas for the purposes of limiting radiation exposures and monitoring for airborne radioactivity. Monitoring for airborne particulates and radon will occur using appropriate instruments and monitoring for external exposure will occur using personal dosimeters and instrumentation. While the proposed work will not involve tailings or yellowcake, the licensee stated it would follow guidance in Regulatory Guide 8.30, "Health Physics Surveys in Uranium Recovery Facilities," which the NRC staff finds acceptable for mine wastes containing uranium ore. The NRC staff determined that the licensee has appropriately identified the radiation concerns that will be encountered during the proposed work, consistent with SRP acceptance criterion 5.3.3(1), which states the licensee identifies radiation safety concerns unique to reclamation and decommissioning activities.

Attachment L-1 of the LAR is a Radiation Protection (RP) Plan that supplements the RP provisions that were approved in the 1991 Reclamation Plan. The NRC staff reviewed the RP Plan in the LAR to determine its suitability for the proposed work at the licensed site. Because it is primarily meant to address mine waste spoils, staff understands the plan to be applicable to that material but that the 1991 plan remains generally applicable for work on the mill site and specifically applicable if the licensee interacts with 11.e.(2) materials on the site. As such, the NRC staff determined that the LAR describes changes necessary to ensure worker or public safety during reclamation or decommissioning activities. This is consistent with SRP acceptance criterion 5.3.3(2), which states that the plan should describe any changes to an existing radiation safety or monitoring program that would be necessary to ensure worker or public safety during reclamation or decommissioning activities.

Appendix Q, Section Q.3, "Dust Control Plan," and Section 5.5, "Exposure Control," of Attachment L-1 of the LAR describes measures the licensee will take to perform dust and exposure control. Appendix R, Section R.3, "Release Prevention," describes release preventions methods the licensee will utilize during transport of materials. The measures and methods to reduce exposures may include applying water to areas to be excavated, spraying water during excavation and material handling operations, modifying or stopping work during windy conditions, and controlling locations of workstations relative to wind direction. The licensee explained that use of contamination control points and loading methods and coverings are intended to minimize the spread of contamination during loading/unloading and hauling of mine waste. The NRC staff determined that these measures are adequate for dust control of the mine wastes being unloaded and added to the repository, consistent with SRP acceptance criterion 5.3.3(3).

The licensee stated in Section 5.4.4, "Bioassays," of Attachment L-1 of the LAR, that it does not anticipate performing bioassays during construction of the Mine Waste Repository. The licensee does not anticipate exposures to exceed 10 percent of the exposure limit and will rely upon air sampling results to demonstrate exposures were not exceeded. The licensee committed to bioassays for uranium analysis for intake assessment for any individual exposed to an airborne uranium concentration of 30 percent of DAC as averaged over a 40-hour work week. The NRC staff note that license conditions 20 and 29 of License SUA-1475 already require a written procedure to be established for bioassay analyses and specifies compliance with select provisions of draft Regulatory Guide 8.22 (January 1987). The bioassay method for assessing exposure to the mine waste is not anticipated to vary significantly from these procedures and the licensee committed to considering all contaminants of concern in uranium ore in its response to RAI 6.3-3. This can easily be done assuming secular equilibrium conditions exist with the radionuclides in the uranium decay chain, as found above. The NRC staff determined that the licensee's existing bioassay program is adequate, consistent with SRP acceptance criterion 5.3.3(4).

The licensee stated, in Section 4.0, "Radiological Monitoring" of Attachment L-1, that it will meet the Lower Limits of Detection (LLD) requirements and quality assurance program as defined in Regulatory Guide 8.30, "Health Physics Surveys in Uranium Recovery Facilities," and Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring." The licensee did not describe workplace air sampling in accordance with Regulatory Guide 8.25, "Air Sampling in the Workplace," but the NRC staff determined that this is acceptable because the scope of Regulatory Guide 8.25 is indoor air sampling, while construction of the Mine Waste Repository is entirely outdoors. The licensee does not anticipate exposures to exceed 10 percent of the annual dose limit. The proposed scope of work and anticipated exposures are limited to low grade uranium ore and associated radon in outdoor areas of the licensed site. The planned work area monitoring, as outlined in subsections of Sections 5 and 6 of the LAR, involves grab sampling of air in the work area, personal air sampling, radon-222 monitoring (if needed), and use of TLDs, or equivalent, as well as area exposure rate surveys. The NRC staff considers this to be consistent with the provisions in Regulatory Guide 8.30 given the nature of the work and, as previously noted, worker participation in the licensee's bioassay program (which while not anticipated to be needed during construction of the Mine Waste Repository, is available). For these reasons, the NRC staff determined the airborne monitoring plan to be adequate, consistent with SRP acceptance criterion 5.3.3(5)

