FOURTH FIVE-YEAR REVIEW REPORT FOR
UNITED NUCLEAR CORPORATION SUPERFUND SITE
CHURCH ROCK
MCKINLEY COUNTY, NEW MEXICO

September 2013

Prepared by:

US Environmental Protection Agency
Region 6
Dallas, Texas

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CONCURRENCES
FOURTH FIVE-YEAR REVIEW
UNITED NUCLEAR CORPORATION SUPERFUND SITE
CHURCH ROCK
EPA ID# NMD980622864

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LIST OF ACRONYMS/ABBREVIATIONS

Acronym	Definition
ACL	Alternate Concentration Limit
Al	aluminum
ALARA	As Low as Reasonably Achievable
AOC	Administrative Order on Consent
ARARs	Applicable or Relevant and Appropriate Requirements
As	arsenic
Bgs	below ground surface
Be	beryllium
BTVs	Background Threshold Values
Cd	Cadmium
CAP	Corrective Action Plan
CDC	Centers for Disease Control
CERCLA	Comprehensive, Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
Cl	Chloride
cm/sec	centimeters per second
Co	cobalt
COCs	Contaminants of Concern
COPCs	Contaminants of Potential Concern
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
EPA	U.S. Environmental Protection Agency
EPC	Exposure Point Concentration
Fe	Iron
FS	Feasibility Study
Ft	feet
Gpd	gallons per day
Gpm	gallon per minute
GRAs	General Response Actions
GWPS	Ground Water Protection Standards
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
ICs	Institutional Controls
License	NRC's Source Materials License SUA-1475
m^2	meter squared
MCLs	Maximum Concentration Levels

Acronym	Definition
mg/l	milligrams per liter
Mn	manganese
MNA	Monitored Natural Attenuation
Mo	molybdenum
MOU	Memorandum of Understanding
NA	Natural Attenuation
NCP	National Contingency Plan
NECR	Northeast Church Rock
Ni	nickel
NMED	New Mexico Environment Department
NMEID	New Mexico Environmental Improvement Division
NMWQCC	New Mexico Water Quality Control Commission
NNEPA	Navajo Nation Environmental Protection Agency
NO3	nitrate
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	U.S. Nuclear Regulatory Commission
NTE	Not to Exceed
ORD	EPA Office of Research and Development
OUs	Operable Units
OU1	Ground Water Operable Unit
OU2	Surface Soil Operable Unit
Pb	lead
pCi	picocuries
$pCi/m^2/sec$	picocuries (pCi) per meter squared (m^2) per second (sec)
pH	pH is a measure of acidity or alkalinity
PHA	Public Health Assessment
POC	Point of Compliance
PRGs	Preliminary Remediation Goals
ProUCL	Pro Upper Confidence Limit
Ra	radium
RAOs	Remedial Action Objectives
RAP	Remedial Action Plan
RfD	Reference Doses
RI	Remedial Investigation
RI/FS	Remedial Investigation and Feasibility Study
RME	Reasonable Maximum Exposure
ROD	Record of Decision
Sb	antimony
SDWA	Safe Drinking Water Act

Acronym	Definition
Sec	second
Se	selenium
SFS	Supplemental Feasibility Study
Site	Church Rock Uranium Mill Superfund Site
SO4	sulfate
SWA	Southwest Alluvium
SWSFS	Site Wide Supplemental Feasibility Study
TBC	to be considered
TBD	To be decided
TDS	total dissolved solids
Th	thallium
TI	technical impracticability
TTHM	total trihalomethane
TTs	Treatment Technology Action Levels
U	Uranium
UAO	Unilateral Administrative Order
UCL95	95% upper confidence limit
UMTRCA	Uranium Mill Tailings Radiation Control Act
UNC	United Nuclear Corporation
UPL95	95% upper prediction limit
V	Vanadium

EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) has conducted the fourth Five-Year Review (FYR) of the United Nuclear Corporation (UNC), Church Rock Uranium Mill Superfund Site (Site) in McKinley County, New Mexico. The triggering action for this review was the completion of the Third FYR report in September 2008.

The UNC Site is located 17 miles northeast of Gallup and on the southern border of the Navajo Nation. The UNC Site is comprised of the former ore processing mill facilities and a byproduct material (tailings) disposal area (hereinafter Tailings Disposal Area).

At the UNC Site, there are two agencies with overlapping jurisdiction—EPA and NRC. As stated in a 1988 Memorandum of Understanding (MOU) between EPA and NRC, NRC assumed the role of lead regulatory agency for the Tailings Disposal Area reclamation and for surface area closure activities. At the same time, acting under a 1988 Record of Decision (ROD), EPA developed and implemented its own site action requirements for ground water contamination outside of the Tailings Disposal Area in accordance with CERCLA and the NCP. EPA now refers to the ground water response action as Operable Unit 1 (OU1).

To summarize, until recently, NRC generally addressed the surface of the UNC Site and the Tailings Disposal Area, while EPA addressed ground water and reviewed and commented on NRC action. On September 29, 2013, however, EPA issued another UNC Site ROD calling for the disposal of waste from the Northeast Church Rock Mine Site (NECR Site) at the UNC Site. EPA refers to this waste disposal action as OU2 or the Surface Soil Operable Unit. To complete the OU2 remedy, EPA will be coordinating with NRC.

UNC is the primary responsible party for both the UNC Site and the NECR Site. In September 1997, UNC became a wholly-owned indirect subsidiary of General Electric (GE). Collectively these parties are referred to as "UNC/GE." UNC/GE have been working cooperatively with EPA at the UNC Site under an EPA administrative order for OU1.

The recommendations from the 2008 FYR, along with a description of the actions that EPA has taken in response to those recommendations, and a description of the outcome of those actions are presented in Table 22 of this 2013 FYR.

Protectiveness Determination and Recommendations for Follow-up Action

The assessment documented in this FYR found that the remedy at OU1 (the ground water operable unit) currently protects human health and the environment in the short term. Actions taken as part of OU1 have minimized potential human exposures to contaminants found in the ground water and reduced the potential for the repository tailings to act as a source of ground water contamination. Issues identified in this Fourth FYR are presented in Table 24 and the corresponding Recommendations and Follow-up Actions are presented in Table 25.

For the OU1 remedy to be protective in the long term, the following actions need to be taken:

1. Evaluate and revise the estimated background contaminant levels at the UNC Site and reevaluate UNC Site cleanup standards (*i.e.,* remediation goals) through the NCP decision-making process.
2. Complete the ongoing SWSFS Part III to develop and analyze remedial alternatives.
3. Continue the experimental efforts to create a subsurface hydraulic barrier in Zone 3 to slow down and contain the migration of the seepage-impacted ground water in the northern subsurface area.
4. Determine whether the Southwest Alluvium (SWA) extraction wells have provided improvement in ground water quality with respect to uranium contamination when compared to Natural Attenuation (NA).
5. Evaluate the use of various mechanism(s) of Natural Attenuation (NA) in the SWA for uranium as well as for other COCs in all hydrostratigraphic zones as part of the ongoing remediation effort to attain cleanup standards.
6. Renew efforts to establish ICs that will help protect human health by restricting the use of contaminated ground water on affected Navajo Nation, Tribal Trust, and Indian Allotment lands.
7. Evaluate whether a Technical Impracticability (TI) waiver is appropriate for the Applicable or Relevant and Appropriate Requirements (ARARs) related to sulfate and TDS. This evaluation would be done as part of the ongoing SWSFS, Part III.
8. Evaluate the anthropogenic origin and the transient nature of the artificially created ground water aquifers to determine the impact of these factors on future EPA ground water decision making.

The surface soil operable unit (OU2) status quo is protective of human health and the environment. The remedy described in the 2013 OU2 ROD, which provides for the disposal of NECR mine waste at the UNC Site Tailings Disposal Area is also expected to be protective of human health and the environment upon completion. At present, remedial design activities are underway which will adequately addressed all exposure pathways that could result in unacceptable risks in these areas.

In short, this FYR finds that the remedial action that has been taken to address ground water contamination at the UNC Site and the remedial action that has been taken to address contamination on the surface of the UNC Site are presently protective of human health and the environment and should remain protective in the short term.

Carl Edlund, Director
Superfund Division
U.S. EPA, Region 6

9/27/13
Date

Five-Year Review Summary Form

SITE IDENTIFICATION		
Site Name: United Nuclear Corporation		
EPA ID NMD030443303		
Region: 6	**State:** NM	**City/County:** Church Rock / McKinley County

SITE STATUS	
NPL Status: Final	
Remediation status (choose all that apply): X Under Construction (OU2) **X** Operating (OU1)	
Multiple OUs? YES	**Construction completion date:** 10/31/1989 for OU1
Has site been put into reuse? NO	

REVIEW STATUS	
Lead agency: EPA Other Federal Agency: not applicable	
Author name: Janet Brooks with additional support provided by Earle Dixon of NMED	
Author title: Remedial Project Manager	**Author affiliation:** EPA
Review period: 09/17/2008 to 09/17/2013	
Date(s) of site inspection: 04/18/2013	
Type of review: Post-SARA	
Review number: 4th (fourth)	
Triggering action: Previous Five-Year Review Report	
Triggering action date: 09/17/2008	
Due date *(Five-Years after triggering action date)*: 09/17/2013	

Five-Year Review Summary Form (continued)

Issues/Recommendations

OU(s) without Issues/Recommendations Identified in the Five-Year Review:	**OU2**
Issues and Recommendations Identified in the Five-Year Review:	**OU1**

OU1 Issue #1 Category: Establish Background Levels

Issue: The 1988 ROD did not provide a clear evaluation of the post-mining/pre-tailings background water quality in establishing the UNC Site cleanup standards. The COCs or cleanup levels for the UNC Site were not specifically identified in the 1988 ROD. UNC addressed cleanup levels in the UNC SWSFS Part I investigation report that included: 1) a thorough review and update of the UNC Site COCs based on screening with current EPA Maximum Concentration Levels (MCLs), health based criteria, background water quality; and 2) an update and recommendation for revision of the UNC Site cleanup levels. Parts I and II of the SWSFS have been reviewed and accepted by the EPA but has not yet modified the COC list and monitoring program.

The NRC has approved several revisions to License standards, COCs, and monitoring programs recommended by UNC. EPA has discussed those revisions with the NRC but has not modified the cleanup levels or remedy set forth in the 1988 ROD to be consistent with NRC revisions. Such consistency, where appropriate, would help to integrate and coordinate the ground water and source control/surface reclamation activities to achieve comprehensive reclamation and remediation of the UNC Site, which is called for in the MOU between the EPA and the NRC.

Recommendation: Evaluate and revise the estimated background contaminant levels at the UNC Site and reevaluate UNC Site cleanup standards (*i.e.,* remediation goals) through the NCP decision-making process.

Affect Current Protectiveness	Affect Future Protectiveness	Implementing Party	Oversight Party	Milestone Date
N	Y	UNC	EPA, NRC	TBD

OU1 Issue #2 Category: Remedy Performance

Issue: The ground water remedy cannot attain the cleanup levels within a reasonable time frame because the source of anthropogenic recharge to the ground water system is no longer available and has resulted in a significant loss of aquifer saturated thicknesses. By loss of saturated thickness, we mean that, if you measured a cross section of the wet part of the subsurface layer, measuring from the top to the bottom, the part of the layer containing the ground water would be smaller than it used to be. Losing saturated thickness, in this case means that there is less ground water to pump. In fact the aquifer is so depleted that ground water levels do not support extraction of contaminated water at pumping flow rates that are efficient and maintainable. In short, since the mines no longer discharge water, there is not enough water to pump from this aquifer, which was essentially created by the discharge of ground water from the mine.

Recommendation: Complete the ongoing SWSFS Part III to develop and analyze remedial alternatives.

Affect Current Protectiveness	Affect Future Protectiveness	Implementing Party	Oversight Party	Milestone Date
N	Y	UNC	EPA, NMED	TBD

Five-Year Review Summary Form (continued)				
OU1 Issue #3 Category: Remedy Performance				
Issue: One of EPA's goals in Zone 3 is to reduce the subsurface migration of contaminated ground water that is contaminated by seepage from tailings. To accomplish this reduction, EPA has been pumping the ground water to reduce the hydraulic head moving this contamination. [1] The Zone 3 extraction well system cannot hydraulically control the migration of tailings seepage-impacted water northward toward and eventually on to the Navajo Nation lands. All current extraction and hydraulic barrier implementation and any future pumping to reduce the pressure head will only yield short-term results. Because the structural tilting or dip of the impacted hydrostratigraphic strata also drives ground water flow northward, there is an irreducible elevation head that cannot be decreased by pumping. Counteracting this hydraulic force is the clogging of the formation's pore spaces by the seepage-induced chemical alteration of feldspar to kaolinite clay in the aquifer matrix. This alteration-clogging action reduces the formation's permeability and impedes the flow of seepage-impacted ground water. Eventually, there will be a balance between the irreducible hydraulic head and the trapping of seepage-impacted ground water from loss of permeability. In short, while pumping cannot completely reduce the hydraulic head that is causing the northward subsurface migration of contaminants, eventually it appears that clogging of the pores in the subsurface will impede the ground water that has been contaminated by seepage from the tailings and the subsurface migration will cease. The 2012 Ground Water Flow Model will be able to predict when this condition will occur.				
Recommendation: Continue the experimental efforts to create a subsurface hydraulic barrier in Zone 3 to slow down and contain the migration of the seepage-impacted water in the northern subsurface area.				
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
N	Y	UNC	EPA, NRC, NMED	TBD
OU1 Issue #4 Category: Monitoring				
Issue: UNC has indicated in its 2007 and 2012 Annual Review Report that there is no significant difference between the SWA uranium concentration levels in ground water and uranium concentration level trends that existed before the shutoff of the extraction wells and after shutoff of the extraction wells in 2001. The SWA extraction well system was temporarily shut off in 2001 to conduct an 18-month Natural Attenuation (NA) test and the wells have remained off since then. The conclusion reached by UNC is that NA is as effective as extraction of contaminated water in the reduction of uranium levels in the SWA. Although review of the 2012 Annual Review Report indicates that UNC's conclusion appears valid for most wells in the SWA, for some wells the levels of uranium have shown increasing trends since the extraction system was shut off. Consequently, the question still remains as to whether or not the operation of the extraction system in the SWA is effective for				

[1] Hydraulic head = pressure head plus elevation head. Pressure head is caused by seepage-impacted mound of water pushing the water downward and away as the pressure tries to reach neutral, at which point the pressure head will not be able to move the seepage-impacted water. Elevation head will continue to push the water because the hydrostratigraphic units are not flat but dipping northward.

Five-Year Review Summary Form (continued)				
improving ground water quality with respect to uranium and whether NA can be relied upon as part of the remedy to mitigate tailings seepage impacts on ground water. One factor that makes it difficult to determine whether NA could be as effective as extraction is that the UNC report relies on a 2006 statistical analysis of background contaminant concentration levels that does not agree with the 2008 Pro Upper Confidence Limit[2] (ProUCL) statistical finding. The 2008 ProUCL findings were developed by N.A. Water Systems for UNC.				
Recommendation: Determine whether the Southwest Alluvium (SWA) extraction wells have provided improvement in ground water quality with respect to uranium contamination when compared to Natural Attenuation (NA).				
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
N	Y	UNC	EPA, NRC	TBD
OU1 Issue #5 Category: Natural Attenuation				
Issue: Uranium concentrations in the SWA ground water do not exceed the uranium cleanup level of 5.0 milligrams per Liter (mg/l) called for in the 1988 ROD. However, they do exceed the 2003 promulgated EPA Safe Drinking Water Act (SDWA) Maximum Contaminant Level (MCL) for uranium of 0.030 mg/l.				
Recommendation: Evaluate the use of various mechanism(s) of Natural Attenuation (NA) in the SWA for uranium as well as for other COCs in all hydrostratigraphic zones as part of the ongoing remediation effort to attain cleanup standards.				
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
N	Y	UNC	EPA, NRC	TBD
OU1 Issue #6 Category: Institutional Controls (IC)				
Issue: In light of the technical difficulties of achieving Site ground water cleanup levels using engineering controls, Institutional Controls (ICs) may have to play a larger role in protecting human health at the UNC Site. Consequently, ICs should be evaluated in the SWSFS Part III.				
Recommendation: Renew efforts to establish ICs that will help protect human health by restricting the use of contaminated ground water on affected Navajo Nation, Tribal Trust, and Indian Allotment lands.				
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
N	Y	UNC, Navajo Nation Council, and BIA	EPA, NRC	TBD
OU1 Issue #7 Category: Technical Impractability				

[2] ProUCL is a comprehensive statistical software package with statistical methods and graphical tools to address many environmental sampling and statistical issues.

Five-Year Review Summary Form (continued)				
Issue: Sulfate and TDS concentrations are not dependent on continued operation of extraction systems in the hydrostratigraphic units at the UNC Site, but rather these constituent concentrations are controlled by natural geochemical reactions, primarily the chemical equilibrium with gypsum and/or anhydrite. UNC's conclusion that concentrations of sulfate and TDS will continue to exceed cleanup levels as long as the SWA and Zone 1 are saturated appears to be well supported. UNC has performed a TI evaluation and recommended that EPA invoke a TI waiver of the sulfate and TDS standards as well as for the manganese standard.				
Recommendation: Evaluate whether a Technical Impracticability (TI) waiver is appropriate for the Applicable or Relevant and Appropriate Requirements (ARARs) related to sulfate and TDS. This evaluation would be done as part of the ongoing SWSFS, Part III.				
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
N	N	UNC	EPA, NRC	TBD
OU1 Issue #8 Category: Transient, Anthropogenic Aquifers				
Issue: The definition of background water at the UNC Site is not a natural water source but instead an anthropogenic artificial aquifer created by mine water effluent that was pumped from the Westwater Canyon Member of the Morrison Formation, which contains the uranium ore body. This water is also referred to as the ground water beneath the UNC Site which has been contaminated by the seepage-impacted water from the tailings. Thirty years of water level records have confirmed that this "ground water" aquifer is also transient in nature as the source of artificial recharge has been eliminated.				
Recommendation: Evaluate the anthropogenic origin and the transient nature of the artificially created ground water aquifers impact on future EPA ground water decision making				
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
N	N	EPA	EPA, NRC	TBD

Protectiveness Statement(s)

Operable Unit:	***Protectiveness Determination:***	***Addendum Due Date***
2	Will be Protective	*(if applicable): N/A*

Protectiveness Statement:

The surface soil operable unit (OU2) status quo is protective of human health and the environment. The remedy described in the 2013 OU2 ROD, which provides for the disposal of NECR mine waste at the UNC Site Tailings Disposal Area is also expected to be protective of human health and the environment upon completion. At present, remedial design activities are underway which will adequately addressed all exposure pathways that could result in unacceptable risks in these areas.

Operable Unit:	***Protectiveness Determination:***	***Addendum Due Date***
1	Short-term Protective	*(if applicable): N/A*

Protectiveness Statement:

The remedy at OU1 (the final source remedy) currently protects human health and the environment in the short term. Actions taken have minimized potential human exposures to contaminants found in the ground water and reduced the potential for the repository tailings to act as a source of ground water contamination. For the remedy to be protective in the long term, the following actions need to be taken:

1. Evaluate and revise the estimated background contaminant levels at the UNC Site and reevaluate UNC Site cleanup standards (*i.e.,* remediation goals) through the NCP decision-making process.

Five-Year Review Summary Form (continued)

2. Complete the ongoing SWSFS Part III to develop and analyze remedial alternatives.

3. Continue the experimental efforts to create a subsurface hydraulic barrier in Zone 3 to slow down and contain the migration of the seepage-impacted water in the northern subsurface area.

4. Determine whether the Southwest Alluvium (SWA) extraction wells have provided improvement in ground water quality with respect to uranium contamination when compared to Natural Attenuation (NA).

5. Evaluate the use of various mechanism(s) of Natural Attenuation (NA) in the SWA for uranium as well as for other COCs in all hydrostratigraphic zones as part of the ongoing remediation effort to attain cleanup standards.

6. Renew efforts to establish ICs that will help protect human health by restricting the use of contaminated ground water on affected Navajo Nation, Tribal Trust, and Indian Allotment lands.

7. Evaluate whether a Technical Impracticability (TI) waiver is appropriate for the Applicable or Relevant and Appropriate Requirements (ARARs) related to sulfate and TDS. This evaluation would be done as part of the ongoing SWSFS, Part III.

8. Evaluate the anthropogenic origin and the transient nature of the artificially created ground water aquifers impact on future EPA ground water decision making.

Site wide Protectiveness Statement

For sites that have achieved construction completion, enter a site wide protectiveness determination and statement.

Protectiveness Determination:	**Addendum Due Date (if applicable):**
Short-term Protective	N/A

Protectiveness Statement:

The remedial action that has been taken to address ground water contamination at the UNC Site and the remedial action that has been taken to address contamination on the surface of the UNC Site are presently protective of human health and the environment and should remain protective in the short term.

1.0 Introduction

The purpose of a five-year review is to evaluate the implementation and performance of a remedy in order to determine if the remedy is or will be protective of human health and the environment. This FYR is required because hazardous substances, pollutants, or contaminants (hereinafter "contaminants") remain on-Site above the risk-based levels determined in the 1988 Record of Decision (ROD), thereby preventing unlimited use and unrestricted exposure. The methods, findings, and conclusions of the review are documented in this fourth FYR report. In addition, this report summarizes issues identified during the review and includes recommendations and follow-up actions for them. Progress on the recommendations from the previous FYR is discussed.

Protectiveness is generally defined in the National Contingency Plan (NCP) by the risk range and the hazard index (HI). Evaluation of the remedy and the determination of protectiveness should be based on and sufficiently supported by data and observations. The methods, findings, and conclusions of these evaluations are documented in FYR reports. In addition, FYR reports identify issues found during the review, if any, and make recommendations to address them. The NMED provided support for the performance of this review.

The EPA Region 6, performed this FYR pursuant to Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) §121(c), 42 U.S.C. §9621(c) and the National Contingency Plan (NCP). CERCLA §121(c) states:

> *If the President selects a remedial action that results in any hazardous substances, pollutants, or contaminants remaining at the site, the President shall review such remedial action no less often than each 5 years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented. In addition, if upon such review it is the judgment of the President that action is appropriate at such site in accordance with section 104 or 106 [42 U.S.C. §§ 9604 or 9606], the President shall take or require such action. The President shall report to the Congress a list of facilities for which such review is required, the results of all such reviews, and any actions taken as a result of such reviews.*

The EPA interpreted this requirement further in the NCP; 40 Code of Federal Regulations (CFR) §300.430(f)(4)(ii), which states:

> *If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every five years after initiation of the selected remedial action.*

The EPA has conducted a review of the remedial actions implemented at the UNC Church Rock site (the UNC Site), Church Rock, New Mexico. This review was conducted from February to September 2013. It is the Fourth FYR for the UNC Site. Previous FYRs for the UNC Site were conducted in 1998, 2003, and 2008. This report, entitled "Fourth Five-Year Review Report" documents the results of the review.

The triggering action for the review is the signature date of the previous FYR report, September 17, 2008.

Statutory review is required for sites where the selected remedy does not allow unlimited use and unrestricted exposure after the cleanup actions are completed and the cleanup goals have been met. This FYR is required because hazardous substances, pollutants, or contaminants (hereinafter "contaminants") remain at the UNC Site above levels that allow for unlimited use and unrestricted exposure.

1.1 Synopsis

This report presents: technical information from the last five years of work; the work done in the last five years; a description of Site issues; and the recommendations for the next five years.

There are three types of ground water on the UNC Site. Two types are manmade (anthropogenic) and have been defined in the 1988 ROD and subsequent UNC Site documents. The two types of manmade water were mine water from the Church Rock Mines and mill water from the UNC mill. The third type was natural water already in the ground and not from the mines or mill. The water that existed in the ground before mining is called "natural ground water" in the rest of this report.

The mine water came from the Northeast Church Rock Mine and the Kerr McGee Church Rock Mine. The mine water was pumped from the mine shafts and flowed down the local arroyo. The mine water soaked into the ground under the arroyo. In the rest of this report, we refer to this ground water pumped from the mine shafts and into the arroyo as "post-mining/pre-tailings ground water" or as "background ground water."

A byproduct of milling uranium is tailings slurry. Tailings slurry is a thick liquid that is a mixture of water, chemicals, and waste ore. After taking uranium out of the crushed ore rock, the remaining tailings slurry is piped to tailings disposal ponds (cells). Some of this tailings slurry seeped into the ground water. In the rest of this report, we refer to the ground water that has been impacted by the slurry as "post-mining/post-tailings ground water" or the "seepage-impacted ground water."

The 1979 UNC dam break released tailings slurry that flowed down the Pipeline Arroyo for many miles. The tailings slurry water also soaked into the ground and rocks under the tailing disposal cells and under the arroyo. In the rest of this report, the surface dirt, sand and gravel in the Pipeline Arroyo that is contaminated with tailings slurry is called the Southwest Alluvium.

The Southwest Alluvium lies on top of bedrock. The bedrock is mostly made of sandstone with some shale called the Upper Gallup Sandstone Formation. The 1988 ROD has divided the bedrock into different units based on whether they are mostly sandstone or mostly shale. The sandstone units are called Zone 1 and Zone 3 and are separated by a shale unit called Zone 2. Only Zone 1 and Zone 3 sandstones are contaminated with tailings slurry water. In the rest of this report these sandstone bedrock areas are referred to as “Zone 1” and “Zone 3.”

Over time all of the UNC Site tailings slurry has dried up. The dry tailings from the tailings slurry still exist but no longer contain any water. The contaminated water flowed out of the tailings into the Zone 1 and Zone 3 and this water has moved away from the tailings disposal cells. The water in the Southwest Alluvium flowed underground and southwest and north along the Pipeline Arroyo. The Zone 1 and Zone 3 underground water flowed northward toward the Navajo Reservation. The water has not moved onto the Navajo Reservation but may do so in the future.

The ground water that was polluted was not natural ground water. The ground water that was polluted was the manmade ground water that was pumped from the mines and which then drained into the Southwest Alluvium and into the Zone 1 and into the Zone 3.

The background ground water from the mines is a different type of ground water than the seepage-impacted ground water. Both of these manmade ground waters contain radioactive elements. The background ground water that came from the mines contains uranium, radium, and other metals. The seepage-impacted ground water also contains radium, metals and other contaminants because of the milling process. The seepage-impacted ground water does not contain much uranium because it was removed during the milling process. The seepage-impacted ground water is very acidic because of the acid added during the milling process. This is different than the background ground water which does not have the high acid content that the seepage-impacted ground water has. It is important to be able to tell these two types of ground water apart because it is the seepage-impacted ground water that UNC/GE is required to cleanup. They are not required to cleanup the background ground water.

The manmade ground water is going away naturally because no water is being added anymore. The mines quit discharging water down the Pipeline Arroyo when they quit mining. All of the water in the tailings slurry has already drained into the underlying Southwest Alluvium, Zone 1 and Zone 3 so there’s no water being added from the existing dry tailings.

Pumping has not occurred in the Southwest Alluvium since January 2001 and the contaminated ground water continues to shrink in volume. Historically, only the non-hazardous sulfate and total dissolved solids (TDS) exceed UNC Site standards in the Southwest Alluvium. In October 2011, the following ground water contaminants exceeded UNC Site standards: chloride, manganese, sulfate, and TDS.

Pumping does not work in the Zone 1 anymore because there isn't enough water left to pump from the wells located in the Zone 1 sandstone. The seepage fluids from the tailings slurry contained elevated concentrations of metals, radionuclides, and major ions including sulfate and chloride. In October 2011, only sulfate, manganese, and TDS (all of which are non-hazardous) exceeded the UNC Site standards outside of the property boundary in Section 1 of Township 16 North, Range 16 West. Within the UNC Site, the following exceeded the UNC Site standards in October 2011: cobalt, nickel, total trihalomethanes (all hazardous) and the non-hazardous sulfate, manganese, and TDS.

Zone 3 is still being pumped but at some point in the future, there will not be enough water to pump anymore. The seepage fluids from the tailings slurry contained elevated concentrations of metals, radionuclides, and major ions including sulfate and chloride. Some of the contamination found in the Zone 3 ground water is also from the background ground water that came from the mine discharge. It can be hard to tell the difference between the background ground water and the seepage-impacted ground water. The following detected ground water constituents exceeded UNC Site standards in October of 2011: aluminum, beryllium, cadmium, cobalt, gross alpha, lead-210, manganese, molybdenum, radium 226 & 228, sulfate, thorium-230, TDS, total trihalomethanes, uranium, and vanadium.

2.0 SITE CHRONOLOGY

For a detailed chronology of events influencing Site activities, see Table 1.

3.0 BACKGROUND

3.1 Physical Characteristics

The Site is located 17 miles northeast of Gallup, New Mexico and on the southern border of the Navajo Indian Reservation (Figure 1). The Site also sits along the southern margin of the San Juan Basin. UNC operated the UNC Site as a uranium mill facility from 1977 to 1982. The Site includes a former ore processing mill and Tailings Disposal Area, which cover about 25 and 100 acres, respectively (Figure 2). The Tailings Disposal Area is subdivided by dikes into three cells identified as the South Cell, Central Cell, and North Cell.

To the northwest and adjacent to the UNC Site is the former Northeast Church Rock (NECR) mine, an underground uranium mine which was also operated by UNC and which is currently subject to EPA response actions directed by EPA Region 9. To the north of the UNC Site is another former uranium mine that was operated by Rio Algom (formerly Kerr-McGee and

Quivira). The area surrounding the UNC Site is sparsely populated and the primary land use is grazing for sheep, cattle, and horses.

Pipeline Canyon runs through the UNC Site from northeast to southwest. Site alluvium occurs along this drainage feature, including its floodplain. Upslope, Pipeline Canyon passes into Pipeline Arroyo (into which uranium mine water was formerly discharged). Pipeline Canyon is locally flanked by gentle mesas and land that has been regraded in conjunction with milling and former waste handling activities.

The Site lies in an arid, desert climate, with an average annual precipitation of 10.6 inches per year. The evapotranspiration rate is estimated at 61 inches per year (MWH, 2004). Surface water occurs seasonally and flows from northeast to southwest along Pipeline Arroyo.

3.2 Site Hydrogeology

The Site is situated on alluvial valley fill, sandstone, and shale of Cretaceous age at the southern margin of the San Juan Basin. The stratigraphic units identified in the vicinity of the UNC Site, in descending order, are as follows:

- Alluvium
- Dilco Member of the Crevasse Canyon Formation
- Upper Gallup Sandstone
    - Zone 3, upper sandstone
    - Zone 2, shale and coal
    - Zone 1, lower sandstone
- Upper D-Cross Tongue Member of the Mancos Shale

The upper D-Cross Tongue Member of the Mancos Shale, which has a low permeability, acts as an aquitard to prevent or retard the downward migration of ground water. Lithologic well logs indicate that the thickness of the upper D-Cross Tongue is approximately 130 feet (ft) thick in the vicinity of the UNC Site (Canonie Environmental, 1987).

Geologic surface mapping showed the sedimentary bedrock strata are overall very gently dipping (inclined) toward the north (though the bed contacts undulate and are locally flexured).

From approximately 1969 to 1986, large quantities of ground water were pumped from the nearby upgradient NECR and Quivira mines to dewater the underground workings (water was pumped from the Westwater Canyon Member of the Jurassic age Morrison Formation located several hundred feet beneath the ground surface). This mine water was discharged to the local arroyo known as Pipeline Arroyo, which runs across the UNC Site. A portion of the mine discharge water infiltrated into the alluvium and Zone 1 and Zone 3 of the Upper Gallup Sandstone Formation in the vicinity of the UNC Site by spreading laterally and downward from the discharge source along the length of Pipeline Arroyo, creating an artificially high water table beneath the UNC Site.

An amendment to EPA National Pollutant Discharge Elimination System (NPDES) Permit NM0020401 was issued on December 12, 1974, to allow the discharge of mine effluent outfall serial number 001 to "an unnamed arroyo to the Puerco River in the Little Colorado River Basin..." to be changed from the following existing effluent characteristics and discharge limitations:

Effluent Characteristic	Daily Average	Daily Max
Total Suspended Solids	400 mg/l	800 mg/l
Total Uranium	N/A	2 mg/l
Dissolved Radium 226	N/A	25 pCi/l

The above were changed to the following effluent characteristics and discharge limitations on the effective date and lasting through December 31, 1975:

Effluent Characteristic	Daily Average	Daily Max
Total Suspended Solids	100 mg/l	200 mg/l
Total Uranium	N/A	2 mg/l
Dissolved Radium 226	N/A	30 pCi/l

During the period beginning on January 1, 1976, and lasting through June 30, 1977; the following effluent characteristics and discharge limitations were:

Effluent Characteristic	Daily Average	Daily Max
Total Suspended Solids	20 mg/l	30 mg/l
Total Uranium	N/A	2 mg/l
Dissolved Radium 226	N/A	30 pCi/l

During the period beginning on July 1, 1977, through the date of expiration of January 27, 1980; the following effluent characteristics and discharge limitations were:

Effluent Characteristic	Daily Average	Daily Max
Total Suspended Solids	20 mg/l	30 mg/l
Total Uranium	N/A	2 mg/l
Dissolved Radium 226	N/A	3.3 pCi/l

The NECR mine shaft was sunk in 1968 and natural ground water was encountered at an elevation of about 6,692 feet above sea level in the Gallup Sandstone. Ground surface elevation of the UNC Tailings Disposal Area is at about 6,950 feet above sea level.

The UNC uranium mill operated from 1977 to 1982. Uranium ore was processed at the facility using a combination of crushing, grinding, and acid-leach solvent extraction methods. The milling operation produced tailings (acidic slurry of ground rock and fluid). From processing, an estimated 1.5 million tons of tailings were disposed in the tailings impoundment within the Tailings Disposal Area. The contaminated acidic slurry seeped downward beneath the Tailings Disposal Area, eventually encountering the mine discharge water[3]. The actual timing and location of this mixing front cannot be determined but is generally located by various chemical concentrations during water sampling. In addition, the seepage-impacted[4] water is generally low in uranium due to being removed during the milling process.

Due to the migration of radionuclides and other contaminants into the ground water, pursuant to the Comprehensive, Environmental Response, Compensation and Liability Act (CERCLA), the UNC Site was listed on the National Priorities List (NPL) of Superfund sites by the EPA, 48 Fed. Reg. 40658 (Sept. 8, 1983). The EPA conducted a Site Remedial Investigation (RI) and Feasibility Study (FS) from 1984 through 1988. The RI report confirmed that mine discharges to Pipeline Arroyo from the nearby uranium mines and tailings seepage from the Tailings Disposal Area contaminated the alluvial sediments, and Zone 1 and Zone 3 of the Upper Gallup Sandstone Formation.

Under a 1988 Memorandum of Understanding (MOU) between EPA and the U.S. Nuclear Regulatory Commission (NRC), 53 Fed. Reg. 37887 (September 28, 1988), NRC is designated the lead federal agency responsible for regulating the reclamation and closure activities completed at the Tailings Disposal Area pursuant to the NRC's Source Materials License SUA-1475 (License) and the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978, 42 U.S.C. §7901 *et seq.* Under the MOU, the NRC-regulated reclamation and source control actions are subject to EPA monitoring and review to ensure that such actions will allow attainment of the CERCLA requirements outside of the Tailings Disposal Area. The EPA is the lead federal agency responsible for remediation of ground water contamination outside of the Tailings Disposal Area.

Three classes of ground water have been defined for the UNC Site. Two of these classes are anthropogenic and have been defined in the 1988 ROD and subsequent UNC Site documents as: 1) post-mining/pre-tailings (background) and 2) post-mining/post-tailings (commonly referred to as tailings-impacted or seepage-impacted). The third class of ground water is derived from natural recharge and is described by the ROD as pre-mining/pre-tailings (natural). The existing ground water contamination is primarily the results of the post-mining/post-tailings ground

[3] post-mining/pre-tailings (background)
[4] post-mining/post-tailings (commonly referred to as tailings-impacted or seepage-impacted)

water (commonly referred to as tailings-impacted or seepage-impacted) moving away from the Tailings Disposal Area and mixing with the post-mining/pre-tailings ground water (background) in the Southwest Alluvium and Zone 1 and Zone 3 of the Upper Gallup Sandstone Formation.

The UNC Site ground water OU consists of the three uppermost water-bearing units or aquifers, all of which were mostly artificially created by up-gradient mine dewatering, as explained above. From the geologically youngest to the oldest (based on the age of the strata—not the age of the aquifer), these units are referred to as: (1) alluvium (Quaternary age unconsolidated materials along Pipeline Canyon, having a maximum thickness of approximately 150 ft and a maximum width of approximately 4,000 ft); (2) Zone 3 (uppermost stratigraphic unit of the Cretaceous age Upper Gallup Sandstone, having a thickness of 70 to 90 ft in the area of the Tailings Disposal Area); and (3) Zone 1 (lowest stratigraphic unit of the Cretaceous age Upper Gallup Sandstone, having a thickness of 80 to 90 ft in the area of the Tailings Disposal Area). Zones 1 and 3 are in contact with the alluvium at the Tailings Disposal Area, thus allowing movement of contaminated ground water directly into both Zones 1 and 3. The movement of Tailings seepage into Zone 1 is believed to have occurred mainly via two borrow pits (Borrow Pit Nos. 1 and 2) that were excavated in the impoundments down to Zone 1. These two borrow pits were later reclaimed to prevent an ongoing source of seepage to Zone 1. Zone 1 and Zone 3 are separated by Zone 2, comprising approximately 15 to 20 ft of coal and shale which acts as an aquiclude, strongly inhibiting vertical hydraulic communication and contaminant transport.

Mine water was discharged to the Pipeline Arroyo (Figure 2), which infiltrated into the alluvium and then into Zone 3 and Zone 1 creating aquifers. The mine-discharge water is referred to as the *post-mining, pre-Tailings water* in the 1988 ROD and is considered the background water for the UNC Site. From 1968 to 1977, mine water was treated in settling ponds near the mine site to remove suspended radium and other metals prior to discharge to the Pipeline Arroyo. Starting in 1977 and ending in 1983, mine water was processed in an ion-exchange plant at the mine site prior to discharge to the arroyo. Seepage from the tailings, which were deposited at the Tailings Disposal Area beginning in 1977, then impacted this background water. Impact from the tailings seepage has been observed in the alluvium southwest of the tailings impoundment (SWA) and in Zone 3 and Zone 1 to the northeast and east of the impoundment (EPA, 1998).

The ground water in the alluvium flows to the southwest along Pipeline Arroyo. The ground water in Zones 1 and Zone 3 flows in a northeasterly direction. The source of the water in all three formations is in large measure believed to be the result of historical mine-discharge water infiltration (ORD, 2013). Water levels in all three formations reached their highest levels between 1977 and 1986. The amount of saturated thickness in the three units has decreased significantly since the mine water discharge ceased in 1986. Based on the increasing depth to the top of the water table surface, hydrologic conditions depict an overall trend toward a pre-mining state of little to no saturation. Table 2 presents the projected well dryness dates for each hydrostratigraphic unit. Canonie Environmental, 1987 predicted that the aquifer system would revert back to its original dry or near-dry state by 2065.

In 2012, EPA Office of Research and Development (ORD) was tasked by EPA Region 6 to provide comment on the background conditions of the near-surface aquifer system created by the NECR and Quivira uranium mine dewatering activities over the 17 year period of discharges from 1969-1986. On March 25, 2013, ORD issued an official memorandum on the background ground water conditions in the SWA and Zones 1 and 3 of UNC Site. The memorandum describes how infiltration of mine discharge water became the “background” condition of water chemistry for the shallow aquifer system at the UNC Site. As explained later in this FYR, the 2012 Ground Water Flow Model for the UNC Site recognizes three types of ground water at the UNC Site. Two of these classes are anthropogenic and have been defined in the 1988 ROD and subsequent UNC Site documents:

1) post-mining/pre-tailings (background);
2) post-mining/post-tailings (commonly referred to as tailings-impacted or seepage-impacted); and
3) ground water derived from natural recharge and described in the 1988 ROD as pre-mining/pre-tailings (natural).

The memorandum also recognizes that milling disposal operations at the UNC Site created an acidic tailings mound of ground water on top of the artificially created shallow aquifer system that subsequently seeped upward, intercepted the tailings mound, and created a plume of contamination. ORD also concluded that: “It is important to note that the artificial aquifer system is only a temporary system and has been gradually drying up since cessation of mine water discharge at the [UNC Site]. Eventually, the aquifer will revert back to its original dry or near-dry state since no net recharge to the aquifer system is occurring.” In short, there was no (or very little) ground water in the vicinity of the UNC Site until the up-gradient mine discharged ground water from the mine, and that water percolated into the ground. This artificial aquifer intercepted the tailings mound at the UNC Site from below. Now that the mine is no longer dewatering, this manmade aquifer is drying up. The aquifer no longer intercepts the tailings. In fact, ground water data from October 2002 show that the water table is now 40 to 70 feet below the tailings in the Tailings Disposal Area.

3.3 Land and Resource Use

Operation of the NECR uranium mine began in 1968 and uranium milling at the UNC Site began in 1977. Milling activities ceased in 1982, and the Tailings Disposal Areas have since achieved interim closure status in accordance with UNC’s License for radioactive material. Currently, activities at the UNC Site are limited to operation and maintenance (O&M) of the ground water remedial program, and the maintenance of the interim tailings cover. The interim tailings cover meets the NRC requirements for compliance with the radon gas emission level, but the final cover has not been constructed over the South Cell evaporation ponds. Final remedial actions, including backfilling of the evaporation ponds, capping of the evaporation pond area, and completion of the final drainage swales at the Tailings Disposal Area, will be completed after remedial actions related to the surface soil OU remedial action for the NECR mine waste disposal are completed.

The surrounding lands include the Navajo Reservation, Tribal Trust Land, Indian Allotment Land, and UNC-owned property. These lands are sparsely populated and the primary land use near the site is grazing for sheep, cattle, and horses. The 2010 Census population for the Church Rock Chapter is 2,868 and 1,109 for the Pinedale Chapter (US Census, 2010). Land use has not changed since the 1988 ROD.

The 2008 UNC FYR report made note of the planning for a 1,000 unit housing complex in the vicinity of Springstead approximately seven miles to the southwest of the UNC Site. Contact with the Fort Defiance Housing Authority developer in February 2013 indicated there are no plans or available funding, and it is no longer a viable project. On November 19, 2008, the Navajo Nation opened the 64,000 square foot Fire Rock Casino approximately 10 miles southwest of the UNC Site.

Four water wells are within a 4-mile radius of the UNC Site, the nearest being 1.7 miles northeast of the UNC Site which is Navajo Nation windmill 15K-303 that is 614 ft deep and completed in the Gallup Sandstone Formation (poor water quality). There is a water pipeline from Pinedale that supplies potable water to area residents. Nearby residents also use bottled water for drinking.

3.4 History of Contamination

The UNC uranium mill was granted a radioactive materials license by the State of New Mexico in May 1977, and operated from June 1977 to May 1982. The mill, designed to process 4,000 tons of ore per day, extracted uranium using conventional crushing, grinding, and acid-leach solvent extraction methods. Uranium ore processed at the UNC Site came from the 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 acid slurry of ground waste rock and fluid (tailings) that was pumped to the Tailings Disposal Area. An estimated 3.5 million tons of tailings were disposed in the tailings impoundments (EPA, 1998).

3.4.1 Tailings Disposal and Leaching

Tailings liquids were stored in the areas of Borrow Pits Nos. 1 and 2, the North Cell, and the South Cell. The North Cell has been the primary source of tailings seepage. An estimated 5 million gallons was previously available to migrate into the alluvium and Zone 3 located beneath the North Cell. Zone 1 is not affected by the seepage source in the North Cell, because it is hydraulically separated from this source by Zone 2.

The borrow pits were present in the Central Cell area. Borrow Pit No. 1 was used to dispose of tailings and Borrow Pit No. 2 was used to retain tailings liquids (EPA, September 1988). The liquid stored in Borrow Pit No. 2 has been neutralized since 1983. However, it has been proposed that prior to 1983, both borrow pits behaved as a single hydraulic unit and provided a source of acidic seepage to the alluvium, Zone 3, and Zone 1.

The tailings are estimated to be a mixture of approximately 80 percent coarse tailings and 20 percent fine tailings (Canonie, 1991). The coarse tailings typically produce lower radon emissions than the fine grained fraction. Field investigation data collected in 1986 showed the coarse tailings to have a range of 108 to 227 pCi/g radium with an average radium content of 154 pCi/g. Data for the fine-grained tailings showed a range of 285 to 1099 pCi/g radium with an average radium content of 547 pCi/g. From 1993 through 1995 and in accordance with the Tailings Reclamation Plan, UNC's contractors performed reclamation action for the Tailings Disposal Area. During reclamation actions, the tailings were regraded so that coarse tailings or other material (i.e., windblown tailings) covered the fine-grained tailings to provide a minimum seven-foot thickness of coarse tailings over the fine-grained tailings. The purpose was to minimize radon emissions from the tailings and reduce the amount and thickness of soil that would be needed to cover the Tailings Disposal Area, including the coarse tailings which were placed on top of the fine tailings. The tailings disposal cell caps were constructed using 18 to 24 inches compacted soil which was overlain with 3 inches of rock mulch. The final layer consisted of compacted soil (EPA, 2012).

3.4.2 Tailings Spill

In July 1979, the primary dam on the South Cell breached, releasing approximately 93 million gallons of acidic tailings pond water to the Pipeline Arroyo and the Puerco River drainage system. A small emergency retention dam captured approximately 1,100 tons of solid material from the release. The South Cell primary dam was repaired shortly after its failure. Cleanup and assessment of the resultant spill was conducted according to state and federal criteria, with oversight by the EPA, NRC, Navajo Area Indian Health Service, DOE, NMEID, and Center for Disease Control (CDC). Surface water, ground water, and air monitoring were expanded after the spill and during the cleanup over the next year. Arroyo sediments, vegetation, livestock, and some local residents were tested for potential effects caused by the release by NMEID or other agencies. An evaluation of the UNC spill cleanup was performed in 1979 and reported in a 1980 NRC report (NUREG/CR-2449). The multi-agency response and assessment of the 1979 UNC tailings dam release and cleanup results were as follows:

- Six Navajo residents most likely exposed to spill contaminants were tested at the Los Alamos National Laboratory for radiation exposure where they displayed normal levels of radioactivity.

- Surface water quality impacts from the spill were no longer evident, but the water quality was primarily influenced by mine dewatering and natural runoff.

- Ground water quality along the arroyo and Puerco River was highly variable and naturally geochemically similar to spill liquid quality and mine dewatering discharge. Wells completed in the alluvium were more likely to show some elevated concentrations of metals and radioactivity related to the spill, but alluvium with high clay content appeared to effectively remove many spill contaminants.

- Channel sediment sampling indicated the most elevated concentrations of radionuclides were located in the first few miles of the breached impoundment and in the first foot of depth. Levels of uranium-238 and radium-226 were not elevated above background. Levels of lead-210 were most elevated in the first few miles below the dam break and thorium-230 were most elevated many miles downstream. No evidence of spill contamination was found below two feet of depth in channel sediments.

- During the cleanup, air particulate and thorium-230 levels were significantly elevated above background levels. Following the spill, within 12 weeks of continuous air monitoring levels of uranium, radium, lead, and thorium had returned to background levels.

- Native grasses, shrubs, and corn samples collected along the Puerco River contained levels of radionuclides that were considered background for the region. Vegetation collected along the arroyo bottom was elevated in thorium-230 and radium-226, but not at levels that were statistically significant compared to background levels.

- Livestock were potentially exposed to three sources of radioactivity: natural runoff, mine dewatering discharge, and spill liquid. Animals that were exposed to Puerco River water showed higher levels of radioactivity than control animals. Lead-210 and radium-226 levels appeared to be correlated with the age of the animal and prolonged exposure to mine dewatering discharge and natural runoff rather than short term exposure to spill water and contaminants.

- Recommendations from the assessment included: 1) the Puerco River should not be used as a primary source of water for human consumption, livestock watering, or irrigation; 2) additional study of mine dewatering effluent and natural runoff was needed to define potential hazards from prolonged use; 3) consumption of Church Rock area livestock livers and kidneys should be avoided but sampled to re-evaluate long-term risks from consumption of such tissues; 4) wells that draw water from the alluvium should be sampled annually for gross alpha activity; and 5) new wells should not draw water from the upper 100 ft of alluvium which should be sealed off from lower producing zones.

3.4.3 Ground Water Contamination

The NECR Mine was dewatered to access the uranium ore in the deep bedrock unit approximately 1,500 to 1,700 ft below the surface. The saturated uranium ore-bearing unit is the Westwater Canyon Member of the Jurassic age Morrison Formation. Water from the mine was discharged to the northwest branch of Pipeline Arroyo at a location just north of the mine. Water was also discharged to the arroyo from a nearby mine operated by Kerr McGee (subsequently Quivira now Rio Algom). Mine water was discharged to the arroyo from March 1969 through February 1986 at an average rate of approximately 3,000 gpm. The mine water discharges infiltrated the alluvium and Zones 1 and 3 of the Upper Gallup Sandstone Formation, significantly recharging these aquifers, which were probably dry prior to receiving the mine water discharge, and creating an artificially high water table under the UNC Site. In the EPA's RI report, it was estimated that discharge water infiltrated into the alluvium at a rate of 250 gpm.

The large volume of continuous mine dewatering effluent that infiltrated and saturated the mostly dry alluvium and limited parts of Zones 1 and 3 created an artificial aquifer system with a water chemistry and quality similar to that of the mine discharge effluent. This artificial aquifer was designated in the 1988 ROD as the ground water aquifer. The ground water quality that existed prior to contact with the acidic mill tailings seepage water was designated as the "*background"* water for reference and comparison even though it was not naturally occurring. Formally named as, "*the post-mining, pre-tailings background water*," it was initially unaffected by Tailings seepage, and it exceeded New Mexico Water Quality Control Commission (NMWQCC) numerical ground water standards for several contaminants, including sulfate and TDS.

The leaching or seepage of tailings fluid containing radioactive and non-radioactive contaminants and associated constituents (tailings seepage) occurred from the tailings disposal cells downward through the underlying soils and into the ground water. This tailings seepage contaminated the alluvium and Zones 1 and 3, which had already been significantly saturated and recharged by the mine water discharges. These seepage-impacted areas are shown on Figure 3. The alluvium was impacted in three areas: southwest of the South Cell, north of the North Cell and in Section 36 to the north of the Tailings Disposal Area. These areas are referred to in the 1988 ROD as the South or SWA, North Alluvium, and Section 36 Alluvium. They have been mapped by evaluating ground water chemistry conditions using monitoring well samples that show a mixing effect between existing water and the more concentrated acidic tailings seepage. The affected alluvial ground water typically displays a relatively low (acidic) pH[5] and elevated concentrations of nitrate, sulfate, TDS, bicarbonate, chloride, select heavy metals, and

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[5] Higher pH water or soil is more alkaline. Lower pH water or soil is more acidic.

select radionuclides. Tailings seepage-impacted ground water in Zone 1 and Zone 3 also displays a water quality geochemistry similar to that of the impacted alluvial ground water.