In Section 7.0, "Release of Equipment and Material," of Attachment L-1, the licensee committed to the release of equipment and material consistent with the guidance in Regulatory Guide 8.30, Table 2. The construction of the Mine Waste Repository will occur outdoors on the licensed site and involve low grade uranium ore. The guidance in Regulatory Guide 8.30 states surface contamination is not anticipated to be a problem because of the very low specific activity of the ore. In Section 5.3, "Oral Ingestion and Skin Absorption," of Attachment L-1, the licensee commits to frisking of personnel prior to leaving controlled areas. A contamination limit for skin and clothing of 1,000 dpm/100 cm^2 alpha activity is stated, which is consistent with Regulatory Guide 8.30 and an ALARA limit of 250 dpm/100 cm^2 for skin will also be applied. The staff notes that the licensee committed, in its response to RAI 6.3-11, that it would meet the 1987 Guidelines for Decommissioning consistent with License Condition 11 of license SUA-1475 if encountering mill tailings during the mine waste repository activities. For these reasons, the NRC staff determined the contamination control program to be adequate, consistent with SRP acceptance criterion 5.3.3(6).

In Appendix Q, "Dust Control and Air Monitoring Plan," the licensee described installation of 3 downwind and 1 upwind (i.e., background) air monitoring perimeter stations as shown in Figure Q.4.-1, "Air Monitoring Station Locations." As stated in the licensee's response to RAI 6.3-2, it intends to demonstrate compliance with the public dose limit by using a method consistent with 10 CFR 20.1302(b)(2)(i) based on the net annual average airborne concentration at the controlled area predominately downwind boundary. Existing license conditions 30 and 31 of License SUA-1475 address monitoring of other environmental media at the site. As stated in response to RAI 6.3-4, the licensee will utilize the Rn effluent limit for "with daughters present," which is consistent with guidance in FSME-ISG-01, "Evaluations of Uranium Recovery Facility Surveys of Radon and Radon Progeny in Air and Demonstrations of Compliance with 10 CFR 20.1301," for demonstrating compliance with the public dose limit. For these reasons, the NRC staff determined the environmental radiological program is adequate, consistent with SRP acceptance criterion 5.3.3(7).

The licensee stated, in Section 8.0, "Incidents, Notification Requirements, and Records," of Attachment L-1, that records of the RP Program implemented during construction activities will be maintained by the Radiation Safety Officer (RSO). The licensee stated records will include "surveys and calibrations, individual monitoring results, prior occupational doses, special exposures, dose to public, notifications of incidents, reports to individuals, and any planned special exposures." Sections 5 and 6, "Internal Radiation Dose Assessment" and "External Radiation Dose Assessment," respectively," of Attachment L-1 discuss the methods the licensee anticipates for monitoring personnel and public radiological exposures. Also, in Section 1.4 of Attachment L-1, "As Low As Reasonably Achievable Policy," the licensee states that the site RSO will assess the RP Program monthly as part of the ALARA commitment. For these reasons, the NRC staff determined the licensee has assured that it will have processes consistent with the recordkeeping requirements of 10 CFR 20.2102 and the ALARA requirements of 10 CFR 20.1101, which is consistent with SRP acceptance criterion 5.3.3(8).

6.3.4 Evaluation Findings

The NRC staff has completed its review of the radiation safety controls and monitoring for worker, public, and environmental protection during construction of the proposed Mine Waste Repository. This review included an evaluation using the review procedures in SRP Section 5.3.2 and the acceptance criteria outlined in Section 5.3.3.

The licensee has provided an adequate evaluation of radiation safety controls and monitoring required for worker, public, and environmental protection during construction of the proposed Mine Waste Repository. This includes a radiation protection program consistent with 10 CFR 20.1101, which requires development, documentation, and implementation of a radiation protection program ensuring compliance with 10 CFR Part 20 requirements and the use of procedures and engineering controls to achieve occupational and public doses that are as low as is reasonably achievable. The NRC staff finds that the licensee will adhere to the 10 CFR Part 40, Appendix A, Criterion 8, requirements for implementation of control measures to limit dust emissions from tailings that are not covered by standing liquids, including wetting or chemical stabilization. The NRC staff finds the licensee's plan and procedures to be consistent with 10 CFR 40.42(g)(4)(iii), which requires a licensee to describe methods that ensure protection of workers and the environment against radiation hazards during decommissioning.

6.4 References

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7. NON-11E.(2) BYPRODUCT MATERIAL

In this section of the SER, the NRC staff documents it's evaluation of portions of the LAR (UNC 2018) that address disposal of non-11e.(2) byproduct material mine waste. The NRC staff followed the guidance in NRC Regulatory Issue Summary (RIS) 2000-23, which is included as Appendix I of NUREG-1620 (NRC 2003). Section 1.3 of the LAR contains the licensee's evaluation of the Appendix I guidance. Unless otherwise stated, the NRC staff's evaluation is based on information contained in Section 1.3 of the LAR.

7.1 Background

As described in Section 1.2 of this SER, UNC submitted a license amendment request to fulfill an Administrative Settlement Agreement and Order on Consent (AOC) for the UNC Church Rock mine and mill site (EPA 2015). The removal action described in the AOC includes removal of mine waste from the Mine Site and placement of this material on top of the existing uranium mill tailings disposal area at the Mill Site. The mine waste is not 11e.(2) byproduct material because it was not processed primarily for its source material content. Mine waste is also not source material, which is ores which contain by weight one-twentieth of one percent (0.05%) or more of uranium, thorium, or any combination thereof. This is because the licensee will segregate mine waste containing 0.05 or more weight percent uranium for disposal offsite. Mine waste is also not special nuclear material because it contains no plutonium, uranium-233, uranium enriched in the isotope uranium-233 or in the isotope uranium-235. Because mine waste contains no source, special nuclear material, or byproduct material, it is also not low-level radioactive waste as defined in 10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste."

The NRC's guidance for disposal of non-11e.(2) byproduct material in uranium mill tailings disposal areas is contained in the NRC's Regulatory Information Summary (RIS) 2000-23, which is also included in Appendix I to NUREG-1620 (NRC 2003). UNC proposed to place the mine waste in a repository constructed over a portion of the existing uranium mill tailings disposal area at the Church Rock Mill Site. This section of the SER documents the NRC staff's evaluation of whether UNC's proposal is consistent with the guidance in RIS 2000-23.

7.2 Applicable NRC Guidance

RIS 2000-23 contains guidance the NRC staff follows when reviewing a request to approve disposal of non-11e.(2) byproduct material in uranium mill tailings impoundments. The licensee addressed each of the eight criteria in Section 1.3 and Table 1.3-1 of the LAR. The NRC staff has evaluated the licensee's submittal. The NRC staff's analysis and conclusions for each of the criteria are presented below.

> <u>Criterion 1</u> *In reviewing licensee requests for the disposal of wastes that have radiological characteristics comparable to those of Atomic Energy Act of 1954, Section 11e.(2) byproduct material [hereafter designated as "11e.(2) byproduct material"] in tailings impoundments, the Nuclear Regulatory Commission staff will follow the guidance set forth below. Since mill tailings impoundments are already regulated under 10 CFR Part 40, licensing of the receipt and disposal of such material [hereafter designated as "non-11e.(2) byproduct material"] should also be done under 10 CFR Part 40.*

This criterion identifies the regulations that should be followed when considering a request to dispose of non-11e.(2) byproduct material in a uranium mill tailings impoundment. In Section 1.2 of the LAR, UNC has proposed license condition changes that would incorporate commitments, statements, and representations contained in the revised LAR as conditions of the license. If approved, the condition would allow for receipt and disposal of the mine waste in a separate repository constructed on top of the existing uranium mill tailings disposal area.

In Section 1.4 of the LAR, UNC describes the mine waste as consisting of soil, waste rock, mine debris (metal, concrete, wood), and vegetation. Section 1.4 of the LAR also states that mine waste containing more than 200 picocuries per gram (pCi/g) radium-226 or 500 milligrams per kilogram (mg/kg) total uranium will be transported to an alternative off-site disposal or reprocessing facility (i.e., it will not be disposed of in the proposed repository).