3.5 Initial Response

Prior to 1988 ROD issuance, UNC undertook the following actions under its NRC License and requirements by NMEID. Initial corrective action to address ground water concerns began with tailings seepage investigations and neutralization of the acidic tailings. These actions were performed from 1979 through 1982. Tailings neutralization included the addition of ammonia and lime to the tailings to raise the pH. NMEID also required that UNC remediate ground water in Zones 1 and 3. Ground water remediation began in 1982 and consisted of: installation and operation of wells to extract tailings seepage; neutralization of the extracted water, and discharge of the neutralized water into the tailings disposal cells for evaporation.

Implementation of the processes for reclamation and ground water remediation under the NRC License began in 1986 when the NRC assumed mill site licensing responsibility from the State. A draft reclamation plan was submitted to NRC in 1987 and the final plan was approved in March 1991. The NRC required that reclamation construction activities begin in 1988, three years prior to final approval of the reclamation plan. The ground water remediation, as required under NRC regulations and in the License, was incorporated into the reclamation plan. The Corrective Action Plan (CAP) included cleanup standards for the UNC Site as determined by the NRC.

EPA's involvement at the UNC Site began in 1981 when the UNC Site was placed on the Interim Priority List under CERCLA. The Site was proposed for listing on the NPL in 1982 and placed on the NPL in 1983, because of seepage from the tailings and the resulting off-site migration of radiological and chemical constituents in the ground water. The EPA commenced the remedial investigation and feasibility study (RI/FS) in March 1984 with the RI field activities being conducted from March 1984 through August 1987. The objectives of the RI field activities were to determine the nature and extent of ground water contamination in the SWA, and in Zone 1 and Zone 3 of the Upper Gallup Sandstone. The EPA released the RI and FS reports in August 1988, along with a proposed plan-of-action fact sheet for the UNC Site ground water remediation. A Public Health Assessment (PHA) was included in the FS report. The PHA addressed the potential hazards to public health associated with the potential use of the impacted ground water near the UNC Site. The PHA concluded that the potential risk associated with the use of ground water from Zones 1 and 3 exceeded $1X10^{-6}$ excess lifetime cancer risk. To protect human health, EPA has set the acceptable risk range for carcinogens at Superfund Sites from 1 in 10,000 to 1 in 1,000,000 (expressed as 1×10^{-4} to 1×10^{-6}). A $1x10^{-6}$ excess lifetime cancer risk means that, in a lifetime of exposure to site contaminants, a resident would have a one in a million excess risk of getting cancer, when compared to the average person in the United States. The average risk of cancer is about one in three in the United States. Where the aggregate risk from carcinogenic contaminants of concern (COC) based on existing Applicable or Relevant and Appropriate Requirements (ARARs) (see explanation of ARARs below in section 3.6.1) exceeds 1 x 10^{-4}, or where remediation goals are not determined by ARARs, EPA uses the 1 x 10^{-6} as a point of departure for establishing preliminary remediation goals for carcinogens. This means that accumulative risk level of 1 x 10^{-6} is used as the starting point (or initial "protectiveness" goal) for determining the most appropriate risk level that alternatives should be designed to attain. Factors related to exposure, uncertainty and technical limitations may justify modification of initial cleanup levels that are based on the 1 x 10^{-6} risk level.

In addition to the carcinogenic risk, the Hazard Index (HI) for the UNC Site was found to exceed 1.0. The HI is used to measure the risk to human health posed by toxicity that is not related to the carcinogenic effect of the contaminant at issue. For non-carcinogenic toxic chemicals, the toxicity assessment is based on the use of reference doses (RfDs) . A reference dose is the concentration of a chemical known not to cause health problems. The estimated potential site related intake of a compound is compared to the RfD in the form of a ratio, referred to as the hazard quotient (HQ). If the HQ is less than one, no adverse health effects are expected from potential exposure. When environmental contamination involves exposure to a variety or mixture of compounds, a hazard index (HI) is used to assess the potential adverse effects for this mixture of compounds. The HI represents a sum of the hazard quotients calculated for each individual compound. HI values that approach or exceed 1.0, generally represent an unacceptable health risk that requires remediation (See Table 8 of the risk assessment).

The RI report concluded the following:

- In the SWA, an area of seepage-impacted ground water is present that extends a minimum of 1,000 feet past the South Cell. The extent of the seepage-impacted ground water was beyond the furthest down-gradient well (at that time). Alluvial contaminants included TDS, nitrate, sulfate, heavy metals (selenium, manganese, cadmium, and molybdenum), and radionuclides (predominantly gross alpha, but gross beta, radium-226, and radium-228 were also detected). Uranium was also detected at a level exceeding an HQ for children (2.7).

- In Zone 3, an elongate area of seepage-impacted ground water was present more than 2,000 feet from the north cell. Contaminants included TDS, ammonia, low pH, sulfate, nitrate, heavy metals (cadmium, chromium, manganese, arsenic, and beryllium), and radionuclides (thorium, uranium, gross alpha, gross beta, radium-226, and radium-228).

- In Zone 1, seepage-impacted ground water in two areas had migrated northeast and east at least 800 feet from former Borrow Pit No. 2. Contaminants included TDS, acidic pH, nitrates, heavy metals (cadmium, arsenic, and manganese), and radionuclides (thorium, uranium, gross alpha, and gross beta).

On August 26, 1988, the EPA and NRC signed a MOU that provided for coordination of: 1) the NRC reclamation and closure activities at the Tailings Disposal Area; and 2) the EPA CERCLA ground water remedial action. The intent of the MOU was to "*establish the roles, responsibilities, and relationship between*" the EPA and NRC, and to "*help assure that remedial actions occur in a timely and effective manner.*" The MOU recognized that the EPA would conduct a CERCLA RI/FS and sign a 1988 ROD that addressed ground water contamination outside of the Tailings Disposal Area. The EPA would then require UNC to implement the selected CERCLA remedial action under EPA oversight.

3.6 Basis for Taking Action

This section describes the contaminants found in the ground water impacted by Tailings seepage at the UNC Site. No other media are relevant to this review.

3.6.1 Applicable or Relevant and Appropriate Requirements

Section 121(d) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), 42 U.S.C. § 9621(d), requires that on-site remedial actions attain or waive promulgated Federal environmental Applicable or Relevant and Appropriate Requirements (ARARs), or more stringent promulgated State environmental ARARs, upon completion of the remedial action. The 1990 National Oil and Hazardous Substances Pollution Contingency Plan (NCP) require compliance with ARARs during remedial actions and during removal actions to the extent practicable. ARARs are identified on a site-by-site basis for all on-site response actions where CERCLA authority is the basis for cleanup. The ARARs established in the 1988 ROD for this Site which were evaluated as part of this review include:

- National Primary Drinking Water Standards;
- New Mexico Water Quality Control Commission (NMWQCC) Regulation Standards (including Human Health "Drinking Water Standards");
- Resource Conservation and Recovery Act standards applicable to background (required three monitoring wells: one upgradient monitoring well and two downgradient monitoring wells used to determine background concentration values); and
- Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings (40 CFR 192), as adopted by 10 CFR 40, Appendix A, pursuant to Uranium Mill Tailings Radiation Control Act (UMTRCA).

Contaminant-specific ground water ARARs presented in the 1988 ROD are shown in Table 3. 40 CFR §300.430 (f)(1)(ii)(B)(*1*) states that *requirements that are promulgated or modified after ROD signature must be attained (or waived) only when determined to be applicable or relevant and appropriate and necessary to ensure that the remedy is protective of human health and the environment.* Accordingly, any new potential ARARs must be attained only under certain specific conditions. The protectiveness of the existing 1988 ROD ARARs in light of revised federal or state standards is discussed in Section 5.

3.6.2 Contaminants of Concern

The 1988 ROD identified contaminant specific ARARs from the federal Safe Drinking Water Act (SDWA) National Primary Drinking Water Standards (Maximum Contaminant Levels or MCLs) and the NMWQCC regulation standards. The 1988 ROD also identified health based criteria (for those contaminants where MCLs and NMWQCC standards were not available) as to be considered (TBC) criteria, along with background levels where the post-mining, pre-tailings background levels were higher than federal or state standards or health based criteria. The health based criteria and background levels identified for the UNC Site, in addition to ARARs, are collectively referred to as the 1988 ROD cleanup levels for the purposes of this FYR and are shown in Table 3. Although not specifically stated as "cleanup levels" in the 1988 ROD, these ARARs, health based criteria, and background levels represent the cleanup levels that have been used throughout the course of the CERCLA cleanup effort (1988-2013). Specifically, the cleanup levels established in the 1988 ROD are as follows:

- Post-mining, pre-tailings background levels were established for iron, manganese, sulfate, nitrate, and TDS.

- MCLs were selected as the cleanup levels for arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, radium-226, radium-228, and gross alpha. The basis for thorium-230 is the gross alpha standard of 15 pCi/L.

- NMWQCC standards were selected as the cleanup levels for aluminum, cobalt, copper, molybdenum, nickel, zinc, chloride, and uranium-238. NMWQCC standards and MCLs were the same for barium, cadmium, chromium, lead, mercury, and silver.

- Health based criteria were calculated using Reference Doses (RfD), assuming a 70-kilogram individual who consumes 2 liters of water per day, for antimony, beryllium, thallium, and vanadium.

Table 2 of the 1988 ROD (Contaminant-Specific Ground Water ARARs) identifies cleanup levels for the twenty-eight contaminants detected in Site ground water during the RI (*see also* Tables 4 and 5 of the 1988 ROD). Of the 28 cleanup levels, 19 are ARARs, four are health-based criteria and five are post-mining/pre-tailings background levels. Table 6 of the 1988 ROD identifies those Site contaminants that exceed the cleanup levels and the aquifer(s) in which they were exceeded. This information is summarized in Table 3. At the time the 1988 ROD was prepared, the alluvium was divided into North Alluvium, South (or Southwest) Alluvium and Section 36 Alluvium target areas. The remedy selected by EPA in the 1988 ROD for the alluvium focused on the Southwest Alluvium (SWA) target area (as shown in Table 3 of this FYR).

While preparing the Remedial Design in 1989, UNC evaluated the existing ground water data to determine which contaminants exceeded the 1988 ROD cleanup levels. The Remedial Design proposed only those contaminants exceeding the cleanup levels for inclusion in the monitoring program. This evaluation of the ground water data showed that 14 contaminants were below the cleanup levels (antimony, barium, beryllium, chromium, copper, iron, lead, mercury, silver, thallium, vanadium, zinc, uranium-238, and thorium-230). Radium-226 and radium-228 combined only exceeded the cleanup level in Zone 3. NRC standards (as documented in the License) were also considered in the Remedial Design Report. The License identified 15 contaminants, including four not previously identified in the 1988 ROD (lead-210, chloroform, cyanide, and naphthalene). The NRC's GWPS were exceeded in Zone 3 for all 15 analytes. However some of these analytes (e.g., arsenic) were detected at concentrations below NRC's standards for Zone 1 and the SWA.

Review of the Remedial Design Report (Tables 1.1 and 1.2) suggests that the comparison to cleanup levels and standards may have used different sets of wells (or errors exist in the tables), because unexpected results are noted (for example, the NRC beryllium standard of 0.05 mg/l is exceeded in Zones 1 and 3, while no exceedance is indicated for the EPA cleanup level of 0.017 mg/l). It was also noted that the contaminant sulfate, which is elevated throughout the UNC Site, is not identified as exceeding the cleanup level. At this time project documents refer to uranium and not uranium-238, as listed in the 1988 ROD. Those contaminants identified in the Remedial Design Report as exceeding either the 1988 ROD cleanup levels, the NRC standards, or both, are summarized in Table 4 of this FYR report.

After evaluating all of the exceedances identified in the Remedial Design Report, UNC developed a list of 29 performance monitoring analytes. This list was proposed in the Remedial Design Report and the Remedial Action Plan (RAP), both of which were approved by the EPA and the NRC. Since beginning the Remedial Action in 1989, UNC has monitored this list of analytes. The 29 analytes were incorporated into NRC's License. Several of the 29 analytes monitored by UNC (e.g., ammonia, sodium, potassium, and bicarbonate) are not identified as exceeding either EPA's cleanup levels or the NRC standards, but were required to be monitored under the NRC License.

Ground water cleanup criteria established following the basis for taking action

In 1996, at the request of UNC, the NRC used the existing ground water monitoring data and knowledge of the UNC Site to conduct a re-evaluation of background concentrations for certain contaminants (NRC, 1996). Although the NRC does not regulate those contaminants and has no GWPS for them, it recommended that the background values for manganese, nitrate, sulfate, and TDS established by EPA as cleanup levels in the 1988 ROD be revised. The NRC recommended the cleanup level for nitrate to be 190 mg/l. Other background studies have been performed by UNC consultants as a compilation of efforts under the NRC License and for

EPA (e.g., NRC, 1996; Earth Tech, 2000). Based on another UNC proposal, the NRC updated the combined radium-226 and radium-228 License standards to 5.0, 5.2, and 9.4 pCi/L, for Zone 3, the SWA, and Zone 1, respectively (NRC SUA-1475 License Amendment 37, August 9, 2006). The NRC chloroform standard has been changed to the total trihalomethane (TTHM) MCL value of 0.080 mg/l (License Amendment 37). The NRC has also removed cyanide and naphthalene from the License monitoring requirements based on a proposal from UNC.

The EPA reviewed those studies and proposed modifications to the background values, NRC standards, and monitoring requirements. The EPA communicated to the NRC that the proposed modifications for removing cyanide and naphthalene from the monitoring program were acceptable. The EPA also communicated to the NRC that the recommended revised nitrate and radium values were acceptable and plans to modify the cleanup levels for those contaminants in future decision-making following completion of the SWSFS Part III to be consistent with the NRC's License standards. The EPA plans on revising the background levels, as appropriate, following the completion of the SWSFS, which includes a thorough and comprehensive review of the existing cleanup levels, newly promulgated standards as potential new ARARs, and more recent health based toxicological information and background water quality data. Since the 2008 FYR was completed, UNC has completed Parts I and II of the SWSFS including a statistical analysis of background and impacted water; screening of remedial alternatives; and an updated baseline Human Health Risk Assessment (HHRA). A summary of this work is presented and discussed in Section 5.0.

The relationship between the 1988 ROD cleanup levels, the current NRC standards, and the current ground water monitoring program is shown on Table 5. As indicated in this table, a number of Site-related contaminants identified in the 1988 ROD have never been or are no longer monitored as part of the remedial activities because either they were never detected, were originally below the established cleanup levels, or have since decreased in concentration below the established cleanup levels.

4.0 REMEDIAL ACTIONS

4.1 Ground Water Operable Unit – OU1

4.1.1 Remedy Selection

Extraction and evaporation of contaminated ground water was selected as the remedy for the UNC Site in the 1988 ROD signed on September 30, 1988. As stated in the 1988 ROD, the selected remedy incorporates source control remedial action (surface reclamation, capping, and mill decommissioning) under the NRC's licensing requirements as specified in the MOU between the EPA and the NRC. Both ground water and source control/surface reclamation remedial actions were to be integrated and coordinated to achieve comprehensive reclamation and remediation of the UNC Site. Both the NMEID and the NRC reviewed and commented on the 1988 ROD and endorsed the remedy. The selected remedy expanded upon the remediation previously required by the NRC under the License for Zone 1 and Zone 3, and added a requirement for ground water extraction in the SWA. For purposes of integrating and coordinating the ground water remediation, the NRC ground water CAP was subsequently amended to include remediation in the SWA.

The remedy set forth in the UNC 1988 ROD consists of the following six components:

1. Implementation of a monitoring program to detect any increases in the areal extent, or concentration of, ground water contamination outside the Tailings Disposal Area;

2. Operation of existing seepage extraction systems in the Upper Gallup Aquifers (because seepage from tailings had migrated into the underlying Zone 1 and Zone 3 sandstones, the selected remedy included operation of the existing East Pump-Back wells in Zone 1 and the Northeast Pump-Back wells in Zone 3 until adequate dissipation of the tailings seepage mound has been achieved; operation of the two pump-back systems were to be integrated with active seepage remediation that may be required by the NRC inside the Tailings Disposal Area);

3. Containment and removal of contaminated ground water in Zone 3 of the Upper Gallup Sandstone utilizing existing and additional wells (the 1988 ROD states that "Seepage collection in Zone 3 will be designed to create a hydraulic barrier to further migration of contamination");

4. Containment and removal of contaminated ground water in the SWA utilizing existing and additional wells (the 1988 ROD states that "Seepage collection in the SWA will be designed to create a hydraulic barrier to further migration of contamination while the source is being remediated");

5. Evaporation of (extracted) ground water using evaporation ponds supplemented with mist or spray systems to enhance the rate of evaporation;

6. Implementation of a performance monitoring and evaluation program to determine water level and contaminant reductions in each aquifer and to evaluate the extent and duration of pumping actually required outside the Tailings Disposal Area.

The goal of the selected remedy at the UNC Site was to restore ground water outside the Tailings Disposal Area Site to federal and state standards, health based criteria, or background levels, to the maximum extent practicable, and to the extent necessary to adequately protect public health and the environment. However, as stated in Appendix A of the 1988 ROD, it was recognized that cleanup levels might not be reached within a reasonable time period due to the physical characteristics of the aquifers. Appendix A discusses hydrogeologic uncertainties and contingencies for the selected remedy. The contingencies are stated in the following way:

> *"…However, operational results may demonstrate that it is technically impracticable to achieve cleanup levels in a reasonable time period, and a waiver to meeting certain contaminant-specific ARARs may require re-evaluation as a result. Operational results may also demonstrate significant declines in pumping rates with time due to insufficient natural recharge of the aquifers. The probability of significant reductions in saturated thickness of aquifers at the UNC Site must be considered during performance evaluations since much of the water underlying the Tailings Disposal Area is the result of mine water and tailings discharge, both of which no longer occur. In the event the saturated thicknesses cease to support pumping, remedial activity would be discontinued or adjusted to appropriate levels"* (1988 ROD, Appendix A – Hydrologic Impact of Selected Remedy).

4.1.2 Remedy Implementation

General

Prior to implementation of the remedy selected in the 1988 ROD, extraction of contaminated ground water and monitoring of water quality and elevation were ongoing components of a remedy under the direction of NMEID. The extracted contaminated ground water was neutralized by the addition of lime and stored in Borrow Pit No. 2, which was lined with a one-foot thick layer of compacted clay. This remedial action also included the addition of lime to the tailings disposal cells to neutralize tailings liquid and cause precipitation of metals. The field RI performed by the EPA from November 1984 to February 1985 added another 29 wells to the existing network of wells at the UNC Site including: 17 wells in Zone 3; 7 wells in Zone 1; and 9 wells in the SWA. The 29 wells were completed with 4-inch diameter casing, and 4 temporary wells were completed with 2-inch diameter casing for use as observation wells during pump testing. This information regarding the history of remedy implementation and well completion at the UNC Site is provided to show the extent of the effort that has been made to extract contaminated ground water and to monitor hydrologic conditions over a span of approximately 32 years (1981-2013).

In 1989, EPA issued a Unilateral Administrative Order (UAO), Docket No. CERCLA 6-11-89, issued June 29, 1989, to UNC. The UAO requires UNC to undertake ground water remediation at the UNC Site by implementing the remedy selected in EPA's 1988 ROD. The key dates of remedial design, remedial action, and relevant agreements and documents are listed in Table 1. The implementation and performance of the remedy set forth in the 1988 ROD for each hydrostratigraphic unit are described in the following three sections.

Before the issuance of the 1988 ROD, remedial activities pursuant to UMTRCA began in 1982 and 1984 in Zone 1 and Zone 3 seepage-impacted areas, with the installation and operation of pump-back wells under NMEID direction and oversight in its capacity as a UMTRCA agreement state. Approximately 300 borings and wells had been completed across the UNC Site prior to the EPA's RI at UNC (EPA RI, 1985). Table 6 presents a summary of the early series of wells installed at the UNC Site prior to the EPA RI. Early UNC reports present maps and results from samples and data collected at these well locations. The EPA's August 1988 UNC Draft Final Remedial Investigation Report Figure ES-1, Site Location Map, presents the locations of the early 400 and 600 series wells. Some of these early wells still exist at the UNC Site in 2013. In addition to the wells required as part of remedy implementation of the 1988 ROD, many wells have been installed at the UNC Site under various authorities.

Zone 3

In accordance with the 1988 ROD and implementation of the remedy, the purpose of the Zone 3 extraction well system was to create a hydraulic barrier to control further contaminant migration toward the north and to dewater the target area. The location of the Zone 3 extraction wells and the target area for remediation are shown on Figure 4. The volume that the well system would have to pump to dewater the target area identified in the remedial design was originally estimated at 200 million gallons.

The extraction well system for this target area consisted of the five existing Northeast Pump-Back wells originally installed under NMEID direction, as well as an additional twelve Stage I wells and seven Stage II wells located down-gradient of the pump-back wells (Figure 4). The Northeast Pump-Back wells began operating in 1982 and were incorporated into the extraction well system by the NRC and the EPA, after the return of the UMTRCA regulatory program from NMEID to the NRC in 1986. The Stage I wells began operating in 1989. The Northeast Pump-Back wells are designated with the "600" series of numbering and began extraction of contaminated water in 1983. The Stage I wells are designated with the "700" series of numbering.

In 1991, after ground water recovery rates from the pump-back and Stage I wells began to decline; the Stage II wells were added. The Stage II wells were expected to enhance system performance as predicted saturation declines reduced the productivity of the Stage I and Northeast Pump-Back extraction wells. The Stage II wells were also designated with the “700” series of numbering.

The well system design included decommissioning criteria that allows shutdown of individual wells, or the system, if the efficiency of the wells declines so much that continued operation provides no benefit. Wells that provide “no benefit” are defined as wells that do not produce a minimum yield of 1.0 gpm. Under the design provisions, wells that produce less than 1.0 gpm were to be cleaned and stimulated, and if the wells still did not produce 1.0 gpm then they were to be decommissioned.

The Northeast Pump-Back wells and Stage I wells met the decommissioning criteria and were shut down in 2000. The Stage II wells were determined to be accelerating the movement of Tailings seepage in the down-gradient direction and, therefore, were also shut down in 2000, with the approval of the EPA, the NMED, and the NRC. Approximately 162 million gallons of ground water had been extracted prior to system shut down.

In June 2002, a series of four “Plume Boundary” performance monitoring wells were installed along a south-north line in the area of the nose of the Zone 3 plume (Figure 4). These wells were installed to monitor the position, approximate arrival time, and resulting water quality impact of the tailings seepage as it slowly moved north. Well PB-02 was converted to an extraction well in November 2005.

With the shutdown of the Stage II extraction wells in 2000, active remediation of the Zone 3 ground water seepage-impacted area ceased until 2003. At that time UNC initiated the pilot-scale hydraulic fracturing test in Zone 3 to explore the possibility of enhancing permeability in order to improve ground water extraction efficiency. The pilot test was conducted in 2003 to determine the applicability of the technology to the UNC Site. A hydraulic fracture well (HF-3) was installed and fractured in an area northwest and outside of the Zone 3 plume (MACTEC, 2004). After pre- and post-aquifer pumping and falling head tests at HF-3, the technology was judged to be feasible, and it was decided to proceed with Phase I full scale hydraulic fracturing at locations within the Zone 3 plume. This work began in 2004 with the following goals: 1) providing hydraulic containment of the leading edge of the tailings seepage plume, 2) allowing the formation’s remaining buffering capacity to attenuate the tailings seepage, and 3) initiating dewatering in the main body of the seepage-impacted area.

Seven Phase I recovery wells were successfully installed and hydrofractured in two areas: one in the southern part of the plume (RW-15, RW-16, and RW-17); and one in the northern area of the plume (RW-11, RW-12, RW-13, and RW-14). The wells were subjected to the same hydraulic fracturing technology utilized at the pilot test well HF-3 location (MACTEC, 2006). Unfortunately, the Phase I hydrofractured recovery wells did not achieve the anticipated improvement in pumping efficiency as demonstrated earlier at the pilot test well HF-3 location. Since the seven wells were determined to be better positioned to capture seepage-impacted ground water, they continued to pump and extract ground water. The recovery wells are designated with the "RW-1" abbreviation and series numbering. The locations of the Phase I pumping wells are shown in Figure 4 and Figure B-1 in Appendix B of the UNC 2012 Annual Report.

The Phase I extraction system was reconfigured in 2007 by shutting off some wells, adding an additional extraction well (RW-A) at a new down-gradient location, and converting a down-gradient monitoring well (PB-02) into an extraction well. An additional 6.8 million gallons of ground water (for a cumulative total of 168.8 million gallons) was extracted from 2003 to 2007. Due to fouling and/or insufficient yield, RW-12, RW-13 and RW-15 have been taken off-line and are no longer pumping. As of the end of 2012, wells PB-02, RW-11, RW-16, RW-17, and RW-A were still operational. Ground water extraction with this revised pumping configuration for the RW series wells continues at the optimal rate possible in an effort to slow the northward migration of the Zone 3 tailings seepage.

In conjunction with the Zone 3 hydrofracturing effort, UNC also conducted an in-situ alkalinity stabilization pilot study from October 2006 to February 2007. The strategy of the pilot study involved injecting alkalinity-rich ground water into areas where seepage-impacted acidic conditions exist in Zone 3 using water from a non-impacted, deeper aquifer supply well (Mill Well) producing from the stratigraphically lower Westwater Canyon Member of the Morrison Formation. Conceptually, the injected water would flow through the Zone 3 formation to recovery wells where the water would be extracted for treatment and disposal. The pilot objective was for the alkaline rich water to contact and buffer the higher acidity of seepage water along a mixing front and, then the recovery wells would capture the neutralized, seepage-impacted ground water. It was anticipated that the increased pH of the seepage-impacted water would make it geochemically difficult for contaminants to remain in solution and migrate. The more alkaline pH ground water environment would subject contaminants to immobilization through chemical precipitation and mineral surface adsorption reactions.