Appendix Z of the LAR contains the results of a series of pre-design studies related to the relocation of the mine wastes. In Appendix Z, UNC documented results of a series of field investigations to determine the radiological characteristics of the mine waste. The results of the field investigations are contained in Table 3 of Appendix C (Radiological Survey Report – ML18267A334) of the pre-design studies. UNC's field investigations also included testing to determine the radiological characteristics of the existing uranium mill tailings. These results are contained in Table 4 of Appendix C (Radiological Survey Report – ML18267A334).

The NRC staff has reviewed the information provided by UNC and has determined that the mine waste has radiological characteristics that are comparable to those of the existing uranium mill tailings. Therefore, the NRC staff concludes that the LAR is consistent with Criterion 1.

> <u>Criterion 2</u> *Special nuclear material and Section 11e.(1) byproduct material waste should not be considered as candidates for disposal in a tailings impoundment, without compelling reasons to the contrary. If staff believes that such material should be disposed of in a tailings impoundment in a specific instance, a request for Commission approval should be prepared.*

UNC Mine Waste does not contain special nuclear material or 11e.(1) byproduct material waste. Therefore, the NRC staff concludes that Criterion 2 is met.

> <u>Criterion 3</u> *The 11e.(2) licensee must provide documentation showing necessary approvals of other affected regulators (e.g., the U.S. Environmental Protection Agency or State) for material containing listed hazardous wastes or any other material regulated by another Federal agency or State because of environmental or safety considerations.*

This criterion relates to the presence of any listed hazardous wastes in the non 11e.(2) material identified for placement in an 11e.(2) byproduct material impoundment. Additionally, this criterion seeks clarification as to whether or not the material is regulated by another Federal or State agency. This criterion also requests that the licensee, UNC, provide documentation of approval by the affected regulators. LAR Table 1.3-1 states that materials meeting the definition of hazardous waste in 40 CFR 261 have not been detected in the non 11e.(2) material. USEPA Regions 6 and 9, as well as the New Mexico Environment Department, the Navajo Nation EPA, and the Department of Energy are all involved in the consideration of the relocation of the mine waste to the existing mill tailings impoundment. The licensee has included a letter in Appendix AA of the LAR (UNC, 2020) from EPA that explains the relationship between the other Federal and State entities involved in this project. The NRC staff reviewed the letters and considers them approval of EPA, New Mexico Environment Department, and the Navajo Nation EPA. Note that DOE's concurrence and commitment on this action is addressed below in Criterion 7.

> <u>Criterion 4</u> *The 11e.(2) licensee must demonstrate that there will be no significant environmental impact from disposing of this material.*

UNC has prepared an environmental report, which identifies the potential environmental impacts of the proposed action. As part of its review process, the NRC staff prepared an environmental impact statement (EIS). The NRC staff's evaluation of this criterion is subject to the forthcoming EIS.

> <u>Criterion 5</u> *The 11e.(2) licensee must demonstrate that the proposed disposal will not compromise the reclamation of the tailings impoundment by demonstrating compliance with the reclamation and closure criteria of Appendix A of 10 CFR Part 40.*

Based on its review of the LAR as described in the previous sections of this SER, the NRC staff concludes that disposal of the mine waste (non-11e.(2) byproduct material) in a repository constructed on top of the existing uranium mill tailings disposal area does not pose any additional burden to meeting the Appendix A criteria. That is, UNC has demonstrated that the proposed design contained in the LAR meets the Appendix A criteria. Therefore, the NRC staff concludes that the LAR is consistent with this criterion.

> <u>Criterion 6</u> *The 11e.(2) licensee must provide documentation showing approval by the Regional Low-Level Waste Compact in whose jurisdiction the waste originates as well as approval by the Compact in whose jurisdiction the disposal site is located, for material which otherwise would fall under Compact jurisdiction.*

Mine Site Mine Waste is not low-level waste and is, therefore, not within the jurisdiction of any regional low-level waste Compact and the licensee need not provide documentation showing approval by any Compact.

> <u>Criterion 7</u> *The U.S. Department of Energy (DOE) and the State in which the tailings impoundment is located, should be informed of the U.S. Nuclear Regulatory Commission findings and proposed action, with a request to concur within 120 days. A concurrence and commitment from either DOE or the State to take title to the tailings impoundment after closure must be received before granting the license amendment to the 11e.(2) licensee.*

This criterion identifies steps that must be taken before an amendment to license SUA-1475 authorizing disposal of non-11e.(2) byproduct material can be granted. In order for the government custodian to be able to make an informed decision, it must be aware of any approvals and constraints imposed by other affected regulators. As discussed in the evaluation of Criterion 3, the NRC staff considers the letter in Appendix AA of the LAR as approval from EPA, New Mexico Environment Department, and Navajo Nation EPA. The NRC staff will send this safety evaluation to the DOE and request concurrence within 120 days as specified in the guidance. The NRC staff understands that absent a request from the State of New Mexico to be the government custodian, that the Department of Energy is prepared to assume that role upon license termination pursuant to UMTRCA Title II.

<u>Criterion 8</u> The mechanism to authorize the disposal of non-11e.(2) byproduct material in a tailings impoundment is an amendment to the mill license under 10 CFR Part 40, authorizing the receipt of the material and its disposal.

Additionally, an exemption to the requirements of 10 CFR Part 61, under the authority of 10 CFR 61.6, must be granted, if the material would otherwise be regulated under Part 61. (If the tailings impoundment is located in an Agreement State with low-level waste licensing authority, the State must take appropriate action to exempt the non-11e.(2) byproduct material from regulation as low-level waste.) The license amendment and the 10 CFR 61.6 exemption should be supported with a staff analysis addressing the issues discussed in this guidance.

UNC submitted the LAR to modify its existing license to allow for placement of the mine waste in a repository constructed on top of the existing uranium mill tailings impoundment at the Church Rock mill site. If the NRC staff approves UNC's LAR, it will amend license SUA-1475, which would allow UNC to move forward with the relocation of the mine waste.

With regard to the second paragraph of criterion 8, an exemption from 10 CFR Part 61 is not required because non-11e.(2) byproduct material mine waste is not low-level waste and is not regulated under 10 CFR Part 61.

7.3 <u>Evaluation Findings</u>

The NRC staff has reviewed the information in Section 1.3, Table 1.3-1, and Appendix AA of the LAR following the guidance in NRC RIS 2000-23. Based on its review, the NRC staff concludes that the LAR is consistent with the applicable criteria in the guidance. The NRC staff observes that Criterion 4 is dependent on the conclusions reached in the EIS. Additionally, the NRC staff recognizes that Criterion 7 remains dependent on concurrence and commitment from the Department of Energy.

7.4 <u>References</u>

10 CFR Part 40. Code of Federal Regulations, Title 10, Energy, Part 40, "Domestic Licensing of Source Material."

EPA, 2015. Administrative Settlement Agreement and Order on Consent for Design and Cost Recovery. Agreement Between United Nuclear Corporation, The General Electric Company, and US EPA Regions 6 and 9. Last accessed at https://www.epa.gov/navajo-nation-uranium-cleanup/northeast-church-rock-mine-legal-document-and-settlements . Last accessed September 2020.

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UNC, 2020. License Amendment Request, dated September 24, 2018, as updated. ADAMS Accession No. ML18267A235, ML20132A276, ML19157A165, ML19182A017, ML19322D036,

ML19248D035, ML19280A935, ML19287A007, ML19315A006, ML19305D526, ML19338D979, ML20156A413, ML20091H049, ML20160A140, ML20190A167

SUBJECT: SAFETY EVALUATION REPORT OF LICENSE AMENDMENT REQUEST, DATED SEPTEMBER 24, 2018, UNITED NUCLEAR CORPORATION (UNC) SUBMITTED A REQUEST TO THE U.S. NUCLEAR REGULATORY COMMISSION (NRC) TO AMEND ITS SOURCE MATERIALS LICENSE NO. SUA–1475 FOR THE FORMER UNC CHURCH ROCK URANIUM MILL AND TAILINGS SITE UNDER THE REQUIREMENTS SPECIFIED IN TITLE 10 OF THE CODE OF FEDERAL REGULATIONS (10 CFR), PART 40, DOMESTIC LICENSING OF SOURCE MATERIAL

DATED: SEPTEMBER 30, 2020

ADAMS Accession No.: ML20210M050 ***via email**

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