The alkalinity pilot study well field array consisted of a centrally-located, single extraction well (EW-1) surrounded by four injection wells (IW-1, IW-2, IW-3, and IW-4). Outside of the extraction-injection well array were four additional extraction wells located and designed to provide overall hydraulic control during the study (0517, 0518, 0608, and EW-2). Newly installed and existing wells were utilized for the study (ARCADIS BBL, 2007). Unfortunately, during the study, observed injection and extraction rates were significantly lower than anticipated. Due to these low rates, UNC decided to core the entire thickness of the Zone 3 formation within the pilot study area for petrologic analysis. Well EW-1 was cored to provide sample number CDNEW-1 of the arkosic sandstone in Zone 3 (ARCADIS BBL, 2007). The analysis of this core, along with several historic Zone 3 cores, showed that the pore spaces between the sand grains in the saturated zone were clogged with finely crystalline kaolinite clay. Samples from the unsaturated zone and those from other historic cores did not contain the kaolinite. Based on these analyses, UNC concluded that buffering reactions between the feldspars and the acidic tailings seepage produce a secondary clay mineral, kaolinite. The alteration of feldspar to kaolinitic clay had significantly reduced the hydraulic conductivity of the formation by effectively clogging the pore spaces between the sand grains, and thus significantly limiting the potential for water to flow through the formation (ARCADIS BBL, 2007). UNC ultimately concluded that it would not be possible to effectively implement the in-situ alkalinity stabilization technology to enhance the Zone 3 remedy in the envisioned time of five years. The pilot study indicated it could take the proposed remedy enhancement 10 times longer to accomplish the remedy goals, which was as much as 50 years or more.

Despite the setbacks from the hydrofracturing and alkalinity injection efforts, five new extraction wells were installed in the northern part of Zone 3 south of the Section 36 boundary during September 2006 (NW-1, NW-2, NW-3, NW-4, and NW-5). Three of these new wells started pumping in February 2009: NW-1, NW-2, and NW-3. In November 2009, these wells were re-optimized into a new pumping scheme. Wells NW-1, NW-2, and NW-4 were active pumping wells, and NW-3 and NW-5 were taken off line because they drew background water from the northwest area of Zone 3 (Chester Engineers, 2009). Well NBL 2 that was installed in 2007 was subjected to injection testing and a pilot study in October and November 2009. The results of the 2009 testing and study supported the installation of yet another new array of extraction wells. In May and June 2010 three more new extraction wells were installed south of the Section 36 boundary in the northernmost part of the Zone 3 area (IW A, MW 6 and MW 7). In April 2011 alkalinity-amended Mill Well water with two grams of sodium bicarbonate per liter was mixed and injected at IW A. Wells MW 6 and MW 7 were used to monitor changes in water level and ground water quality.

As noted above during the 2008-2013 period, three of the seven Zone 3 RW wells were taken off line because they had fouled (RW-12, RW-13, and RW-15). Four RW extraction wells (RW-11, RW-16, RW-17, and RW-A) and one PB well (PB-02) were operational in 2012. The remedy enhancements in Zone 3 are meant to buffer, intercept, slow down, direct, and extract impacted ground water. The configuration and pumping scheme of the injection-extraction well arrays tries to minimize the withdrawal of background water and the tendency to draw it westward while maximizing the volume of impacted water that is extracted.

Table 7 presents a list of the Zone 3 performance monitoring wells at the UNC Site. As required by ARARs, on a quarterly basis in Zone 3, 23 wells are monitored for the depth in feet to the static water level (elevation) and 11 wells are sampled for laboratory analysis of a prescribed set of parameters. Appendix B, Zone 3 Monitoring Data, in the 2012 UNC Annual Report also provides a summary and history of monitoring and remediation activities for Zone 3. Figure 4 presents all the Zone 3 monitoring well locations and it is taken from Figure B-1 in the 2012

UNC Annual Report.

Zone 1

The remedial action in Zone 1 has consisted of source remediation (neutralization and later dewatering of Borrow Pit No. 2) and pumping a series of extraction wells from 1984 through 1999. Water elevation measurements are taken from 15 of the Zone 1 monitoring wells and water quality samples are collected from 8 wells. The locations of these features are shown on Figure 5 which is taken from Figure C-1 in the 2012 UNC Annual Report. Table 8 presents a list of the Zone 1 performance monitoring wells at the UNC Site. Appendix C, Zone 1 Monitoring Data, in the 2012 UNC Annual Report also provides a summary and history of monitoring and remediation activities for Zone 1.

The extraction wells were shut off and decommissioned in 1999, with the approval of the EPA, NMED, and NRC because pumping rates had significantly declined over time due to insufficient natural recharge and the loss in saturation reached levels that did not support operation. With the shut down and decommissioning of the extraction wells, active remediation of the Zone 1 ground water seepage-impacted area ceased. A total of 2.9 million gallons of ground water had been extracted when the system was decommissioned. In the 2010 SWSFS Part II report Section 4 (page 39), the estimated volume of remaining tailings seepage impact fluid in Zone 1 was 8,567,042 gallons in an area of 11 acres.

Southwest Alluvium

The remedial action for the SWA has consisted of four extraction wells (801, 802, 803 and 808) that were designed as a barrier/collection system in the target area. The system was located approximately 400 feet down-gradient from the southern edge of the South Cell of the tailings impoundment and up-gradient of the NRC's four Point of Compliance (POC) wells (EPA 28, GW-1, GW-2, 632) for the SWA. The locations of extraction wells and monitoring wells are shown on Figure 6.

The wells were designed to create a hydraulic barrier for controlling further migration of contaminated ground water while the source was being remediated. Source control was achieved by regrading and re-contouring the South Cell and installing a low-permeability soil cover. Water elevation measurements are taken from 17 of the SWA monitoring wells and water quality samples are collected from 15 wells. Six of the hydraulically up-gradient monitoring wells have gone dry. Down-gradient monitoring well SBL-01 was installed in October 2004 to better define the down-gradient limit of the seepage-impacted area. Table 9 presents a list of the SWA performance monitoring wells at the UNC Site. The 2012 UNC Annual Report also provides a summary and history of monitoring and remediation activities for the SWA. Figure 6 presents all the SWA monitoring well locations and it is taken from Figure A-1 in the 2012 UNC Annual Report

Active remediation of the SWA seepage-impacted area was temporarily discontinued in February 2001 to evaluate the ability of the contaminants to naturally attenuate (NA) in the aquifer. We refer to this evaluation as the NA Test.

Such testing was part of UNC's effort to evaluate the appropriateness of obtaining a Technical Impracticability (TI waiver) under the provisions of the National Contingency Plan, 40 CFR Part 300, for certain ARARs identified in the 1988 ROD. These ARARs are state standards for sulfate and Total Dissolve Solids (TDS). Concentrations of those contaminants had shown little change over time during operation of the extraction system. The TI waiver evaluation report, submitted by UNC in 2002, recommended a TI waiver for the sulfate and TDS standards. It will be considered during performance of the SWSFS and future EPA decision-making. In the interim, UNC has been allowed to leave the extraction wells shut off. A total of approximately 131.1 million gallons of ground water had been extracted when the system was temporarily decommissioned in 2001. In the 2010 SWSFS Part II report Section 4 (page 39), the estimated volume of remaining tailings seepage impact fluid in the SWA was 170,022,900 gallons in an area of 67 acres.

Water Collection and Treatment

Ground water produced from all Site extraction wells is evaporated in two five-acre, evaporation ponds (Figure 2), and a spray evaporation system installed on the surface of the re-graded and covered tailings. An evaporation mist system constructed on the interior berm between the two evaporation ponds is available to enhance the disposal of the extracted water. Additionally, the UNC Site is equipped with 28 water cannons distributed across the surface of the regraded and covered tailings. The cannons were designed to spray water at a rate to optimize evaporation and prevent saturation of the tailings. Both the mist system and cannons are only to be used during the summer months. During the winter months, a small amount of water accumulates in the evaporation ponds from winter precipitation. It has not been necessary to operate the evaporation mist system or the water cannons since 2001 when the rate of ground water extraction declined significantly. These systems remain in good repair should they be needed again.

Based on observations and a study of water levels in the evaporation ponds in 2005 and 2007, no evidence of leakage has been observed. No evidence of leakage from the ponds was observed during the 2008-2012 time period (Larry Bush, 2013).

Remedy Implementation Summary

The remedial systems at the UNC Site were implemented as directed by the 1988 ROD and have operated as intended for a period of time. As areas have been dewatered, extraction well efficiency declined and the wells were decommissioned in accordance with decommissioning criteria set forth in the 1988 ROD. In 2013, four out of the six components specified in the 1988 ROD are inactive (Nos. 2; 3; 4; and 5), and two of the components are active (No. 1 and 6). The tailings seepage mound has dissipated (U.S. Filter, 2004). The effort to restore ground water quality outside the Tailings Disposal Area to various standards, criteria, and background levels appears to have reached the maximum extent practicable within a reasonable time frame. Operational results from the performance monitoring program indicate a significant reduction in the saturated thickness of the aquifer units which severely limits the capacity to extract impacted ground water. Tables 10, 11, and 12 present the reduction in saturated thickness for the SWA, Zone 3, and Zone 1 monitoring wells, respectively, through 2012.

4.1.3 NRC-Lead Surface Reclamation and Source Control

The MOU between the EPA and the NRC clarified that the NRC would exercise its authority over surface reclamation and source control. The 1988 ROD stated that, "…Upon approval of a final reclamation plan, both ground water and source control/surface reclamation remedial actions will be integrated and coordinated to achieve comprehensive reclamation and remediation of the UNC Site" (1988 ROD, p. 41). The following section provides a background for the source control portion of the remedy, which falls under the purview of NRC's License.

Source Control

The source control measures include regrading and recontouring the tailings, placing a low permeability compacted soil cover over the regraded tailings, and constructing drainage swales on and around the reclaimed impoundments. The cover consists of an initial interim cover of compacted soil, followed by the final cover of compacted soil and rock as a radon barrier and for erosion protection. The source control measures were designed primarily to effectively minimize infiltration, seepage, and mobilization of contaminants from the tailings (EPA, 1998).

Reclamation of the South Cell occurred between 1991 and 1996 and included regrading and recontouring of the tailings and placement of the interim and final covers over those portions of the South Cell not occupied by the evaporation ponds. The interim cover comprised 12 inches of compacted soil with average permeability measurements of $3x10^{-8}$ centimeters per second (cm/sec). The final radon cover comprises an additional six inches of compacted soil and a six-inch soil/rock matrix layer for erosion protection. The area of the South Cell occupied by the evaporation ponds will be reclaimed after the ground water remediation is complete and the evaporation ponds are no longer needed (EPA, 1998).

The remediation of the North Cell began in 1989 and consisted of regrading and recontouring of the tailings area and placement of twelve inches of compacted soil as the interim cover. Similar to the South Cell, the interim cover eliminated direct contact of surface precipitation with tailings material and minimized future infiltration. Final reclamation of the North Cell was performed in 1993 and consisted of placing a radon cover consisting of an additional six inches of compacted soil and a six-inch soil/rock matrix layer for erosion protection. Drainage swales on the North Cell maximize surface drainage from the cover while controlling the velocity of surface runoff to prevent excessive erosion (EPA, 1998)

Reclamation of the Central Cell and Borrow Pit No. 2 occurred between 1989 and 1995. The work consisted of dewatering Borrow Pit No. 2, regrading and recontouring the tailings, backfilling the borrow pit with debris from mill decommissioning, and placement of the interim and final cover layers. For the Central Cell, the interim cover was completed in 1991 and the final radon cover was placed in 1994. The backfilling of Borrow Pit No. 2 occurred from 1991 to 1994. The placement of the interim and final covers was completed in 1994 and 1995, respectively (EPA, 1998).

The results of the *Emanation Testing of the Final Radon Cover over UNC's Church Rock Tailings ' Site* were reported to the NRC on January 3, 1997 (UNC, January 1997). The report documented the tests conducted on September 26, 1996. Sampling included the collection of 115 radon samples from the surface of the radon cover, and calculations determined an average radon flux for the tailings of 6.46 picocuries (pCi) per meter squared (m^2) per second (sec). All tailings areas with a radon cover have a radon flux less than the UNC Site License standard of 20 $pCi/m^2/sec$ with the exception of the South Cell in the vicinity of the evaporation ponds, where the radon barrier has not been installed yet. By radon flux we mean the flow of radon gas past a given point. Flux means flow.

The 1988 ROD did not formally establish any ICs; however certain enforcement documents, governmental controls, and informational controls are in place.

No proprietary controls establishing land use restrictions are in place. However, discussions with the Navajo Nation continue regarding their potential utility and effectiveness for Zone 3. It is likely that some form of land and/or ground water use control will become necessary to ensure long-term protectiveness, by preventing exposure to contaminated ground water that has migrated off-Site.

4.1.4 System Operations and Maintenance (O&M)

System Operations and O&M Requirements

Required operation and maintenance (O&M) activities at the UNC Site are stipulated in the NRC License. The O&M activities are also specified in a number of internal documents kept at the UNC Site. Ground water O&M is required under CERCLA by the 1988 ROD and UAO. The O&M activities include:

- Operation, maintenance, and monitoring of the ground water extraction wells and associated piping.

- Maintenance of the final radon barrier and interim covers on the tailings piles.
- Operation and maintenance of the evaporation ponds, misters, and cannons.
- Maintenance and sampling of ground water monitoring wells.
- Maintenance of fences and gates.

As discussed above, the operation of the extraction well systems for the SWA and Zone 1 aquifers has been discontinued. Ground water extraction continues at Zone 3 at several wells along the seepage impacted front. Apart from the low rate of extraction at Zone 3, only maintenance and monitoring activities for those systems are being performed at this time. Personnel are at the UNC Site daily during the week to perform O&M activities.

Problems with Implementing System Operations/O&M

Zone 3 extraction wells are operational but they require constant maintenance. Pumps fail and burn out on a regular basis. Clay coats the pump impellers requiring disassembly and cleaning to restore operational efficiency.

O&M Costs

The O&M costs are not stipulated in any of the decision documents for the UNC Site. The NRC License contains a condition requiring UNC to provide a financial surety to cover the cost to implement the remaining reclamation and closure activities. The EPA UAO also requires UNC to submit financial assurances to the EPA Region 6.

Current O&M costs are associated primarily with ongoing performance monitoring and ground water extraction at Zone 3. Ground water samples are collected quarterly from a total of 34 wells. The list of sample contaminants that are measured in the quarterly water samples by laboratory analysis is shown in Table 4. Ground water elevations are measured at 43 wells, also on a quarterly basis. Annual O&M costs are summarized in Table 13.

The annual system operations/O&M values shown in Table 13 are estimates that take into account O&M costs for both the ground water remediation and the NRC License compliance. These costs are closely interrelated and are tracked together. O&M costs were fairly constant during 2008-2010, but they increased significantly during 2011-2012 due to additional work to support an NRC License Amendment Request and compliance issues.

4.2 Surface Soil Operable Unit – OU2

4.2.1 Remedy Selection

On March 29, 2013, EPA, in consultation with the New Mexico Environment Department (NMED), signed the Record of Decision selecting the remedy for OU2 of the UNC Site. The surface soil OU2 does not currently exist at the UNC Site. The surface soil OU is planned for the disposal of approximately 1,000,000 cubic yards of uranium protore (low grade ore), waste rock, and overburden from the nearby NECR Mine site. The surface soil OU will be installed on top of the existing tailings disposal cells. Principal threat waste (PTW) from the NECR Site will not be disposed at the UNC Site and is not part of the OU2 remedial action. PTW is defined as material with radioactivity that exceeds 200 pCi/g Ra-226.

Because of the similarity of the threat posed by the mine waste in the areas on the NECR Site where mine waste has been deposited and consolidated (Consolidation Areas) and the threat posed by the tailings that make up the UNC Site Tailings Disposal Area, as well as the relative proximity of these facilities (less than 1 mile); the EPA invoked its authority under CERCLA Section 104(d)(4), 42 United States Code (U.S.C.) §9604(d)(4), to temporarily treat these related facilities (the NECR Site Consolidation Areas and the UNC Site Tailings Disposal Area) as one for the purposes of Section 104 of CERCLA, 42 U.S.C.§ 9604. Treatment of the UNC Site Tailings Disposal Area and the NECR Site Consolidation Areas as one begin with completion of the 2013 ROD, but this treatment is temporary and will end once all the NECR Site waste has been disposed at the UNC Site Tailings Disposal Area.

4.2.2 Remedy Implementation

The ROD for the surface soil OU2 was signed in March 2013, near the end of this FYR period. AOC negotiation for the surface soil OU2 is underway between the EPA and the UNC/GE. UNC/GE is concurrently preparing the Sampling and Analysis Plan required for the Remedial Design while negotiations are underway. Field work is planned for fall 2013 with analysis of data and completion of a Data Gap Report due winter 2014. The remedial design will be completed after all data has been collected and analyzed and submitted to the NRC via a license amendment (expected to occur in 2015).

Disposal of mine waste from the NECR Site within the surface soil OU2 at the UNC Site will require acceptance by the NRC and is contingent on an amendment of UNC's NRC license to allow for disposal. That license amendment process will begin when UNC submits for NRC review and evaluation a request for an amendment of its NRC license to accommodate disposal of mine waste from the NECR Site within the Tailings Disposal Area at the UNC Site. The NRC license amendment process takes between two and three years. Remedial action is expected to take at least four years upon NRC approval.

4.3 Remedial Action Objectives

The RAOs established in the 1988 ROD for OU1, included:

- Contain down-gradient contaminant migration within each target area.

- Restore ground water down-gradient of the Tailings Disposal Area, to the maximum extent practicable, to meet the cleanup criteria.
- Restore ground water at the Tailings Disposal Area to a level that allows attainment of cleanup criteria at its boundary.

The RAOs established in the 2013 ROD for OU2, included:

- Prevent exposure to current and future human and ecological receptors from internal/external radiation, ingestion, dermal contact, and inhalation (*i.e.*, inhalation of associated gas or dust) of soil, mine waste, and tailings contained within the surface soil OU2 containing concentrations of radionuclides and their daughter products that exceed remediation goals.
- Prevent migration [on-site and off-site into soil, sediment, ground water, air (as gas or dust), and surface water] of soil, mine waste, and tailings located within the surface soil OU2 containing concentrations of radionuclides and their daughter products such that exposure to current and future human and ecological receptors from internal/external radiation, ingestion, dermal contact, and inhalation (*i.e.*, inhalation of associated gas or dust) of soil, mine waste, and tailings does not exceed interim remediation goals.
- Prevent the migration of concentrations of contaminants located in the soil, mine waste, and tailings contained within the surface soil OU2 to ground water where the migration of those contaminants would result in ground water concentrations that exceed remediation goals established in the EPA's 1988 ROD for the Ground Water OU1 (including any amendment), and, through this action, prevent human and ecological receptors from being exposed to ground water with concentrations of contaminants that exceed remediation goals established in the 1988 ROD, including any amendment.

The RAOs pertinent to the surface soil OU2 action includes the construction (or reconstruction) of parts of the Tailings Disposal Area on the UNC Site to contain the mine waste from the NECR Site. Additionally, the license amendment, if granted by NRC, after its review and evaluation, would accommodate disposal of mine waste from the NECR Site within the Tailings Disposal Area at the UNC Site. Once all required actions are completed under the conditions of the NRC license and final decommissioning activities are completed for the UNC Site, and the NRC license is terminated, it is expected that there would be a transfer of this UMTRCA Title II site as established through the NRC site transfer process to the DOE Long-Term Surveillance and Maintenance Program (LTS&M) that is administered by the DOE Office of Legacy Management.

Under this DOE program, the UNC Site would be maintained and managed under the DOE to provide for continued containment and protectiveness. Prior to DOE's acceptance of this UMTRCA Title II site for long-term surveillance and maintenance a determination must be made by the NRC that the UNC Site is deemed ready for transfer to DOE without any outstanding technical, regulatory, or jurisdiction issues. In addition with input from DOE, that NRC identifies an appropriate long-term maintenance fee to enable DOE to effectively perform its LTS&M

duties, including any that are unique post-closure issues because of the mine waste.

5.0 PROGRESS SINCE THE LAST REVIEW

The Third FYR (2008) identified twelve issues that could prevent the remedy from being protective of human health and the environment, and provided recommendations to resolve the issues. The 2008 UNC FYR Issues and Recommendations are summarized in Attachment 7.

As nearly all of the issues/recommendations from the Third FYR were to be addressed in the SWSFS, this section addresses the status of each issue/recommendation at the end of this section. Additionally, this section addresses the overall progress made toward completing the SWSFS and some brief history leading to sections of the SWSFS. The section will also summarize other Site activities regarding the remedy during this FYR period which includes:

- SWSFS
- 95% Upper Prediction Limits (UPL95[6]) Background Threshold Values[7] (BTVs)
- Ground Water Flow Model
- Zone 3 Injection Program

5.1 Site Wide Supplemental Feasibility Study

The September 1988 ROD selected a remedy of extraction of contaminated ground water at the UNC Site. The 1988 ROD also included contingency language as there was uncertainty as to - whether the selected remedy could achieve the objectives of the 1988 ROD by removing contaminated ground water, controlling further contaminant migration, and restoring impacted ground water to compliance standards in a reasonable time frame at the UNC Site. As the extraction system pumping capacity for each of the three hydrostratigraphic zones diminished and all three systems were shut down by 2001, the remedy defaulted to performance monitoring of each aquifer’s capability to slowly and naturally attenuate Contaminants of Potential Concern (COPCs).

After almost 20 years of active Site remediation and passive remediation by NA processes, the 1988 ROD cleanup goals are still unattained. This issue was noted in the 2003 FYR, and UNC responded by performing a limited scope, Supplemental Feasibility Study (SFS) in 2004 which

[6] In statistics, the prediction interval is an estimate of an interval in which future observations will fall, with a certain probability, given what has already been observed. When we say an estimate has a 95% upper prediction limit, that means that we are 95% certain that our estimate of a future number will be no higher.
[7] The Background Threshold Value is an upper limit estimate of the background contaminant concentration (either naturally occurring or anthropogenic) used to represent environmental contaminants not specifically related to the site under investigation.

focused on Zone 3. The EPA reviewed the 2004 SFS and determined that a comprehensive SWSFS was necessary and in 2006 directed UNC to perform a SWSFS with a stated objective of evaluating possible remedial alternatives to meet Site remediation goals of the 1988 ROD. In addition to this requirement, the EPA further obligated UNC to include in the SWSFS a review of Site standards and if necessary a proposal for revised ARARS. The organization of the SWSFS became: Part I – Remediation Standards Update; Part II – Development and Screening of Remedial Alternatives, and Part III – Detailed Analysis of Remedial Alternatives.

Following the disapproval of a draft SWSFS in 2008, Part 1 of the SWSFS was approved by the EPA in 2009 (EPA letter from Mark Purcell to UNC-Larry Bush, February 11, 2009). In April 2011, UNC submitted a revised SWSFS including Part I (for use as a reference) and Part II. Part III was not included in the 2011 volume and had not been issued at the time of writing this fourth FYR report. Work on the SWSFS Part III has progressed to where revised cleanup standards are required in order to analyze which remedial alternatives would be able to restore ground water to those revised constituent standards. The NRC is currently evaluating a License Amendment Request dated April 17, 2012, and has issued a request for additional information on June 4, 2013, to UNC/GE.

Section 5.1 of this 2013 FYR report summarizes the key results from Parts I and II. For more detail, please refer to the April 2011 report, *Revised Site-Wide Supplemental Feasibility Study Parts I and II, Church Rock Site, Church Rock, New Mexico*.

5.1.1 SWSFS Part I – Remediation Standards Update

Part 1 of the SWSFS presented: a review of existing Site remediation/cleanup standards; new or revised, promulgated or enacted ARARs since the 1988 ROD; proposals to revise background ground water quality based on statistical methods; a summary of UNC's updated baseline HHRA; and potential land use or exposure scenario changes. This Section provides discussions on cleanup standards, changes to standards since issuance of the 1988 ROD and background ground water quality data. The HHRA and future land use and exposures are discussed in Section 5.1.3.

Cleanup Standards Review

The two sources of cleanup standards for ground water at the UNC Site are from the EPA 1988 ROD and the NRC Source Materials License SUA-1475 provided in Table 14. For clarification, in this Section, terms used regarding ground water remediation standards are as follows: cleanup standards is used broadly to identify any numerical standard that has been established for the UNC Site either through the 1988 ROD or the NRC license; ARARs and remediation goals are used interchangeably to specify the remediation standards established in the 1988 ROD; and GWPS are established through the NRC license. As previously noted, the EPA assumes primary authority for ground water outside of Section 2 where ARARs apply. NRC assumes primary authority within the licensed area, Section 2 and Section 36 containing the Tailings Disposal Area, and ground water below this area is subject to GWPS (Figure 3). Table 14 of this FYR provides both sets of cleanup standards with notes providing the source of the ARAR that was established in the 1988 ROD.

New, Revised, Promulgated or Enacted Standards since the 1988 ROD

The SWSFS Part 1 Section 3.5 presents a summary of cleanup levels and other comparison values and briefly addresses potential new ARARs based upon various current contaminant standards. The section also refers to *Table 15* of the SWSFS titled *Contaminant Specific Ground Water Cleanup Levels and Other Comparison Values*. *Table 15* of the SWSFS is provided in Attachment 8 of this report. For this FYR report, due to the limited discussion in Section 3.5 of the SWSFS and the complexity of *Table 15*, modified portions of *Table 15* from the SWSFS are presented and discussed in this and following subsections.

Many of the issues from the third FYR (2008) address the need to reconsider the ARARs in the 1988 ROD as many numerical standards from which the ARARs were established have changed since the issuance of the 1988 ROD (see Attachment 7, Issues, 3, 5, 6, and 7). When comparing 1988 ROD contaminant specific ground water ARARs to current ARARs: NMWQCC ground water standards, MCLGs, MCLs, Treatment Technology Action Levels (TTs), Federal Secondary Drinking Water Standards, NRC GWPS, and NRC 10 CFR Appendix A to Part 40-5C-Maximum Values for Ground-Water Protection; there are multiple analyte specific standards in the 1988 ROD that are greater than a current ARAR standard. These include aluminum, antimony, arsenic, beryllium, cadmium, iron, lead, manganese, nickel, thallium, vanadium, uranium, sulfate, nitrate, and TDS. When comparing the same sets of standards to the 1988 ROD ARARs, there are also instances where a concentration in the 1988 ROD is less than a current standard. These include barium, chromium, copper, and silver. Table 15 of this FYR provides the ARAR to current standards comparison and identifies current standards less than the 1988 ROD ARAR in light blue and current standards greater than a 1988 ROD ARAR in light green. The table also includes one contaminant and one contaminant group that were not included in the 1988 ROD ARARs where a ground water standard exists and may be considered a potential COC. These are lead-210 and TTHMs.

Background Water Quality

Background ground water at the UNC Site represents two conditions. As described in the 1988 ROD: "*The first condition refers to the quality of the ground water in the alluvium and the Upper Gallup Sandstone in the vicinity of the site prior to mine dewatering. The second condition refers to the quality of ground water in the same units after mine water discharge, but prior to tailings disposal.*" In general, background ground water at the UNC Site is mine water discharge that has not been impacted by seepage from the Tailings Disposal Area.

For many Site COCs, concentrations of COCs in background ground water concentrations were determined and established as ARARs in the 1988 ROD; however, the 1988 ROD also specified that if additional information became available suggesting differing COC background concentrations, an evaluation would be necessary to determine the impact on remedial actions in each aquifer. Following issuance of the 1988 ROD, UNC contested the background level ARARs for nitrate, sulfate, and TDS. In response and as the lead regulatory agency for the UNC Site, NRC conducted a statistical analysis of background ground water quality data and concluded that the ARARs for the contested constituents and manganese were too low; as the background levels used to establish the ARARs were not based on data representing spatial and temporal variations at the UNC Site (NRC, 1996).

Further leading to the statistical analyses of background ground water quality conducted as Part 1 of the SWSFS, beginning in 2000, UNC conducted multiple geochemical evaluations to define the conditions causing concentrations of manganese, sulfate and TDS to remain above remedial goals. Studies concluded that gypsum was a continuing source for sulfate which represented most of the TDS concentrations in background ground waters in all three hydrostratigraphic zones and that natural conditions would continue to cause these constituents to exist in ground waters above ARARs. It was also concluded that manganese exceedances were unrelated to seepage-impacted water and that the remedial goal was most likely not achievable and possibly not appropriate.

Following initial statistical analysis and geochemical studies conducted by UNC to support changes to ARARS based on background ground water quality (N.A. Water Systems, 2008f), the EPA instructed UNC to perform further statistical analysis using EPA's ProUCL software (N.A. Water Systems, 2008g). The statistical analysis was to be conducted for each hydrostratigraphic zone in order to: estimate the 95% upper confidence limit (UCL95[8]) for the means of background populations of COPC concentrations from samples determined to be representative of background ground water quality and compare the UCL95 background concentrations to pre-established comparison values to determine which remedial goals should be reconsidered as a result of the comparisons.

As indicated in the previous subsection, the ARARs in the 1988 ROD do not always match current standards. In order to compare the statistically based background ground water quality results to specific comparison values, comparison values had to be determined. The comparison values are concentrations of COCs that were selected by the EPA from established standards from various sources to include ARARs, MCLs, NMWQCC standards, health based standards and

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[8] In statistics, a confidence interval is used to indicate the reliability of an estimate. The interval has an upper and lower limit. The level of confidence of the confidence interval would indicate the probability that the confidence range is correct. When we say that an estimate has a 95% upper confidence limit or UCL this means that statistics show that this estimate will be correct 95% of the time.

NRC GWPS. Table 16 identifies the 1988 ROD ARAR comparison value selected for each COC and the source for the value with the selected values highlighted in grey. The table also provides the ARAR in the 1988 ROD. This information is also provided in Attachment 8, *Table 15* of the SWSFS.

Prior to conducting the statistical analyses, data sets had to be evaluated to determine which wells and data sets were representative of background water quality in each of the three hydrostratigraphic zones. Much of this evaluation was conducted by evaluating chemical signatures of seepage-impacted waters and waters considered to be background. Table 17 presents the hydrostratigraphic unit, associated wells, and the timeframe in which samples were collected from each well that were used in UCL95 statistical calculations for determining background ground water quality. Note that the variation in well background sample dates is designed to include data up through October 2007 exclusive of the time when the wells went dry or when sample results indicated the wells became impacted by tailings seepage**.** Figure 7 illustrates the process used to develop and analyze the background water quality data for the UCL95 statistics. For further review of well and data selection for determination of background water quality, please see the February 2006 *Revised license amendment request for changing the GWPS for radium in Source Materials License SUA-1475 (TAC LU0092)*, the October 2008 *Revised Submittal Calculation of Background Statistics with Comparison Values UNC Church Rock Mill & Tailings Site, Church Rock, New Mexico*, and Part 1 of the SWSFS which summarizes information from these documents.

Once the UNC Site background ground water data sets were established, the data sets were subjected to the UCL95 analysis to estimate the mean background concentration value for each analyte and unit. The estimated background concentrations from the UCL95 statistics were then evaluated against the comparison values in Table 18. The ProUCL results indicate that a significant number of background UCL95 mean COPC concentrations for each hydrostratigraphic unit are greater than the comparison values. This means that the 1988 ROD cleanup standards for some COPCs were set lower than the natural background levels for these constituents and they should be considered for revision. The UCL95 values greater than the comparison value within each hydrostratigraphic unit are:

- Southwest Alluvium (8 analytes): Cd, Co, Mn, SO4, NO3, U, TDS, and Pb-210;
- Zone 1 (7 analytes): Cd, Co, Mn, SO4, TDS, Pb-210, and Fe; and
- Zone 3 (12 analytes): As, Cd, Co, Pb, Mn, Mo, SO4, U, TDS, Radium total, Pb-210, and Fe. The detection limit for lead does not get down to the MCL of 15 ug/L and therefore should not be considered greater than the comparison value. Future sampling should include a detection limit below the MCL.

Table 18 summarizes the statistical results for each of the three hydrostratigraphic zones and the background UCL95 mean values calculated for each of the 32 contaminants. Where the background UCL95 mean value is equal to or exceeds the EPA selected comparison value, the cell is marked in light red highlight (total 27). Cells highlighted with yellow indicate the UCL95 statistics are unreliable because of a limited number of detections (total 6).

By extension the process used to estimate the Exposure Point Concentration[9] (EPC) values for COPCs in each hydrostratigraphic unit was the same as the UCL95 background statistics except the data sets for seepage-impacted water were used instead of the background data sets. The data sets used in calculations made for the determination of EPCs are from the period July 2006 through April 2008 which represented the most recent eight quarters of sampling available at the time of the calculations. This time frame was selected to be representative of recent conditions, while providing at least the minimum recommended number of samples to satisfy the requirements of the statistical methods. For this reason, the estimation of UCL95 statistics and EPCs extend only to the current 23 COPCs and did not include trace metals (plus iron) that had previously been dismissed as COPCs.

The three hydrostratigraphic zones by which sample data were grouped are the SWA, Zone 1, and Zone 3. The geographic grouping resulted in the elimination from Zone 1 and Zone 3 data sets of sample data from wells within Section 2 of Township 16 North, Range 16 West. This discrimination of Section 2 data was based on two considerations. One consideration is that Section 2 encompasses the Tailings Disposal Area, which will eventually be administered by the DOE. As such, ground water exposure within Section 2 will be prohibited by DOE controls. The second consideration is that the more extreme effects of seepage impact evident in Zone 1 and Zone 3 wells proximal to the tailings disposal cells are not expected to migrate and occupy areas outside of Section 2. Wells selected in the SWA had to include some located in Section 2 so that a statistically meaningful data set could be developed.

The resultant UCL95 statistics for seepage-impacted water as EPCs are summarized in Table 19 for all three of the hydrostratigraphic units. Table 19 indicates that 14 EPC values were calculated for the SWA; 16 EPC values were calculated for Zone 1; and 22 EPC values were calculate for Zone 3 (total 52). The EPC values were compared to the comparison values and the background UCL95 values. Where the EPC value is equal to or exceeds the UCL95 background value, that cell value is marked in light blue (total 28). Where the EPC value is equal to or exceeds the UCL95 background value and comparison value, that cell is marked in light blue with bold italic font (total 17). Again where the UCL95 background value exceeds the comparison value, that cell value is marked in light red highlight (total 26). Cells highlighted with yellow indicate the UCL95 statistics are unreliable because of the limited number of detections (total 4). Note that the trace metals (Sb, Ba, Cr, Cu, Fe, Hg, Ag, Tl, and Zn) statistics are not included in the tabulations.

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[9] Exposure point concentrations are the concentrations of contaminants at the place where target exposure occurs. The targets include humans, flora and fauna.

A total of 28 EPC values are greater than the comparison values as marked by the light blue highlighted cells. The exceedances of EPC values greater than the comparison values within each hydrostratigraphic unit are as follows.

1. Southwest Alluvium (6 parameters): As, Mn, Cl, SO4, U, and TDS;
2. Zone 1 (8 parameters): Al, As, Co, Cl, SO4, NO3, TDS, and Th-230;
3. Zone 3 (14 parameters): Al, As, Co, Mn, Ni, Cl, SO4, NO3, U, TDS, Ra-226, Ra-228, Ra total, Pb-210, and gross alpha.

A limited number of EPC values exceed both the comparison value and the background UCL95 value as marked in the light blue cells with italicized, bold font. The exceedances of EPC values greater than the comparison values and background UCL95 value within each hydrostratigraphic unit are as follows.

1. Southwest Alluvium (4 parameters): Mn, SO4, U, and TDS;
2. Zone 1 (4 parameters): Co, SO4, NO3, and TDS;
3. Zone 3 (9 parameters): Al, As, Co, Mn, Ni, SO4, TDS, Ra total, and Pb-210.

A large number of the primary COPCs had insufficient data to make an estimate for the UCL95 statistics EPC values and are marked with "N/A" in the cell (SWA = 9 N/As; Zone 1 = 7 N/As, and Zone 3 = 1 N/As).

Also, UCL95 statistics EPC values could not be estimated for any of the nine trace metals (Sb, Ba, Cr, Cu, Fe, Hg, Ag, Tl, Zn) not included among the analytes in the past eight quarters of sample results. The COPC seepage-impacted data sets that had insufficient data to make an estimate for the UCL95 EPC values within each hydrostratigraphic unit are as follows:

1. Southwest Alluvium (9 parameters): Be, Cd, Co, Pb, Mo, Ni, Se, V, and Pb-210;
2. Zone 1 (7 parameters): Be, Cd, Pb, Mo, Se, V, and Pb-210;
3. Zone 3 (1 parameter): Pb.

5.1.2 SWSFS Part II - Development and Screening of Alternatives

Part II of the SWSFS applied the screening of remedial alternatives against the various site contaminant-specific ground water cleanup levels and other comparison values, including promulgated standards. The categories in Table 17 can be viewed as Preliminary Remediation Goals (PRGs) for present purposes. The range of parameter concentration values were applied to the screening and detailed analysis of the SWSFS Part II.

The extent of tailings seepage impact in each of the site hydrostratigraphic units during October 2010 is approximate to the areas depicted in Figure 3 of this report which represents the extent of tailings seepage in October 2012. The area and volume of seepage-impacted ground water in each hydrostratigraphic unit are: SWA = 67 acres and 170,022,900 gallons; Zone 1 = 11 acres and 8,567,042 gallons; and Zone 3 = 62 acres and 14,418,720 gallons. The volumes of seepage-impacted ground water have been calculated integrating the saturated thickness over the entire impacted area to obtain the saturated volume, and then adjusting the saturated volume for the effective porosity which is 31%, 6%, and 8% in the SWA, Zone 1, and Zone 3, respectively.

The process to screen and analyze the remedial alternatives against the PRGs includes the development of General Response Actions (GRAs). Attachment 10 of this report (Table 33 of the SWSFS Part II) presents a preliminary list 10 GRAs that were selected to satisfy the RAOs.

Each GRA category was expanded to include a list of potentially applicable technologies and technology process options, corresponding to the identified GRAs. The technologies were compiled and then reduced by evaluating the process options according to technical implementability. Existing information on technologies utilized at analog sites and site specific characterization data were used to screen out process options that cannot be effectively implemented at the UNC Site. It is important to note that because each of the three hydrostratigraphic units at the UNC Site has different physical, hydraulic, and chemical characteristics, the screening analysis had to apply each alternative separately to each unit. Other considerations in the screening analysis included the character of the background water quality and the already as low as reasonably achievable (ALARA) concentration levels of some COPCs such as sulfate, TDS, nitrate, manganese, and iron. Generally, effectiveness, implementability, and cost are the main criteria used to evaluate and select representative process options. During the screening process, each alternative was evaluated with regard to:

- Short- and long-term effectiveness and reductions achieved in toxicity, mobility, or volume.
- Implementability including technical and administrative feasibility.
- Grossly disproportionate cost (EPA, 1989b, 2000a)

Eight potential remedial alternatives were proposed for the SWA:

- No Further Actions
- Enhanced Extraction-Evaporation
- Hydraulic Containment Using Vertical Pumping Wells
- Passive Treatment Wells
- Vertical Physical Barrier
- Hydraulic Barrier from Injection Wells
- Permeable Reactive Barriers
- Hydraulic Flushing

The screening evaluation of alternatives for the SWA determined that enhanced extraction-evaporation; vertical physical barriers; hydraulic barriers from injection wells; permeable reactive barriers; and hydraulic flushing were screened out. The three remedial alternatives for the SWA that would be evaluated in Part III were no further action, hydraulic containment using vertical pumping wells, and passive treatment wells.

Four potential remedial alternatives were proposed for Zone 1:

- No Further Action
- Institutional Control
- Hydraulic Containment with Extraction and Evaporation
- Enhanced Extraction

The screening evaluation of potential alternatives for Zone 1 determined that hydraulic containment with extraction and evaporation and enhanced extraction were screened out. The two remedial alternatives for Zone 1 that would be evaluated in Part III were no further action and ICs.

Six potential remedial alternatives were proposed for Zone 3:

- No Further Action
- ICs
- Passive Treatment Wells
- Hydraulic Containment with Extraction and Evaporation
- Enhanced Extraction
- Hydraulic Barrier from Injection Wells for Containment

The screening evaluation of alternatives for Zone 3 determined that enhanced extraction was screened out.

Attachment 10 of this report (Table 40 of the SWSFS Part II) presents the combined remedial technology alternatives for each hydrostratigraphic unit that resulted from the screening analysis. Appendix G in the SWSFS Part II presents the cost estimates that were used to support the screening process. Attachment 9 of this report (Appendix G of the SWSFS Part II) presents a summary of the remedial alternative preliminary cost estimates. Based on the screening analysis to implement the potential technologies and alternatives at the UNC Site in conjunction with the cost estimate information, four GRA categories were eliminated from further analysis: enhanced evaporation, permeable reactive barriers, hydraulic flushing, and bioremediation. The six GRA categories that were retained for more detailed analysis in the SWSFS Part III for each hydrostratigraphic unit include: no further action, ICs, containment, extraction, passive treatment wells, and hydraulic barriers.

5.1.3 Updated Risk Assessment

The EPA FS conducted prior to the 1988 ROD presented a PHA for the UNC Site which concluded that adverse health or environmental hazards could result if no action was taken to prevent exposure to ground water contaminants at the UNC Site. As part of the SWSFS, the EPA required that the baseline HHRA be updated by: 1) update the risk estimates for the UNC Site using current risk assessment methods and information; 2) support the reassessment of remediation levels; 3) provide a basis for comparing remedial alternatives.

This section summarizes the results of the revised Site HHRA, including the risk calculations, the evaluation of uncertainty, and conclusions regarding which risk assessment COPCs should be retained (i.e., retained contaminants of potential concern or RCOPCs) for use in future risk management decisions. UNC submitted an updated baseline HHRA in March 2011 and the EPA provided comments July 2011. UNC provided provisional responses to EPA comments in October 2011 and a revised draft baseline HHRA in February 2012. The August 12, 2012, Final Updated Baseline HHRA was approved by the EPA on September 11, 2012.

Hazard and Risk Summary

There is no current human exposure to ground water at the UNC Site except during the quarterly ground water sampling conducted by UNC personnel. There is limited potential for future exposure to contaminants in ground water below the UNC-owned property because no ground water supply wells drawing from any of the three hydrostratigraphic units will be allowed on UNC property. The same restriction will apply once the NRC Source Materials License is transferred to the DOE for long-term surveillance monitoring.

The UNC Mill Site HHRA evaluated the potential future exposure to seepage-impacted ground water contaminants in each of the three hydrostratigraphic units at locations outside Sections 2 and 36. A residential tapwater (i.e., ground water) exposure scenario was selected. Because the hydrogeologic characteristics, contaminants, and remedial alternatives for each of the units are distinct, the risks of potential future exposure to ground water from the three hydrostratigraphic units were:

- SWA – a hypothetical future well located adjacent to the UNC property boundary in Section 3 or 10;
- Zone 1 – a hypothetical future well located adjacent to the UNC property boundary in Section 1; and
- Zone 3 – a hypothetical future well located to the north of, and adjacent to, the UNC property boundary in Section 36 inside the Navajo Nation.

The residential tapwater exposure scenario is based on the assumption that residents would construct homes, live adjacent to the UNC property boundary near the tailings impoundments for up to 30 years, and that residents would use seepage-impacted ground water for all domestic water needs. To assess the potential exposure of hypothetical future residents, three exposure pathways were selected for evaluation:

- Ingestion of ground water as the drinking water source;
- Direct dermal contact with ground water through bathing; and
- Inhalation of volatile compounds in ground water through showering exposure and, for radionuclides, through other domestic tapwater uses.

Attachment 9 provides summary tables of the risk assessment results for all detected COPCs (including the screening process, calculated hazards and risk, and RCOPC selection), as well as comparison values for background concentrations and potential ARARs (described further below).

The updated HHRA indicates that there is significant total non-carcinogenic hazard and total risk associated with a hypothetical residential exposure scenario in each of the hydrostratigraphic units and that the highest hazard and risks are associated with Zone 3 ground water. These calculated values reflect the combined risk of exposure to seepage-impacted water from the tailing cells and non-seepage-impacted background ground water from the mine discharge water because a portion of the risk can be attributed to background COPC concentrations. The HHRA looked at both sources of anthropogenic water because both contain potential future risk to exposure of contaminants that are common in both anthropogenic waters.

Total non-carcinogenic Hazard Index (HI) values exceed 1 in each of the hydrostratigraphic units. If an HI value is greater than 1, there is a possibility that a non-cancer health effect may occur. The ingestion exposure pathway is the most important for non-carcinogenic hazards, where total hazards exceed 1 for each of the hydrostratigraphic units. For the dermal exposure pathway, the total HI values exceed 1 for the SWA and Zone 3. The inhalation exposure pathway is not important with respect to non-carcinogenic hazard for any of the hydrostratigraphic units; chloroform, which is the only volatile COPC which has non-carcinogenic health effects, is present in seepage-impacted ground water only at very low concentrations, most frequently at locations immediately adjacent to the tailings impoundment. The hazard associated with the ingestion exposure scenario in background ground water for Zone 3 exceeds that of the seepage-impacted water from the tailings cells. Specific target organs that may be impacted by exposure to Site contaminants are listed below and summarized as follows:

- SWA – The HIs based on central nervous system effects are 8.7 for the child and 3.6 for the adult, due to the ingestion of, and dermal contact with, manganese in ground water.

Segregated HIs for kidney effects are 2.7 for the future resident child and 1.2 for the future resident adult (due mostly to uranium ingestion) and the HI for thyroid effects is 2.1 for the child (due mostly to cobalt ingestion). Hazard indices for other specific organs or targets are less than one.

- Zone 1 – Several segregated total HIs exceed one for target organs or toxicological effect. The HIs based on thyroid effects are 11.9 for the child and 5.1 for the adult (due mostly to the ingestion of cobalt in ground water). Segregated HIs for the central nervous system are 6.1 for the child and 2.5 for the adult (due to manganese), and for the metabolic system are 2.6 for the child and 1.1 for the adult (due to vanadium). Hazard indices for other specific organs or targets are less than one.

- Zone 3 – The segregated HIs based on thyroid effects are 94.2 for the child and 40.3 for the adult, due mostly to the ingestion of cobalt in ground water. Segregated HIs for skin toxicity are 88.4 for the child and 37.8 for the adult (due to arsenic). Segregated HIs for the central nervous system are 36.3 for the child and 15.1 for the adult, and for the kidney are 9.5 for the child and 4.9 for the adult (primarily due to molybdenum). For the child receptor, the HI for gastrointestinal system effects is 1.3 (due to beryllium) and the HI for reduced body and organ weights is 1.6 (due to nickel) for the child receptor. The segregated HIs for the metabolic system (as indicated by decreased hair cystine) are 2.3 for the child and 1.0 for the adult, due to the vanadium ingestion. Hazard indices for the liver, for both the adult and the child, are less than one. Additionally, the HIs for gastrointestinal system effects and reduced body and organ weights are less than one for the adult receptor.

The updated HHRA indicates that total cancer risk exceeds the EPA's target risk range of 1E-04 to 1E-06 for each of the hydrostratigraphic units. The COCs associated with these risks are as follows:

- SWA – The total carcinogenic risk is 5.0E-04. The chemical carcinogenic risk is 6.2E-05, due primarily to ingestion of arsenic. Radionuclide carcinogenic risk is 4.4E-04, due primarily to radium-226 inhalation and uranium (combined isotopes) ingestion.

- Zone 1 – The total carcinogenic risk is 1.4E-03. The chemical carcinogenic risk is 3.4E-05, due primarily to arsenic ingestion. The radionuclide carcinogenic risk is 1.4E-03, due primarily to radium-226 inhalation.

- Zone 3 – The total carcinogenic risk is 2.2E-02. The chemical carcinogenic risk is 9.3E-03, due primarily to arsenic ingestion. The radionuclide carcinogenic risk is 1.3E-02, due primarily to radium-226 inhalation. The cancer risk due to radium-228 (3.5E-04) is also higher than the EPA's target risk range of 1E-04 to 1E-06.

Background carcinogenic risks were also identified during the HHRA. The background UCL95s for arsenic in the SWA and Zone 1 are similar to the impacted water EPCs in these hydrostratigraphic units; therefore, the associated risks would be similar. Radium-226 and/or radium-228 activities in background water exceed those in seepage-impacted water for the inhalation exposure pathways for the SWA and Zone 1; consequently, the total background carcinogenic risk in the SWA and Zone 1 would be higher than that associated with seepage-impacted water in these hydrostratigraphic units.

There are questions on how the results of the HHRA may be applied due to the following factors:

- Some background hazards or risks either exceed or represent a large portion of the impacted water hazard or risk.
- Background water quality is not considered suitable for use as a primary drinking water source (e.g., due to sulfate and other chemicals that affect potability).
- Toxicity numbers (particularly for non-radionuclides) are typically conservative due to the incorporation of uncertainty factors and modifying factors. Furthermore, summations of total hazards and total risks may or may not be appropriate.
- Toxicity values can also under estimate toxic effects on sensitive subpopulations, such as groups of individuals with pre-existing diseases that may be less able to prevent or eliminate the effects of a contaminant due to weakened natural defenses or detoxification mechanisms. It is possible that Navajo Nation residents with kidney disease could be considered a sensitive subpopulation to contaminants that exhibit kidney toxicity, in the unlikely event that they would be exposed to seepage-impacted ground water. However, background concentrations of some of these contaminants exceed those in seepage-impacted water (e.g., Zone 3 for uranium, molybdenum, and cadmium).
- Inhalation risks may be overestimated for the following reasons:
    - The model for inhalation risk to radium-226 may not be appropriate because radium-226 is not volatile. The evaluation of exposure to the radium-226 decay product radon-222 might be more appropriate, but measurements of radon in ground water are not available. Furthermore, the use of the Andelman volatilization factor may be overly conservative for radium-226; a U.S. Geological Survey report (Lindsey and Ator, 1996) indicates that the typical transfer of radon from well water to residential air is 20 percent of that represented by the Andelman factor.
    - Inhalation exposure concentrations may be lower than estimated, because many local residents don’t have running water in their homes and the models used to approximate RME intake may be inappropriate. However, some local residents may also haul water from local wells and exposure factors for this potential exposure scenario have not been identified.

- Hazards and risks may be underestimated based on usage of the following exposure factors:
    - A 30-year exposure duration may be low with respect to a local resident population;
    - A drinking water ingestion rate of two liters per day may be low with respect to a local population residing in a semi-arid environment;
    - The assumption of a 350-day exposure frequency could be slightly low for the local population, but is bounded at 365 days.
- There is insufficient water available in Zone 1 for use as a potable water source for the exposure duration evaluated in the HHRA.
- Downgradient seepage impacts have been, and are expected to continue to be, limited by NA in all three hydrostratigraphic units.
- Assumptions that certain radionuclide decay products are at secular equilibrium with their parent nuclides.
- Assumption that uranium isotopes are present in proportion to natural abundance.

In summary, for the Reasonable Maximum Exposure (RME) individual that meets assumptions made in this assessment with the established uncertainties, there is a potential for human health risks that exceed the criteria established by the EPA for remedial action to be conducted.

Reassessment of Remediation Levels and Basis for Comparison of Alternatives

The HHRA risk and hazard calculations are made for the purpose of identifying the "baseline" risk associated with COPC exposure, independent of ARARs and NMWQCC ground water cleanup criteria. The results of this risk assessment, together with background risk information and data from the three hydrostratigraphic units at the UNC Site, can be used to support the reassessment of remediation levels within the SWSFS and provide a basis for comparing remedial alternatives.

Consistent with the EPA risk assessment guidance regarding background concentrations (EPA, 2002), COPCs that are present in both impacted and background ground water have been carried through the quantitative risk assessment calculations of the seepage-impacted ground water. Therefore, some of the resulting non-carcinogenic hazard and carcinogenic risk estimates are attributable to the hazards and risk associated with background concentrations. And, background concentrations should be considered in any future reassessment of Site remediation cleanup levels. Considerations may include the following:

- Where background concentrations exceed ARARs, background concentrations may be selected as remediation levels.
- Where background COPC concentrations exceed COPC concentrations in seepage-impacted water, COPCs may be eliminated from further consideration of remedial alternatives.
- Where background water hazards or risks exceed the EPA target levels, it may be more effective and appropriate to implement remediation alternatives that restrict exposure to contaminated ground water as compared to the existing 1988 ROD ground water remedy.

RCOPCs were identified using a two-step process. First, RCOPCs were identified using the following criteria:

- Those COPCs which contribute at least 1E-06 cancer risk to an exposure scenario (i.e., total risk) that exceeds the EPA's target risk range of 1E-04 to 1E-06; or
- Those COPCs contributing an HQ of at least 0.1 to an HI (i.e., segregated total HI) of 1 for non-cancer effects.

The second step was to compare RCOPC concentrations for each of the hydrostratigraphic units against the corresponding background concentrations and background risks. Attachment 9 (Updated Baseline HHRA Final Table 7) summarizes the selected RCOPCs and the rationale used to select them. Table 8 from the Baseline HHRA provides a more complete evaluation of the data and reasons for carrying forward COC's (Attachment 9).

These RCOPCs may require consideration for remedial action in the SWSFS and in future risk management decisions. The SWSFS, which is currently underway, will consider the complicated nature of overlapping human health risks and hazards associated with seepage-impacted and background water. This information will be used to support any future EPA CERCLA decision-making regarding remedy modification and, if necessary and appropriate, provide a basis for potentially waiving ARARs due to technical impracticability (TI), consistent with the NCP and EPA TI waiver guidance.

Attachment 10 includes a table prepared in response to an EPA comment on the original draft of the HHRA, and provides a summary of the following COPC risk assessment and ARAR information for each hydrostratigraphic unit:

- The results of the initial HHRA screening process for detected COPCs;
- Risk and hazard values from Appendix A tables;

- The RCOPC determination from Table 7 (HHRA); and Table 8 from the Baseline HHRA provides a more complete evaluation of the data and reasons for carrying forward COC's (Attachment 9).
- Comparison of the seepage-impacted EPCs (UCL95) for each COPC and hydrostratigraphic unit with (a) the corresponding calculated background UCL95 concentration and (b) the potentially applicable ARAR (e.g., the MCL, NRC License Compliance Standard, or NMWQCC Standard).

This table is provided here for reference; however, the information provided in the table will be analyzed and used in the pending SWSFS.

5.1.4 Part III SWSFS – Detailed Analysis of Alternatives

In July 2009, UNC submitted to the EPA the revised Part II of the SWSFS (Chester Engineers, 2009b), which addressed the development and screening of remedial alternatives. Based upon a series of comments and responses (EPA, 2010; and Chester Engineers, 2010c), UNC submitted the Revised SWSFS Parts I and II in April 2011 (Chester Engineers, 2011b), for which the EPA provided additional comments (EPA, 2011b; 2012b) as provided in Table 20. On October 14, 2011, the EPA determined that the Revised SWSFS Parts I and II (April 2011) was complete provided that the comments on the revised SWSFS Part I and II (which included comments from NMED, NRC, Navajo Nation EPA, and DOE) were addressed in the SWSFS Part III. In the October 2011, letter, the EPA provided UNC with a Notice to Proceed with development of the SWSFS Part III. The EPA comments (26 each) on Part I and II will have to be included and addressed in Part III (see Table 20). In November 2011, UNC provided a written response to the EPA comments with a request for further discussion on each comment by conference call. On December 7, 2011, a conference call between the EPA, UNC, NMED, NNEPA, and NRC was held to discuss the SWSFS Part I and II comments. The conference call discussed/resolved some of the comments and the SWSFS Part III will present information to address or describe how the comment was addressed. UNC is presently continuing work on the SWSFS Part III, but work is temporarily suspended until the EPA accepts the proposed revisions to the BTVs, and NRC approves the License Amendment request for revised Site GWPS to the newly calculated BTVs.

5.2 Development of UPL95 Statistics for Background Water

As previously stated, ground water remediation is conducted under two authorities, CERCLA and the 1988 ROD, and the NRC License. While this section primarily pertains to remedial requirements of the UNC License, there are implications for decisions regarding CERCLA.

The UNC Site background data sets also support estimates of the BTVs which represent values in the upper tail of the background data distribution (e.g., 95% upper percentile) or UPL95. Ordinarily, a sample COPC value that exceeds a BTV can be considered impacted or exhibiting evidence of contamination. Normally, background levels of elements display a statistical variation within a well-defined range, but if a value exceeds a threshold level it could have significance as an indicator of a possible ore deposit, or in this case impact from contamination.

During April 2012, UNC submitted to NRC a License amendment request for revision of some NRC GWPSs based on updated background water concentrations (UNC, 2012; GE, 2012). UNC presented newly calculated BTVs based on the UPL95s (Chester Engineers, 2012a). A UPL95 BTV for a COPC represents the concentration at which a change in ground water quality would be statistically significant and indicate a degradation of quality. If a ground water sample COPC concentration from a monitoring well exceeds the corresponding UPL95 COPC limit by a statistically significant amount which is verified by additional confirmation sampling, then the ground water at that location is out of compliance. The UPL95 BTV exceedance would trigger an investigation to determine the reason for the change or degradation of water quality, and a corrective action would be taken to remedy the degradation. Since the UNC Site ground water monitoring data has been subjected to the UCL95 statistical analysis, the UPL95 statistics provide a more current, extensive, and robust basis for calculating updated background COPC concentrations.

The BTVs UPL95s for the UNC Site hydrostratigraphic units are summarized in Table 21 (this table also includes the 1988 ROD COPCs). The UPL95 calculations were based in part on the extensive background data set comprising ground water quality analytical results from July 1989 through October 2007. The BTVs are anticipated for use in selecting COPCs as part of the SWSFS and for future comparison with compliance sampling data. The calculation of UPL95s was accomplished using current ProUCL software (Singh et al., May 2010, *ProUCL Version 4.1 User Guide [Draft], EPA/600/R-07/041*). The UPL95s (as BTVs (i.e., “not-to-exceed” values)) are appropriate for comparison with compliance samples. UCL95 values discussed in Section 5.1 should not be used for comparison with individual compliance samples because the UCL95s represent a confidence level on the *mean* of the background sample populations. The UPL95 represents the maximum concentration allowed that a specific number of comparison values must fall below in order to avoid an exceedance at a designated level of confidence (e.g., 95%)

To generate the UPL95 values requires selection of a specific future compliance-sampling plan because the statistics are derived in part on the anticipated numbers of future comparisons with sample values. The compliance-sampling schedule comprises a specific number of future comparisons of UPL95s (referred to as “*k”* values). This is done to control the probability of incorrectly accepting the hypothesis that a sample concentration is too high to have been drawn from a background population (referred to as a Type I error, Singh et al., April 2007).

Based on UNC discussions with NRC staff, the following future compliance-sampling plan was applied to the development of the UPL95s: Six (6) years of quarterly POC sampling (for a subtotal of 24 sample sets or = 24) followed by License transfer to the DOE and annual sampling for 30 years (adding 30 sample sets for a total *k* = 54 per POC well). The *k* value for each hydrostratigraphic unit is multiplied by the number of POC wells in the unit.

- For the SWA, which currently has seven POC wells, the *k* value (54 future compliance samples per well) X (7 wells) = 378.

- For Zone 1, which currently has five POC wells, the *k* value (54 future compliance samples per well) X (5 wells) = 270.

- For Zone 3, which currently has four POC wells, the *k* value (54 future compliance samples well) X (4 wells) = 216.

The UNC NRC Site License regulates a total of 13 COPCs as indicated in the fourth column of Table 21. The proposed, revised GWPSs (UNC, 2012) include newly calculated background concentration UPL95s for each hydrostratigraphic unit. For some COPCs the UPL95 statistics did not have enough sample laboratory detections and the resulting UPL95 calculation is considered statistically unreliable. For these parameters the maximum detected background concentration is used instead of the UPL95 statistic. This is the case for lead in the SWA; lead in Zone 1; and cadmium and lead in Zone 3. In 2012 the following UPL95 BTVs and/or maximum detected background concentrations for each hydrostratigraphic unit were submitted as proposed revisions to the UNC NRC License GWPSs:

- <u>SWA – seven (7) proposed revised GWPSs</u>: cadmium [0.025 mg/l]; lead [0.07 mg/l[a]]; nickel [0.078 mg/l]; selenium [0.07 mg/l]; radium total [8.2 pCi/L]; thorium-230 [4.5 pCi/L]; uranium [0.205 mg/l]; and lead-210 [5.9 pCi/L].

- <u>Zone 1 – five (5) proposed revised GWPSs</u>: nickel [0.07 mg/l[a]]; uranium [0.238 mg/l]; radium total [12.1 pCi/L]; thorium-230 [1.6 pCi/L]; and lead-210 [4.7 pCi/L].

- <u>Zone 3 – nine (9) proposed revised GWPSs</u>: arsenic [0.757 mg/l]; cadmium [0.09 mg/l[a]]; lead [0.08 mg/l[a]]; nickel [0.569 mg/l]; uranium [0.395 mg/l]; radium total [35.2 pCi/L]; thorium-230 [17.0 pCi/L]; lead-210 [5.7 pCi/L]; and gross alpha [39.7 pCi/L].

  a – UPL95 statistically unreliable due to too few detections: maximum detected background concentration used instead.

Many of the COPC concentrations for each hydrostratigraphic unit under the 2012 UNC NRC License amendment request have GWPSs that are unchanged: six (6) in the SWA (arsenic, beryllium, vanadium, uranium, chloroform, and gross alpha); eight (8) constituents in Zone 1 (arsenic, beryllium, cadmium, lead, selenium, vanadium, chloroform, and gross alpha); and four (4) constituents in Zone 3 (beryllium, selenium, vanadium, and chloroform). These same results are shown in Table 21 where the UPL95s with olive green highlight-bold font correspond to the proposed, revised GWPSs. UNC is not seeking to revise the GWPS for chloroform in any hydrostratigraphic unit. The current NRC GWPS for chloroform is equivalent to the EPA MCL of

0.08 mg/l (for TTHMs, which is only present in the UNC Site ground water in very limited areas).

UNC is also not seeking to revise the GWPS for uranium in the SWA on the basis of information provided in the GE report from 2006 (GE, 2006). The report by GE entitled, *Regulatory Significance of the Occurrence and Distribution of Dissolved Uranium in Ground Waters of the Southwest Alluvium, Church Rock Site New Mexico*, is a special report that does not conform to the same statistical methods and data set conditions as the ProUCL statistics. The primary purpose of the report was to assist the EPA with deliberations applying the current MCL for uranium (0.03 mg/l) to the SWA. The report is primarily a semi-quantitative discussion of the nature and concentrations of uranium in the SWA based on the buffering of tailings seepage by carbonate minerals and the complexation of uranium with bicarbonate. The report is not a statistical analysis similar to the ProUCL statistics. The conclusion in the paper is that the current 1988 ROD standard of 5.0 mg/l for uranium in the SWA should be revised to 0.30 mg/l which is the same as the NRC GWPS. The EPA MCL standard of 0.03 mg/l is unattainable in the SWA and would require complete desaturation of the aquifer. The UCL95 statistics determined that the background concentration for uranium in the SWA is 0.046 mg/l, and the UPL95 BTV for uranium in the SWA is 0.205 mg/l. Both the UCL95 and UPL95 statistics for uranium in the SWA are lower than the current NRC GWPS, GE recommended value of 0.30 mg/l. The EPA supports a consistent statistical approach and therefore recommends the SWA background value of 0.205 mg/l.

The ORD was tasked by EPA Region 6 to provide comment on the background conditions of the near-surface aquifer system created by the NECR and Quivira uranium mine dewatering activities over the 17 year period of discharges from 1969-1986. On March 25, 2013, ORD issued an official memorandum on the background ground water conditions in the SWA and Zones 1 and 3 of UNC Site. The memorandum describes how infiltration of mine discharge water became the "background" condition of water chemistry for the shallow aquifer system at the UNC Site. The memorandum also recognizes that milling disposal operations at the UNC Site created an acidic tailings mound of ground water on top of the artificially created shallow aquifer system that subsequently seeped and created a plume of contamination. ORD was specifically tasked to provide an opinion on UNC's technical approach applied to establish background conditions for the artificial system prior to tailings disposal. The challenge of establishing background conditions is complicated by the fact that the ground water system is comprised of three different hydrostratigraphic units each of which have developed a unique geochemical condition over time. Determination of a common background condition for all three units is not feasible and each unit must be addressed independently. Some background constituent concentrations exceed primary drinking water standards and, "… it would be unrealistic to consider the artificial [background] aquifer system as a viable source of water for human and/or animal consumption at present or in the future." The memorandum stated that, "the artificial aquifer system is temporary and has gradually dissipated and dried up due to the lack of recharge since mine dewatering discharge stopped and– it will eventually revert to its dry or near-dry state since no net recharge of the aquifer system is occurring."

The ORD technical memorandum concluded that, given the history of development of ground water conditions at the UNC Site, the proposed cleanup and compliance monitoring levels for COPCs using the statistically-based 95th percentile upper prediction limits (UPL95s) for background water samples in the individual units are reasonable and should be adopted.

5.3 Ground Water Flow Model

The 2012 Ground Water Flow Model for the UNC Site includes three classes of groundwater. Two of these classes are anthropogenic and have been defined in the 1988 ROD and subsequent UNC Site documents: post-mining/pre-tailings (background) and post-mining/post-tailings (commonly referred to as tailings-impacted or seepage-impacted). The third class of groundwater is derived from natural recharge and is described by the ROD as pre-mining/pre-tailings (natural).

UNC developed a three-dimensional computer-generated numerical ground water flow model of the UNC Mill and Tailings Site, and the adjacent down-gradient region. The principal objective of the 2012 Ground Water Flow Model is to support EPA decision making related to utilizing an Alternate Concentration Limit (ACL)[CERCLA Sec. 121(d)(2)(B)(ii)] as a potential remedy in any new EPA decision and that may potentially be submitted to the NRC in a License Amendment Request.

The following text is from the July 1987, *Alternate Concentration Limit Guidance, Part I, ACL Policy and Information Requirements Interim Final* defines ACLs:

> To establish ACLs, two points must be defined on a RCRA facility's property …: the Point of Compliance (POC) and the Point of Exposure (POE). The POC is defined in the Subpart F Regulations (40 CFR § 264.95) as a "vertical surface" located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated unit. The POC is the place in the uppermost aquifer where ground-water monitoring takes place and the ground-water protection standard is set. The ACL, if it is established in the permit, would be set at this point.
>
> The point of exposure (POE) is the point at which it is assumed a potential receptor can come in contact, either now or in the future, with the contaminated ground water. Therefore, the ground-water quality at the POE must be protective of that receptor. For example, a facility may have a ground-water contaminant plume restricted to a small portion of its property. In this case, it may be appropriate to assume that people will be exposed through a drinking water well to the ground water immediately at the edge of the plume. The ground water at that Section 264.94 contains the regulatory framework for these

> concentration limits. The approach used by the regulations is to adopt widely accepted environmental performance standards (i.e., MCLs in Table 1), when available, as concentration limits. However, because of the lack of currently available standards, specific concentration limits for only a few specific constituents have been included in the regulations.
>
> Maximum contaminant levels are established for 14 hazardous constituents under the National Interim Primary Drinking Water Standards and are listed in Table I of Section 264.94(a) of the regulations. If a constituent is not listed in Table 1, the standard becomes no degradation beyond background water quality. In such cases, the concentration limit is set at background level. However, variances from these standards are available where the permit applicant can demonstrate that the constituents will not pose a substantial present or potential hazard to human health or the environment. In such cases, the applicant may ask for an "alternate concentration limit" (ACL) under Section 264.94(b) of the regulations. This section of the regulations lists nineteen criteria to be applied in ACL demonstrations. The applicant should, however, be aware of any State or local laws regulating ground water. Many States prohibit the release of any pollutants into the ground water. If the State has an authorized program for 40 CFR Part 264, Subpart F and does prohibit such releases, ACLs may not be allowed.

The focus of the 2012 Ground Water Flow Model is on Zone 3 applications that may potentially be submitted to the NRC. The reason that the Ground Water Flow Model focused on Zone 3 applications is because UNC anticipates that the application of ACLs may be greatest for Zone 3 in the potential of a new EPA decision document. In particular the 2012 Ground Water Flow Model should be able to generally predict the future disposition of the three classes of ground water. The character of seepage-impacted water has been investigated and tracked in the Annual Review Reports since the early 1980s with entry and migration of background ground water through the three hydrostratigraphic units, a secondary focus of the monitoring program. An understanding of the disposition of background ground water (mine discharge water) is a requisite for predicting the future disposition of seepage-impacted water from the tailings cells because the background ground water is in contact with the other two classes of ground water, and the background water often resides in a hydrogeologic position between seepage-impacted water from the tailings cells and the down-gradient natural ground water. Because the background water characteristically is located between the seepage-impacted water and the down-gradient natural ground water made it necessary to initiate the Ground Water Flow Model with the start of mine water discharge in 1968 as one of the model parameters (UNC, 2012).

The Ground Water Flow Model was developed using two industry standard computer programs: MODFLOW 2000 version (Harbaugh et al., 2000) and MODPATH (Pollock, 1994). The model is three-dimensional and incorporates the geometries and hydraulic characteristics of each Site hydrostratigraphic zone that was subject to transient saturation by the two anthropogenic classes of ground water (post-mining/pre-tailings (background) and post-mining/post-tailings (commonly referred to as tailings-impacted or seepage-impacted). The model made extensive use of the MODFLOW cell rewetting process as a way to approximate the propagation of an unconfined wetting front through previously unsaturated geologic media. An unconfined wetting front is where water flows downward from a source through dry soil. The reason an unconfined wetting was approximated is that the anthropogenic water was discharged at the surface and percolated downward through previously dry soil. The model is limited to ground water flow and purely convective transport. Convective transport means that the contaminants in the ground water flow do not react with other contaminants and do not disperse more rapidly than other contaminants. Purely convective transport is simulated by the particle tracking method. The particle tracking method is where the movement of water is stimulated by individual particles. The reason the particle tracking method was used is because the MODFLOW and MODPATH computer systems are generally accepted in the industry and that particle tracking is an industry accepted method of tracking contaminant particles moving through ground water.

As defined in the 2012 Ground Water Flow Model, the conceptual model includes recognition that there was a pre-mining (natural) water table at about elevation 6692 ft. This natural water table had a broad geographical extent, consistent with the observations and interpretations presented in the Ground Water Flow Model report, as well as with regional models of piezometric elevations in the Gallup Sandstone. The pre-mining natural water table and later interface (with anthropogenic background groundwater) was also persistent. This aspect of the conceptual model is consistent with data that demonstrate a very slow migration rate exhibited by the natural, regional groundwater flow system. The conceptual model is also consistent with UNC Site monitoring data, which demonstrates consistent water quality of the pre-mining natural groundwater despite post-mining contact with and surcharging (of head) by background groundwater.

Pre-mining natural ground water occupied the all the available (pore) space in the Gallup Sandstone beneath a water table, which was encountered at elevation 6692 ft (amsl) during the construction of the Northeast Church Rock mine shaft 1 in March 1968. Subsequent discharges of water to Pipeline Arroyo from the Northeast Church Rock Mine and the Kerr McGee Church Rock Mine resulted in mining-related (background) ground water infiltrating the alluvium and Zones 1 and 3. The background ground water migrated down the slightly inclined (approximately by one degree from horizontal) layers of Zones 1 and 3, where it eventually encountered the pre-mining natural water table. Measurements in Zone 1 monitor wells 0(141, 0143, and 0143) having screened intervals below the elevation of the pre-mining natural water table indicate that background ground water contacted the pre-mining natural ground water before 1980, because the piezometric pressures (the height to which water levels rise in a well) increased steadily in those wells for approximately two decades. That increasing pressure is interpreted to have been caused by the accumulation of background ground water on top of the pre-mining natural ground water. The pressure eventually ceased to increase because the volume of background ground water was limited by the cessation of mine water discharge in February 1986.

The approximately 14-year delay between the cessation of mine water discharge and the leveling off of pressure in these wells gives an indication of the rate of migration of the background ground water, which was much faster than the natural rate of migration of the pre-mining natural ground water. The slow rate of natural migration is the result of the Gallup Sandstone descending in depth over 5500 ft over approximately 60 miles to its northern extent beneath the San Juan River, where the ground water eventually discharges.

The ground water underlying the UNC Site is located in the Gallup Sandstone Formation. The Gallup Sandstone is an important regional aquifer in the southern part of the San Juan Basin. The conceptual model in the Ground Water Flow Model reflects the regional hydrogeologic setting of the Gallup Sandstone and associated hydrostratigraphic units described briefly in Section 3.2 of this FYR. Earlier ground water flow models of the San Juan Basin include modeling of ground water flow in the Gallup Sandstone (Stone, 1981 and Kernodle, 1996). The models predicted northward migration of ground water in the Gallup Formation until it eventually discharges to the San Juan River near the Four Corners areas. Ground water recharge to the Gallup Sandstone occurs predominantly where it outcrops at the western and southern margins of its regional extent. Isotopic age dating of ground water in the Gallup Sandstone suggests that recharge rates were greater in the past than at present. Carbon-14 age dating of ground water in the underlying Morrison Formation suggests that ground water in the Morrison Formation has migrated less than 20 miles from the recharge area located in the western portion of the San Juan Basin in the last 40,000 years. So it is reasonable to conclude for the UNC-NECR area Ground Water Flow Model that local ground water also moves slowly in the Gallup Sandstone toward the north.

The pre-mining natural ground water table is also regional in extent. Samples from Zone 1 monitor wells 0141, 0142, and 0143 also provided evidence of the chemical characteristics of the pre-mining natural ground water, which is very different from background ground water. During the sampling history of these wells, from July 1989 through 2013, there were only minor variations of ground water chemistry from the earliest samples. This indicates that over this period of approximately 24 years there is no evidence of progressive chemical change by mixing despite the proximity (in elevation) between the well screens and the elevation of the pre-mining natural ground water table. The sampling history also indicates that deflection of the pre-mining natural ground water by the surcharge of background ground water must have been limited to a relatively narrow geographical area up-dip of these wells. Otherwise, ground water of background quality would have been detected in those wells. There is also no evidence of a natural process that might be expected to induce mixing at some time in the future, beyond the slow and geographically limited process of chemical diffusion.

The conceptual ground water model in the 2012 Ground Water Flow Model utilizes information indicating the Pipeline Arroyo subsurface was dry prior to mine water effluent discharge (Canonie, 1987). The assumption that the Pipeline Arroyo was dry is based on the general absence of saturation in the Upper Gallup Sandstone and overlying formations (Canonie, 1987). Information from the sinking of the NECR Mine shaft in 1969 indicated the pre-mining natural ground water table (Class 3 water in this FYR) is down-dip and north of the UNC Site. The pre-mining natural water table is a flow model initial condition across the Upper Gallup Sandstone Zones 1 and 3. When we say we used the pre-mining natural water table as an "initial condition", we mean that the Flow Model describes what was known about the ground water prior to when mining began (about 1969).

Figure 8 from the Ground Water Flow Model report presents the topographic view of the UNC Site-NECR Site area and the two major geologic structures that intersect the UNC Site, the Pinedale Monocline and the Pipeline Canyon Lineament. Figure 8 also includes the locations of two subsurface geologic cross sections (A-A' and B-B') which also intersect the UNC Site. A-A' and B-B' are shown in greater detail in Figure 9. Figure 9 presents the subsurface geology with respect to the location of the NECR Mine shaft and the elevation of the pre-mining ground water (natural) water table elevation prior to initiation of pumping from the NECR mine workings. The position and elevation of the pre-mining natural water table in the cross sections are based on extrapolation of data gathered in 1968 from the NECR Mine shaft and from the water quality sampling results gathered from 1980 to 2011 from the three Zone 1 monitoring wells (0141, 0142, and 0143) that are the down-gradient from the Tailings Disposal Area. These data indicated the presence of a pre-mining natural water table in Zone 1. Based on these data, the conceptual model includes recognition that the pre-mining natural water table existed at an approximate elevation of 6692 feet above mean sea level and had a broad geographical extent.

The rates of ground water flow in the Gallup Sandstone are very slow relative to the rate of migration of anthropogenic ground water introduced into the UNC area ground water system from decades of mine dewatering discharge that infiltrated through the alluvium of the Pipeline Arroyo and into Zones 1 and 3. The anthropogenic ground water migrated down-dip until it contacted the pre-mining natural ground water. The pre-mining natural ground water was not substantially displaced by or mixed with the later anthropogenic background ground water, which is shown by the consistent quality of ground water sampled from wells screened in the pre-mining natural ground water.

Mining-related (background) ground water has pooled against and spread laterally updip of the pre-mining ground water horizon instead of mixing with the pre-mining natural ground water. The implications of the conceptual model for the Ground Water Flow Model are that: the pre-mining water table is an initial condition of known location; and tailings seepage water will remain updip[10] of the background ground water.

The Flow Model grid and boundary condition geometries were set up to simulate Zone 3 areas of: recharge; areas of infiltration beneath arroyo channels; and wells that may extract or inject water. MODFLOW was used for ground water flow modeling and MODPATH was used for active particle tracking. The active area of the flow model was approximately 4.7 square miles. Six model layers extended from the ground surface to the base of the Upper Gallup Formation (Zone 1). The layers represent four bedrock units, and unconsolidated alluvium and tailings. Zone 3 is represented by model layers 3 and 4 which represent upper and lower sections of Zone 3. The elevation of Zone 1 ranged from the base of the alluvium in the south to approximately 840 feet deep in the northern part of the model area. The outer margins of the Ground Water Flow Model employ no-flow conditions so there is zero flux (flux means flow) across such boundaries. Another type of boundary condition was set over a limited breadth of the Pipeline Canyon to allow for drainage of ground water out of the model through the alluvium (drain cells). The regulation of discharge through the drain cells was based on drain elevation (time variable) and conductance (horizontal primarily). The capability of assigning time-variable elevations to the drains is useful, because the elevation of ground water in the alluvium varied significantly over time in response to the variation in mine water discharge between 1968 and 1986. Figure 10 from the Ground Water Flow Model presents a hydrograph of the combined rate of mine water discharge to the Pipeline Arroyo. This discharge is one of the sources of anthropogenic water to the SWA and Zones 1 and 3. Figure 11 presents a hydrograph of alluvial Well 0627 from 1968-2030, and an extrapolated Ground Water Flow Model drain cell hydrograph.

Figure 11 reflects the impact the discharge of mine water had on recharge-saturation of the alluvium then gradual desaturation after mine water discharge ceased in 1986. River cells were also developed in the model to allow for drainage of the alluvium that filled during the period of active mine dewatering followed by desaturation when dewatering ceased. Recharge areas for the Ground Water Flow Model included the tailings disposal ponds and areas of natural recharge subject to precipitation runoff events. The Ground Water Flow Model used the standard MODFLOW wells to simulate historic pumping by extraction wells in all three hydrostratigraphic zones at the UNC Site.

Simulations of ground water flow had to begin with mine water discharge in 1968, include the disposition of background water and tailings seepage water, and predict through to the future of the tailings seepage-impacted water in Zone 3. MODFLOW divides the time-scope of transient simulations (1968-2011) into user-defined stress periods which are subdivided into

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[10] updip means located up the slope of a dipping plane or surface

time steps in order to improve numerical stability of the iterative solution process or to acquire a solution at a particular time. The first/early time step of simulation was at January 1987, a time when Site-wide observations of well water levels and piezometric elevation maps were starting to be made by Canonie (1987). The second/later time step was October 2011 when the most recent Site-wide piezometric elevation maps were made by Chester Engineers (2012). The model predicted piezometric elevations for January 1987 and October 2011 compared well (matched) to the large format maps prepared by Canonie (1987) and in the 2011 UNC Annual Report.

Particle tracking using MODPATH to simulate purely convective transport of impacted water made full use of the three-dimensional solution for transient heads and cell-to-cell fluxes calculated by the MODFLOW simulations. The technique also provides for particle tracking forward and backward in time. Backward tracking was used to determine the sources of ground water in the general area of seepage-impacted ground water in Zone 3. The particles were tracked backward until they encountered the first water table as an end point or source. Figure 12 present the particle tracking end points for simulation in October 2011. The sources were identified as either north pond, borrow pits 1 or 2, or nontailings (typically an arroyo recharge or river cell). Once the particle tracking simulations identified the source and was calibrated to define the extent of the seepage-impacted plume in 2011, the next step is to make predictive analysis of future migration under simulated conditions.

The Ground Water Flow Model and forward particle tracking were simulated to make a 15-year prediction of future migration to 2026 based on a hypothetical pumping scenario of existing extraction wells in Zone 3. No new recharge was considered and the Zone 3 extraction well pump rates were estimated to decline over time. Figure 13 shows the contours of the predicted piezometric surface elevations in layer 4 (base of Zone 3). The area of seepage-impacted ground water is presented in red forward tracking particle tracking. The particle tracks do not extend north of the northern line of extraction wells most of which operate throughout the extraction well pump rates were estimated to decline over time. Figure 13 shows the contours of the predicted piezometric surface elevations in layer 4 (base of Zone 3). The area of seepage-impacted ground water is presented in red forward tracking particle tracking. The particle tracks do not extend north of the northern line of extraction wells most of which operate throughout the 2011-2026 time period. The simulation shows that the background water occupies a large area of Zone 3 between the down-gradient pre-mining water and the seepage-impacted ground water. The seepage-impacted water is marginalized between the eastern edge of the extent of saturation and the hydraulic mound on the west created as background ground water from mine dewatering discharge. The prediction of the model was tested against the volume of water calculated in the ground water mound that existed in Zone 1 and 3 as a result of mine discharge. The combined volume was approximately 10% of the total volume of mine discharge water which was about the estimated percentage of mine water lost to infiltration based on weir measurements in the alluvial channel.

5.4 Zone 3 Remedial Actions

5.4.1 In-Situ Alkalinity Stabilization Pilot Study

In 2006 to 2007, UNC conducted an in-situ alkalinity stabilization pilot study to evaluate the potential to enhance the ongoing Zone 3 remediation through the use of alkalinity injection wells combined with carefully controlled extraction pumping at the UNC Site. The proposed approach for the pilot study was presented in the In-Situ Alkalinity Stabilization Pilot Study (BBL, 2006), which was approved by the EPA.

The pilot study was initially designed to test the injection of alkalinity-rich ground water from a non-seepage-impacted part of the SWA into the Zone 3 aquifer. The injected water (so-called “fixiviant”) would flow through the Zone 3 formation to recovery wells where the fixiviant could be pumped to the surface for treatment and disposal. However, concerns were expressed by NMED that the ground water from the SWA did not meet applicable ground water standards for sulfate, TDS and manganese. Following the original submission of this pilot study (in October 2005) and subsequent discussions, NMED identified ground water withdrawn from a formation below Zone 3 and the underlying Mancos Shale (the Westwater Canyon Formation), via the onsite Mill Well, as a potential alternative source of ground water to use as the injection water. The pilot study approach was revised to include injection of the Mill Well water (amended with sodium bicarbonate to add alkalinity) into Zone 3, as described in the approved In-Situ Alkalinity Stabilization Pilot Study dated June 2006. The pilot study was conducted from October 24, 2006, to February 15, 2007. The observed injection and extraction rates were unexpectedly low. As a result, the estimated speed of ground water moving between the injection and extraction wells was prohibitively slow and the pilot test was terminated. Data obtained as part of the pilot study indicated that the mineral feldspar in the Zone 3 arkosic sandstone had been altered by the acidic tailings liquids, generating kaolinitic clay that significantly clogged pore spaces and reduced hydraulic conductivity. The pilot study indicated that it would take 10 times longer to accomplish remediation goals than had been hypothesized. Using what had been envisioned as an approximate five year remedy enhancement could actually take 50 years or more. Based on these results, it was concluded that the use of alkalinity rich solutions to remediate the Zone 3 seepage-impacted ground water in-situ was infeasible (ARCADIS BBL, 2007).

5.4.2 Phase I Hydrofracture Program and Continuing Zone 3 Extraction Well Pumping

Extraction of seepage-impacted ground water from a new array of wells in the northern part of Zone 3 in Section 36 was tested in April 2005 as part of the Phase I (i.e., post-pilot) hydrofracture program (MACTEC, 2006). Continuous pumping of these wells began in May 2005. Phase I ended in January 2006; however, as discussed later in this section of the report, the pumping has been continued and supplemented by the installation of additional extraction wells. The locations of the Phase I pumping wells (RW 11, RW 12, RW 13, RW 15, RW 16, RW

17, and PB 2) are shown on Figure 37 and Figure B-1 in Appendix B of the 2012 Annual Review Report. Also shown is the location of a newer extraction well, RW A, which started pumping on September 24, 2007. Due to fouling and/or insufficient yield, RW 12, RW 13, and RW 15 have been taken off-line and are no longer pumping. Of this group, the pumping wells that were operational during 2012 are PB 2, RW 11, RW 16, RW 17 and RW A.

Based on UNC's hydrogeologic analysis and recommended pumping system design (N.A. Water Systems, 2008c), five new extraction wells to intercept and recover seepage-impacted water were installed during September 2008. These well locations are shown on Figure 35 and Figure B-1 (in the front of Appendix B) and are designated NW 1, NW 2, NW 3, NW 4, and NW 5. After an initial test period to determine that all five wells were pumping properly, three of the wells started pumping during February 2009 (NW 1, NW 2, and NW 3). NW 2 and NW 3 were each pumping at approximately 1 gpm and NW-1 at 0.1 gpm. Yields have since declined at all of the wells and most dramatically at NW 1, which has a very low recharge rate and shallow saturated thickness. As discussed in the next section, the pumping scheme was adjusted during November 2009 and June 2012. NW 3 and NW 5 were not pumped to minimize the potential of drawing seepage-impacted ground water to the northwest. Approximately 14,141,544 gallons of ground water have been pumped from this new Zone 3 extraction well network from January 2005 through the end of November 2012, and piped to the evaporation pond.

5.4.3 Evaluation of the Effects and Limitations of Zone 3 Extraction Well Pumping

Twenty-three years of remedial pumping have resulted in significant dewatering of Zone 3. One effect of this is that once the saturated thickness falls to approximately 25 ft or less, well efficiency declines and pumping rates fall to less than 1.0 gpm (Earth Tech, 2001). Table 11 presents the reductions in saturated thickness for Zone 3 monitoring wells between the third quarter of 1989 and the fourth quarter of 2012. In previous versions of this table, values of saturated thickness greater than 25 ft were shaded. For the first time, in 2012, none of the monitored Zone 3 wells met this criterion (last year Well EPA 14 just barely met this threshold with a saturated thickness of 25.10 ft).

The saturated thickness measured in Zone 3 wells has declined by 75 percent on average since the third quarter of 1989. Figure 35 shows that between 1989 and the fourth quarter of 2012, a very large portion of the Zone 3 Remedial Action Target Area has been desaturated (effectively dewatered). The eastern limit of Zone 3 saturation has shifted to the west-northwest over this time period (from the location of the wavy blue line, showing the saturation limit in 1989, to the dashed brown line showing the approximate October 2012 "zero" saturation limit). The effects of both the former and the present-day, reconfigured remediation pumping in partially, locally dewatering Zone 3 are presented in Figure 36. The figure marks the start of recovery pumping from the new well array installed during the hydrofracture study in April 2005.

The in-situ alkalinity stabilization study found that the seepage-induced alteration of feldspathic minerals is reducing the bedrock permeability. This tends to restrict the migration of tailings seepage. The main reason that the ground water flows toward the north is that the Zone 3 bedrock unit dips downward toward the north. The hydraulic head that drives the flow comprises two components: the elevation head plus the pressure head. Hydraulic head in an aquifer means the altitude to which water will rise in a properly constructed well. This is the altitude of the water table in an unconfined aquifer or of the potentiometric surface in a confined aquifer. The elevation head in an aquifer is the elevation of the bottom of the well measuring point in feet above sea level. Pressure head in an aquifer is the height that water rises in a well that is open only at the top and bottom of its casing. When we say there will be no further reduction in the pressure head we mean that pressure within the aquifer is equal to zero. The fact that there is no further reduction in the pressure head is significant because it means that the tailings seepage-impacted water is no longer influencing the direction of ground water gradient.

The long history of extraction pumping in Zone 3 has reduced the pressure head component of the total hydraulic head. However, it is not possible to reduce the slope-related elevation (elevation head) here, and that is a driving force component that cannot be changed (N.A. Water Systems, 2008b). Continued pumping has been helping in the short-term; however, the saturated thicknesses in this hydrostratigraphic unit are quite shallow and eventually there will be no further possible reduction in the pressure head. The effort to counteract the overall hydraulic head is gradually approaching practical limits as the well yields decrease. At some time in the future, seepage-induced permeability reductions will retard further northward migration of seepage-impacted water. The exact timing and location of the development of this critical balance cannot be predicted, but such a condition should inevitably occur.

Another way to look at the inherent difficulty of extraction pumping in the northern part of the seepage-impacted water is to note that along a 1200-ft long, west-northwest trending line of cross section located between Wells NBL 1 and PB 3, the total ground water flux (without any pumping) was calculated to be 512 ft^3/day (2.7 gpm) during January 2005 (N.A. Water Systems, 2008c), which is equivalent to the discharge from a home garden hose turned on low. This flux (flux means flow) estimate will decrease with time proportional to the ongoing reduction of saturated thickness.

The revised Zone 3 pumping system has been declining in performance. Most of these wells have reduced yields that are below 0.5 gpm and RW 13 was taken off line due to low yields. The following physical factors controlled these declining yields:

- Encrustation along the wellbore of iron oxyhydroxides, carbonates, and/or gypsum;
- Precipitation of amorphous aluminosilicates (“clays”) (e.g., EPA 14) which reduces the ability to pump water from a well;
- Alteration of feldspar to clays within the bedrock matrix, which caused clogging; and

- Reduced saturated thicknesses of the Zone 3 aquifer (the thickness of water in the aquifer is decreasing and eventually will decrease to the point where water cannot be measured in the well).

Ground water quality along the northern tracking wells has been oscillating between degrading and improving trends over the last 10 years. Individual well water quality trends of improvement and degradation have been occurring at the same time since May 2007. That is, some wells may have improved water quality at the same time that other wells may have poorer water quality. UNC measures monthly field parameters (pH, conductivity, chloride, and alkalinity (also called bicarbonate)) in all five NW-series wells. The alkalinity concentrations indicate the following: NW 1 is the most seepage-impacted and has the least saturated thickness; NW 4 shows lesser impact; NW 2 shows little to no impact; and NW 3 and NW 5 (not pumped in 2012) are predominantly background water (mine discharge water) and have the greatest saturated thicknesses. Note that NW 1 and NW 4 are the easternmost of these five new wells, and NW 3 and NW 5 are the westernmost. The 2012 Annual Review Report states that "These observations are consistent with our general understanding that the seepage-impacted water is most prevalent towards the eastern limit of saturation; moving westward the prevalence of non-seepage-impacted water increases as does the formation's saturated thickness" meaning that the tailings seepage-impacted water exists in the eastern portion of Zone 3 while background water predominantly exists in the western portion of Zone 3 and that the saturated thickness of the background water increases in saturated thickness toward the west.

Consistent with UNC's original recommendations (N.A. Water Systems, 2008c) and a later update (Chester Engineers, 2009c), UNC adjusted the pumping regime along the NW-series wells to attempt to: (1) minimize the withdrawal of background water; (2) minimize any tendency for seepage-impacted water to be drawn westward; and (3) maximize the withdrawal of seepage-impacted water. As always, the goal is to strike the best balance between containing the seepage-impacted water while minimizing its transport to the more thickly saturated, but non-seepage impacted parts of Zone 3. During November 9 and 10, 2009, the pumping regime was adjusted as follows at the wells listed below:

- NW 1 was left pumping at the current, maximum rate.
- NW 2 pumping rate was reduced by one-half to ~ 0.5 gpm.
- NW 3 was turned off.
- NW 5 remains off. and
- NW 4 pumping was started at the maximum practicable rate.

On May 10, 2012 UNC applied another pumping adjustment because the yield from NW 1 had declined to critically low levels (< 1 gpd = < 6.9×10^{-4} gpm) and this pump was shut off. To help compensate for this shutoff, in early June 2012 the pumping rate at NW 2 was increased from 0.5 gpm to 1 gpm.

All other non-NW-series pumping wells to the south will remain on. UNC continues to evaluate the chemistry and water levels in all these wells, which may result in further modifications to the pumping rates. The modifications to the pumping rates will be done gradually with testing between changes. The goal is to once again have the optimum pumping rates so that the most contamination is removed efficiently.

5.4.4 Injection Well Feasibility Testing and Pilot Study

Injection well feasibility testing, and its historical context, has been discussed in the 2009, 2010, and 2011 annual reports created by Chester Engineers for UNC (Chester Engineers, 2010a; 2011a; and 2012b). The first injection testing was in background well NBL 2 (Chester Engineers, 2009d). By “background well” we mean a well completed in the post-mining, pre-tailings background water that infiltrated Zone 3 from the background mine discharge water. The second injection testing was in the pilot injection well, IW A (Chester Engineers, 2010b).

On April 14, 2011 injection of water amended with sodium bicarbonate started at Zone 3 Well IW A (Chester Engineers, 2011e). The objectives of the injection were to (1) amend the injected water with alkalinity (sodium bicarbonate) to locally buffer and geochemically stabilize the seepage-impacted water, (2) redirect the seepage-impacted water into the capture zones (“capture zone” means the subsurface area contributing ground water flow to a well) of the northernmost extraction wells, (3) extend the life of the extraction wells by arresting the drawdown (“drawdown” means the lowering of the water table resulting from the loss of water from the aquifer.), and (4) provide a hydraulic barrier to the northerly advance of seepage-impacted ground water. Injection will provide a barrier by creating a ground water mound that will provide a pressure head that is greater than the elevation head of the Zone 3 water. The sodium bicarbonate was added to water in a mixing tank at the concentration of 2 grams per liter (equivalent to 16.6 pounds per 1,000 gallons of water). Prior to injection the water level at this location was approximately 191 ft below ground surface (bgs). During injection the operations staff has varied the injection rate causing water levels to rise and vary from approximately 12 ft to 50 ft bgs. More details on the injection and nearby pumping are provided in the Chester Engineers report (2011e).

The injection capacity at IW A declined over time. In late June 2012 the capacity had declined to ~ 0.2 gpm (288 gpd). On June 29, 2012, the injection at IW-A was terminated for this reason. Through this date, a total of 426,363 gallons of water had been injected.

The observed increase in uranium concentration at monitoring Well MW 6, from 0.082 mg/l in July 2011 to 0.321 mg/l in July 2012 (see Table B.1), provided an additional important reason to terminate the injection of alkalinity.

5.5 Progress Summary

The above sections provide the details on progress since the 2008 FYR and have involved a substantial amount of investigative and statistical work. Table 22 presents the recommendations from the 2008 FYR along with a current Action Taken and Outcome statement. It should be noted that milestone dates were not defined in the 2008 FYR and several of the recommendations are dependent on the outcome of the NRC License Amendment for GWPSs and the subsequent completion of the SWSFS Part III; therefore, the Date Action Taken fields are left as to be decided (TBD).

6.0 FIVE-YEAR REVIEW PROCESS

6.1 Administrative Components, Community Notification, Document Review

This FYR has been conducted in accordance with the EPA's Comprehensive FYR Guidance, dated June 2001 (EPA, June 2001). The following activities were conducted:

- the project documents listed in (Attachment 1) were reviewed;
- a fact sheet (Attachment 2) was distributed to the local community;
- a public notice (Attachment 3) was placed in two local newspapers, the Gallup Independent and the Navajo Times;
- a Site inspection was conducted on April 18, 2013. The Site Inspection Checklist is in Attachment 4. Site photographs are in Attachment 5; and
- And interviews (Attachment 6) were conducted with representatives from the U.S. NRC, GE, the Navajo Nation EPA, and the local community (Table 23).

The public notice was placed in the Navajo Times and Gallup Independent in November 2012 to announce the start of the FYR. Copies of the fact sheet announcing the FYR were distributed to persons on the EPA's Site mailing list in November 2012. At the same time, copies of the fact sheet were also placed in the following information repositories maintained for this Site:

Octavia Fellin Public Library
115 West Hill Avenue
Gallup, NM 87301
(505) 863-1291

Navajo Nation Environmental Protection Agency
Superfund Office
Highway 264/43 Crest Road
St. Michaels, AZ 86511
(928) 871-6859 / (800) 314-1846

Local residents living in close proximity to the UNC Site were interviewed on April 16, 2013.

Upon completion of the FYR, copies of the Report will be placed in the information repositories. Additionally, a public notice will be placed in the local newspapers announcing completion of the FYR, summarizing the findings, and the availability of the Report at the information repositories. A community meeting will be held to present the results of the FYR in the fall of 2013 or sometime early in 2014.

6.2 Data Review

The performance of the remedy is evaluated through review of historical documents, the latest ground water performance monitoring data, and the results obtained from various pilot-scale field tests. As noted in Section 3, some contaminants are no longer included in the performance monitoring program. In the 1988 ROD, the EPA established a background nitrate concentration of 30 mg/l as the cleanup level. UNC requested the NRC to re-evaluate the background concentrations for nitrate which was set at 30 mg/l in the 1988 ROD. NRC's analysis recommended the background concentration for nitrate be raised to 190 mg/l. The EPA has discussed the revised standard with the NRC, but has yet to modify the cleanup level established in the 1988 ROD with subsequent decision-making. Therefore, the 1988 ROD nitrate value of 30 mg/l is used in this section of the review. There is no NRC GWPS for nitrate in the UNC License.

The summary of the ProUCL statistics in Section 5 presents the work performed by UNC as part of the SWSFS to address the need for the development of revised background standards, EPCs, BTVs for COPCs and their application to compliance monitoring. Results from the ProUCL statistics are included where appropriate. General hydrogeologic observations related to all three hydrostratigraphic aquifers are discussed first, followed by aquifer and well specific considerations related to saturated thickness, ground water flow direction, velocity, general water chemistry, and COPC concentrations with respect to compliance standards.

6.2.1 General Information

According to previous reports, (Canonie Environmental, 1988), the total discharge of water from area mines to the pipeline arroyo was estimated at 16 billion gallons of which up to two billion gallons of mine discharge water is estimated to have infiltrated and recharged the alluvium and two bedrock aquifers within the UNC Site boundaries. The total volume of ground water treated by the UNC remediation effort from 1982 to 2012 is approximately 307 million gallons. As discussed in Section 4, the only ground water extraction system that is still operational on a limited basis is in Zone 3. The extraction systems for Zone 1 and Zone 3 were shut down in 1999 and 2000, respectively, due to the low pumping well yields of less than 1.0 gpm, however the Zone 3 system was voluntarily restarted in 2003. The SWA extraction system was shut off in 2001 to perform the NA test and has not operated since that time. The Zone 1 and SWA extraction systems did not operate at any time during the period of this review. The general conclusion reached at the time the extraction systems were shut down was that low ground water extraction and evaporation rates would not restore ground water quality to cleanup levels.

UNC and others have conducted several background water quality studies, primarily focused on relationships between major ion concentrations and some metal concentrations (nitrate, TDS, sulfate, bicarbonate, and uranium) and the post-mining, pre-tailings ground water (Canonie

Environmental 1988, 1992; NRC 1996; Earth Tech 2002; and GE, 2006). In 2006, UNC provided summary statistics for arsenic and uranium (GE, 2006). In a letter to UNC in January 2008, the EPA notified UNC of deficiencies in the arsenic and uranium statistics. The EPA directed UNC to follow the EPA's current statistical guidance when performing statistical analyses of ground water monitoring data and selecting appropriate statistical methodologies for background water quality studies. This work is included in Part I of the SWSFS on the comprehensive review of cleanup levels, COCs, ARARs, TBC health based criteria and background water quality. As presented earlier in Section 5, for Parts I and II of the SWSFS UNC performed a statistical analysis of the historical monitoring data for all three hydrostratigraphic units using EPA software, ProUCL, in accordance with the latest EPA guidance for statistical methodology.

In addition, UNC has gathered information on the mineralogy of the formation (alluvial sediments), conducted field experiments, and has performed geochemical analysis (e.g., Billings and Associates, 1986; Canonie, 1988 and 1992; and Earth Tech, 2002). Evaporite minerals, capable of producing concentrations of nitrate, sulfate and TDS upon contact with water are present in the alluvial sediments. Water column, and field infiltration experiments performed at the UNC Site, confirms the potential for much of the nitrate, sulfate, and TDS concentrations observed in the ground water to be sourced from the dissolution of naturally-occurring evaporitic and related minerals upon saturation. Both the ground water and the mine discharge water are believed to be affected by these minerals which the mine discharge water flowed through while infiltrating to the subsurface.

These same geochemical evaluations have also provided information on attenuation capacity (Earth Tech, 2002). By attenuation capacity, we mean the ability of the contaminant concentrations to naturally become lower. The alluvium includes the mineral calcite which, if present in sufficient quantities, is capable of buffering the acidity of the tailings seepage. UNC has shown that NA is occurring in the SWA. UNC's demonstration is based on chemical relationships and trends observed in the monitoring data. The geochemical processes observed in the SWA are similar for Zone 3 and Zone 1 sandstones of the Gallup Formation. In Zone 1 and 3, the elevated levels of TDS, sulfate, and manganese in the ground water are largely due to natural sources and naturally buffer and attenuate tailings seepage impacts in the ground water of the two bedrock sandstone units. Generally for all three hydrostratigraphic units, the tailings seepage-impacted water is very acidic and high in concentrations of dissolved major ions, trace metals and radionuclides. As the tailings seepage-impacted water is naturally buffered by the dissolved bicarbonate in native ground water and from the new bicarbonate produced from the dissolution of calcite in the aquifer matrix, the ground water undergoes a chemical transformation. The ground water pH rises from strongly acidic to mildly acidic-near neutral. The rise in pH causes many of the dissolved metals and radionuclides to form solid mineral complexes, or adsorb on to mineral surfaces of the aquifer matrix. The transformation results in a reduced level of the COPCs in the ground water, but the proportions of TDS, sulfate, and bicarbonate may also fluctuate and even increase as the water adjusts to the transformation of pH over time.

Site-wide, ground water elevations have continued the gradual decline observed since the remedy was initially implemented in 1989. These downward trends have continued after the cessation of the ground water extraction systems in each unit. The continued ground water elevation decline is consistent with a conceptual model of temporary or perched water accumulating from infiltration of mine water discharged into Pipeline Arroyo, and a gradual dissipation of that water after mine dewatering was halted in 1986.

General issues regarding the data review

UNC conducted a specific 18-month NA test from February 2001 to July 2002 to determine whether shutting off the SWA extraction wells would adversely affect water quality (Earth Tech, 2002). The NA test determined that turning off the extraction wells does not have an adverse effect on water quality and that the natural system is as effective as, or more effective than, pumping for controlling the migration of COPCs. In addition, the standards set for sulfate and TDS are not for the protection of human health, but are secondary water quality guidelines. Based on this information, the NA test report included a TI evaluation indicating that sulfate and TDS at non-seepage-impacted background concentrations are also greater than the UNC Site standards. Therefore, UNC has repeatedly proposed a TI Waiver for sulfate and TDS (Earth Tech, 2002c; US Filter, 2004a; N.A. Water Systems, 2005a). However, EPA comments on the analytical methodology and results from the NA test raised concerns about the conclusions and issuance of the TI waiver remains unresolved (EPA Letter Mark Purcell to UNC Larry Bush, February 13, 2004).

In addition, it is noted that although uranium is below the current 1988 ROD cleanup level of 5.0 mg/l, it is above the newly promulgated MCL (2003) of 0.03 mg/l in both seepage-impacted and non-seepage-impacted (background) water within the SWA.

As discussed in Section 5, UNC reported there is a covariant relationship between uranium and bicarbonate concentrations within the SWA (GE, 2006). The proposed revision to the background standard for uranium in the SWA from the ProUCL95 statistics is 0.046 mg/l. If the 0.046 mg/l ProUCL95 background statistic is established as the revised background standard for uranium in the SWA, then during the 2008-2012 period, Wells 632, 509D, EPA 25, EPA 28, GW-1, GW-2, and GW-3 would show exceedances of the proposed uranium background standard. Well EPA 28 is located outside the impacted plume area and the other six wells showing exceedances are located within the plume (Figure 14). Wells 624, 627, 801, EPA 23, and SBL-01 would not show exceedances of the proposed 0.046 mg/l uranium background standard during the review period. Well 801 is located within the seepage-impacted plume area of the SWA and the other four wells are located outside the plume (Figure 14).

The *Annual Review Report – (2012) Ground water Corrective Action, Church Rock Site, Church Rock, New Mexico* (Chester Engineers, 2013) provides temporal evaluations of contaminants for each well by presenting graphs of contaminant concentrations over time. However, the Annual Review Report does not provide an individual isoconcentration contour map for each constituent illustrating the lateral extent of COPCs. Some of the graph scales in the Annual Review Report do not clearly represent small changes of parameters over time, and the presence of multiple data sets in a single graph creates overlap and diminished clarity in some instances.

6.2.2 Southwest Alluvium

Multiple geochemical and physical processes can be used to track the fate and transport of the tailings seepage ground water plume in the SWA. These processes are identified using the data that includes pH, bicarbonate, and sulfate concentrations as shown in Figure 14. As explained in UNC's annual reports and the NA evaluation by Earth Tech (2002), bicarbonate concentrations are the main indicator of the presence and extent of tailings seepage impacts. Following the evidence of the natural buffering-attenuation process that occurs in the SWA, mapping of bicarbonate isoconcentration contours is the most appropriate way to delineate the extent of seepage-impacted water. The higher concentrations of bicarbonate at well locations indicate the areas where the acidic tailings seepage has migrated and been buffered by calcite dissolution in the alluvial material. The area of ground water currently impacted by tailings seepage in the SWA is shown on Figure 14. The estimated volume of tailings seepage water remaining in the SWA in 2010 was approximately 170 million gallons (as noted earlier in Section 4.24). The area of seepage impact extends southwest along the western margins of the Tailings Disposal Cells and continues approximately 1,400 ft across the southeastern corner of Section 3 and approximately 435 ft into the north-central portion of Section 10. The total length of the seepage-impacted area in the SWA is approximately 6,075 ft.

The SWA remedial pumping system remained idle over the entire period of this review (2008 – 2013). Initially, monitoring wells 805, 807, 808, GW-1, GW-2, and GW-3 showed a small rise in their respective water level elevations when the extraction wells (801, 802, and 803) were shut down in February 2001, but have since showed decreasing levels through October 2012. The remainder of SWA monitoring wells (EPA-13, 509D, 624, 627, EPA-23, and EPA-25) did not show any change in their respective water level elevations when pumping ceased in 2001, and they continue to indicate a steady decreasing trend through October 2012. From 2008 to 2012, ground water elevations generally continued to decrease by approximately three to four feet on average, illustrating the overall long-term trend of decreasing levels as water continues to drain out of the SWA (see Figure 15). Ground water in the alluvium has drained down to an elevation where the structural feature known as the Nickpoint (as indicated on Figure 14) marks the location where it has possibly divided into two separate water bodies. South of the Nickpoint the ground water continues to flow southwest along the alluvial channel of the Pipeline Arroyo. North of the Nickpoint the water has become ponded and is slowly draining into the underlying bedrock (Gallup Sandstone) where it will flow north along the dip of the bedding planes (Figure 14).

New ground water velocities were calculated to update the rate of downgradient seepage-impact transport. These estimates are Darcy seepage velocities equal to the product of the hydraulic conductivity and the hydraulic gradient, divided by the effective porosity. The estimated seepage velocities are based on the October 2012 ground water elevation measurements at wells 805, 624, 627, and SBL-01 using a hydraulic conductivity value of 2.5 X 10^{-3} cm/sec. Although, the seepage velocity estimates are variable between SWA well points, the average seepage velocity is approximately 36 ft/year [(11+16+21+60+72)/5]. The 2012 calculated velocity are about 25% lower on average than the 2010-2011 velocities and continue the decreasing velocity trend since the RI as a result of the declining saturated thickness of the SWA. For comparison, the 1988 RI calculated ground water velocity at Well EPA-23 was 730 ft/yr (EPA, 1998). In 2002, the mean ground water seepage velocity for the SWA unit was calculated to range from 98 ft/yr to 127 ft/yr (EarthTech, 2002). The resultant ground water velocities are upper-bound estimates of constituent transport because no retardation[11] or attenuation[12] factors are applied.

A comparison of the seepage isoconcentration maps from 2002, 2004, and 2012 annual reports, indicates that the plume boundaries based on select constituent concentrations are graphically *inferred* due to the limited number of wells for such a large area. In 2012, the SWA aquifer appears to have possibly separated into two distinct saturated bodies north and south of the Nickpoint, but this interpretation is somewhat suspect due to the distance (4500 ft) and limited number of wells available to define this geologic feature and the plume's extent (see Figure 14). At the south end of the SWA plume in the vicinity of Well 624, the plume footprint appears to be approximately the same size in 2012 as it was when Well SBL-01 was installed in 2004. Comparison of the 2012 and 2004 SWA plume maps indicate the overall plume footprint is unchanged in the northern area in the vicinity of well 509D. However, in 2012 the extent of the sulfate plume in the northern area with a concentration below 2,125 mg/l has decreased and the extent of the bicarbonate plume with a concentration greater than 2,000 mg/l has increased. In the southern area of the SWA plume, the extent of the overall area of the plume has increased since 2004 by about 100-200 ft in 2012 along the southern Section 2-northern Section 10 boundary. The extent of the bicarbonate plume has increased slightly and the sulfate plume has decreased slightly.

The tailings fluid is also concentrated in dissolved ions of sulfate, metals and hydrogen; making it denser than the background ground water (mine discharge water) and native ground water. As a result of this geochemical stratification, the tailings seepage-impacted water seeks a lower

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[11] The ratio of the average linear velocity of groundwater to the velocity of the retarded constituent at C/Co=0.5

[12] Reduction in mass or concentration of a compound in ground water over time or distance from the source of constituents of concern due to naturally occurring physical, chemical, and biological processes, such as; biodegradation, dispersion, dilution, adsorption, and volatilization.

vertical elevation in the substrata of the alluvial channel beneath the less dense waters. As a result, the isoconcentration contours of bicarbonate in Figure 14 are highest in the deepest parts of the alluvial channel. The bicarbonate contours also extend out laterally from the central core area of higher concentration, buffered, seepage-impacted water to lower concentration, buffered water. The core of the seepage-impacted water is indicated by bicarbonate concentrations contours greater than 2,000 mg/l, and the less impacted water is indicated by contours at approximately 1,000 mg/l bicarbonate concentrations.

The extent of the migration of the tailings seepage-impacted water is visible at Well 624, but not at Well SBL-01. Tracking the historical concentration of bicarbonate at Well 624 indicates when the tailings seepage front arrived at and was buffered by the alluvial material at the Well 624 location. The increase in bicarbonate at Well 624 starting in May 2000 and is attributed to the migration of the bicarbonate "front" associated with tailings seepage impact. However, the ground water at Well 624 does not show a corresponding increase in the concentration of dissolved uranium due to the presence of higher bicarbonate concentrations caused by buffering. Uranium dissolution and mobility is more favorable under conditions with higher concentrations of bicarbonate. The geochemistry at Well 624 shows no covariance between the bicarbonate and uranium concentrations. Covariance means that when two factors have a relationship to each other and one factor changes, there should be a change seen in the other factor also, either positive or negative. At least two interpretations are possible: (1) at this well location there is little to no adsorbed or precipitated uranium (i.e., solid phase) within the alluvial sediments; and/or (2) aqueous uranium that originated from upgradient tailings seepage impact has been attenuated during transport and has not reached this location.

The non-impacted samples from Well SBL-01 compared to samples from Well 624, the closest seepage-impacted well, are different in their respective geochemical quality. The geochemical quality at SBL-01 reflects the dissolution chemistry of when near neutral pH mine dewatering discharge infiltrated the SWA (magnesium sulfate water type + less bicarbonate). The geochemical quality at 624 reflects the dissolution-buffering chemistry when acidic tailings fluids contacted SWA material and was neutralized (calcium sulfate water type + more bicarbonate).

Like bicarbonate, sulfate concentrations are also greater within the core of the seepage-impacted areas of the SWA because sulfate concentrations from sulfuric acid in the tailings liquids were as much as two orders-of-magnitude greater (super saturated) than the concentrations in the seepage-impacted water. A significant amount of sulfate incorporated in the mineral form as gypsum ($CaSO_4$) had to precipitate from solution in proximity to the concentrated tailings liquids to cause the concentrations of sulfate to drop to levels that are in equilibrium with gypsum. Down gradient and outside of the seepage-impacted water, the dissolution of natural sources of gypsum (or anhydrite) in the alluvium produced sulfate in the background water at levels above the 1988 ROD standard. The general areas where sulfate concentrations are lower than the UNC Site standard of 2,125 mg/l are shown in Figure 14 with a stippled pattern. Sulfate concentrations are lowest in the area between the periphery of the tailings seepage front and the levels elevated above the UNC Site standard due to natural sources.

Historically, only two constituents sulfate and TDS exceed the UNC Site standards in the SWA seepage-impacted ground water outside the UNC property boundary (Sections 3 and 10). The majority of TDS is composed of sulfate ions so TDS concentrations mirror sulfate concentrations (Earth Tech, 2000d). Sulfate and TDS are non-hazardous constituents that also exceed ground water quality standards in the background water (Wells 627, EPA 28 and SBL-01) based on the proposed, revision to background values from the SWSFS Part I ProUCL 95 statistics. Sulfate tends to temporarily fall below the standard in the migrating reaction zone associated with seepage-impacted ground water in the SWA. Background concentrations for sulfate and TDS ahead of the seepage migration front tend to exceed the standards, which reflects local geochemistry and is not related to seepage impact. Behind this migrating front, seepage-impacted ground water quality tends to have sulfate and TDS levels approximately equal to, or lower than, those in the background water due to equilibration with the mineral gypsum.

Locally increasing trends in concentrations of TDS are unrelated to tailings seepage because they were derived from the reaction of the mine discharge water that recharged the original unsaturated alluvium. Evaluation and prediction of constituent concentrations in the SWA is predicated on understanding the geochemical evolution of both the background water quality and later changes associated with passage of the seepage-impact front. Hazardous constituents derived from seepage impact are effectively attenuated to acceptable concentrations within the UNC Site boundary. Both onsite and offsite ground water quality in the SWA meets the NRC GWPSs but not the EPA cleanup standards as identified in the 1988 ROD.

During the 2008-2012 period the SWA ground water monitoring data indicates that four major ion COPC concentrations (TDS, sulfate, manganese, and chloride) exceeded the 1988 ROD cleanup levels at Wells 801, EPA 23, and 509D. Based on long-term trends, exceedances are expected to continue at these wells. During the review period Well SBL-01 had exceedances of TDS, sulfate, manganese, cobalt, and nickel, but this well is outside (downgradient) of the seepage-impacted plume and is representative of background water quality at this down gradient location. Manganese is the only metal that has historically exceeded the cleanup level in seepage-impacted areas. For the remainder of the wells in the seepage-impacted area, manganese concentrations were below the cleanup level during the 2008-2012 review period. Wells 632, 801, GW-1, and GW-2 had some exceedances of lead-2010 in 2010.

Sulfate and TDS exceeded the 1988 ROD cleanup levels in both seepage-impacted water and the background water in the SWA. The highest concentration of sulfate (6,050 mg/l) of any well in the SWA was measured from Well SBL-01 in 2011. Only two wells, GW-1 and GW-2, showed any significant variation in sulfate and TDS levels since the shutoff of the extraction wells in January 2001. Sulfate levels in Well GW-1 increased modestly after shutoff until January 2002 and then leveled off. GW-2 sulfate concentrations remained unchanged after the extraction well shutdown in 2001 until early 2005 when they began to increase above 2,500 mg/l. Sulfate levels increased in GW-2 to a high of approximately 5,000 mg/l in 2009 when they began to decrease-fluctuate, and by October 2012 the concentration was 4,700 mg/l. TDS concentrations in GW-2 behave similar to the trend of sulfate, but they were at a level of about 5,000 mg/l after the SWA extraction system shut down and generally increased-fluctuated to a level of 8,730 mg/l by October 2012. Since the presence of TDS and sulfate are part of the natural geochemical processes in the ground water of the SWA, it is not clear if the fluctuations in concentrations are due entirely to the shut off of the extraction system or a combination of natural process and anthropogenic influence due to pumping. The most likely geochemical reaction for elevated levels of TDS and sulfate in ground water is from the dissolution and precipitation of naturally occurring gypsum and possibly anhydrite within the alluvium (Chester Engineers, 2013).

Finally, Wells 509D and GW-3 exceeded the NRC standard for uranium (0.30 mg/l) once in 2010 and 2012, respectively. There were no exceedances of the 1988 ROD 5.0 mg/l standard. In UNC's 2012 Annual Review Report (Chester Engineer, 2013), graphs are presented showing uranium concentrations over time for all of the wells in the SWA in an effort to show whether the discontinuation of pumping of Wells 801, 802, and 803 in January 2001 had any discernible effect on the long-term trend of uranium concentrations at wells within the zone of influence of the former pumping wells and down-gradient of those pumping wells. The historical uranium concentration graphs show that for those down-gradient wells in closest proximity to the extraction wells (i.e., GW-1, GW-2, and GW-3), uranium concentrations increased after shutdown in January 2001. As of October 2012, only wells GW-3 and 509D appear to show uranium concentration trends that are slightly increasing. The uranium concentration trend in GW-3 began to show a slightly increasing trend in 2009. Since the cessation of the SWA extraction system in 2001, the uranium concentration in Well 509D has been variable, but it appears to have a slightly increasing trend. Concentration trends of uranium in the SWA are the primary indicator that NA is at least as effective a remedy as pumping for the majority of monitoring wells. With the exception of POC Wells GW-3 and 509D, and the very slight increasing trend in non-POC Well EPA 25; uranium concentrations trends over the duration of monitoring have either stabilized or shown decreasing levels since the pumps were turned off. The increasing trend of concentrations at GW-3, 509D, and EPA 25 may not necessarily relate to the shutoff of the extraction system, and it is likely due to a combination of complex factors some of which may not be understood. For example, the saturated thickness (water column height) varies from 3.3 ft in GW-3 to 31.3 ft in 509D.

UNC's geochemical evaluation of the SWA concludes that NA will effectively retard the down-gradient movement of metals and radionuclides, including uranium by neutralizing the acidic tailings seepage and subsequently attenuating the metals and radionuclides by chemical precipitation and adsorption. In order for UNC to gain more technical and regulatory acceptance for NA as one of the remedial alternatives for the SWA and possibly the other hydrostratigraphic units, NMED asked the EPA if the monitoring information and investigative reports to date for the UNC Site were sufficient (personal communication with R. Ford, 2013 and R. Ludwig, 2013). NMED referenced an EPA technical guidance document for Monitored Natural Attenuation (MNA) of Inorganic Contaminants in Ground Water. Mr. Ford indicated that the guidance document was written in a broad manner to cover all types of sites and constraints. Much more geochemical and time dependent work along the flow path was required to better analyze and quantify the extent of NA in the contaminant plume at the UNC Site. Mr. Ludwig noted that to his knowledge there was not a single ground water contamination site in the US that had received official EPA acceptance for MNA of metals or radionuclides as a remedial alternative, and that the decision would likely be left to the regional EPA office that has jurisdiction of the UNC Site.

UNC's conclusion that concentrations of sulfate and TDS in seepage-impacted water, as well as background water, will continue to exceed the cleanup levels as long as the alluvium is saturated appears to be well supported. In as much as the sulfate and TDS concentrations largely result from the reaction of water with evaporite minerals in the formation, there are no remedial technologies known to be available to address these contaminants short of dewatering the alluvium.

6.2.3 Zone 3

The area of ground water currently impacted by tailings seepage in Zone 3 is shown on Figure 3. Figure 16 presents a map of the Zone 3 2012 monitoring well locations and the boundary of zero saturation which constitutes the eastern edge of the tailings seepage-impacted plume. The Zone 3 seepage plume extends north from the North Cell. The total length of the seepage-impacted area is approximately 6,400 ft long and variable in width from a minimum of 300 ft in the north to a maximum of 1,600 ft in the south. An inner core of acidic seepage-impacted water with a pH less than 4.0 occupies an area approximately 3,600 ft long by 300 ft wide. The extent of tailings seepage impact during October 2010 was approximated for Zone 3 at 62 acres and 14,418,720 gallons (Section 5.1). The North Cell is not a continuing source of tailings seepage and the tailings material has released all excess water by gravity drainage. The closest well to the North Cell, Well 106D was installed in 1980 and by late 1991 contained insufficient water for sampling. The next closest monitoring well to the North Cell is Well 613 which has only 28% of its original saturation with approximately 19 ft of water.

The rate of seepage-impacted water migration in Zone 3 has been calculated between wells based on the bicarbonate concentration which varies as the ground water and aquifer solid matrix react to neutralize the acid in the seepage water. An average seepage-impacted water travel time was estimated to be approximately 92 ft/yr until the end of 2008 when the northern edge of impact was determined to have reached Well NBL-01 (Chester Engineers, 2013). Since the end of 2008, there are no estimates of plume migration travel times in the northern area of Zone 3 because of the capture, extraction, injection, and mixing that occurs to bound the plume in this area. The NW series of extraction wells south of the Section 36 boundary have created a mixing zone of spatially variable water quality such that pH and bicarbonate concentrations are not able to distinguish a leading edge for calculating a plume migration rate between well locations. However, the rate of seepage-impacted water migration in Zone 3 is expected to be decreasing because there is no recharge, the saturated thickness is declining, and the injection of mill water at the north end has created a hydraulic barrier to decrease the migration rate even more. The prediction of seepage-impacted water migration was addressed in Section 5 by the ground water flow model.

The restart of the extraction system for Zone 3 began in 2003 with the Phase I hydraulic fracture pilot study. Seven recovery wells were installed in late 2004 and pumped to create a new extraction configuration designed to enhance dewatering of the seepage-impacted area, and remove constituent mass. These wells are located at or near the seepage-impacted front. Several of these recovery wells have fouled and were since taken off line. During the period of this review in late 2008, five new extraction wells were installed to help re-optimize the pumping scheme for Zone 3. In early 2009 an injection well feasibility testing and pilot study was performed. And in mid-2010 three more new extraction wells were installed. In April 2011 alkalinity-amended mill well water was injected to enhance neutralization of the tailings seepage. More detailed summaries of the Zone 3 extraction well system and injection program are provided in Sections 4.2.2 and 5.7 of this report. Figure 16 presents a map of the Zone 3 ground water monitoring well locations and the boundary of zero saturation which constitutes the eastern edge of the tailings seepage-impacted plume. Appendix B of the UNC Annual Review Report-2012 provides an excellent summary of Zone 3 extraction well installation and operational history.

Since 1989 the saturated thickness of Zone 3 has declined by 75% on average (from 60+ ft to less than 25 ft thick) and the hydrostratigraphic unit has been significantly dewatered by 23 years of remedial pumping (Chester Engineers, 2013). Water levels have declined by approximately 2 ft to 5 ft during this Five-Year report period. When saturated thickness falls to less than 25 ft, the well efficiency pumping rates decline significantly to less than 1.0 gpm (Earth Tech, 2001). By 2012, only one Zone 3 well (EPA-14) had a saturated thickness greater than 25 ft, but by the fourth quarter of 2012, only 23.6 ft remained. A comparison of the 2008 FYR and October 2012 ground water data indicates that the bulk of remaining tailings seepage-impacted ground water resides in the west-northwest part of Zone 3 because the extraction system has dewatered much of the seepage in the northeast part. The tailings seepage-impacted ground water is represented by the grayish blue-colored polygon in Figure 16. The seepage-impacted ground water continues to migrate slowly north along the dip of the bedrock unit (Gallup Sandstone) despite the years of extraction pumping. Hydraulic head, which is the sum of the elevation head and the pressure head, drives the flow of ground water northward. The effort to counteract the hydraulic head is reaching practical limits as the extraction system well efficiencies decrease, the wells become fouled, and are subsequently taken off line.

The estimated Zone 3 ground water flux along a 1,200 ft long west-northwest line between wells NBL-01 and PB-03 was 512 ft^3/day (2.7 gpm) during January 2005 (N.A. Water Systems, 2008c). This is roughly equal to the flow from a home garden hose turned on low, a very small amount of water over such a large area. The flux will continue to decrease over time in approximate proportion to the overall decrease in saturated thickness of the aquifer. It is not surprising that the Zone 3 extraction system has continued to decline in performance during the 2008-2012 period despite the efforts of UNC to maintain an active pumping operation. Most of the extraction wells pump at less than 0.5 gpm due to encrustation of the wellbore, precipitation of amorphous aluminosilicates, alteration of feldspars to clays in the sandstone matrix, and overall reduced saturated thickness. UNC has adjusted the extraction system to: minimize drawing in background water; pulling seepage-impacted water toward the west; and maximizing capture of the seepage-impacted water. The pumping configuration was adjusted in November 2009 and May 2012 to optimize capture of seepage-impacted ground water in the northern part of Zone 3. Despite the setbacks to the Zone 3 extraction system, the estimated volume of water removed by pumping from December 2007 through November 2012 is 7,349,430 gallons (Chester Engineers, 2013).

UNC injected a total of 426,363 gallons of alkalinity-amended mill well water at Well IWA from April 14, 2011, until shut down on June 29, 2012. One of the reasons to shut down IWA besides decreased capacity and the difficulty to maintain the injecting water level at 10 ft to 20 ft below ground level was the change in uranium concentration at nearby monitoring Well MW 6. From July 2011 to July 2012, the MW 6 uranium concentration increased from 0.082 mg/l to 0.312 mg/l. Explanations for the change in uranium concentration is possibly due to drawing-in background water from the west toward the east, or it was influenced by the sodium bicarbonate amended water which enhanced the aqueous form of uranium as a mobile uranyl carbonate.

UNC performed a two-stage investigation in 2004 to evaluate potential for the Central Cell to be a continuing source of tailings seepage and recharge to the updip part of Zone 3. In January 2004, UNC submitted the results of a historical data study undertaken to evaluate the potential for the covered tailings to continue as a source for the tailings seepage (US Filter, 2004). The report concluded that it was unlikely, but one area of concern required additional investigation using field data. In July 2004, two piezometers (Z3 M-1 and Z3 M-2) were constructed north of the northeast boundary of the Central Cell to check for saturation (See Figure 16). The piezometers were effectively dry and indicated that the southeasterly portion of the Zone 3 unit is entirely unsaturated at this location. UNC reported that such findings indicate that neither ground water recharge nor seepage impact into Zone 3 is occurring from the Central Cell (Veolia, 2004).

Remedy performance for Zone 3 since 1989 has been evaluated through review of the ground water monitoring data and the results obtained from various pilot-scale tests. As noted in Section 3, some contaminants are no longer monitored. As discussed above, the 1988 ROD nitrate value of 30 mg/l was used in this section of the review for a comparison value for compliance. It is noted that there are currently no exceedances of the NRC standard for nitrate.

Using the same methodology discussed above for the monitoring data review and geochemistry for the SWA, the presence of seepage-impacted ground water in Zone 3 is determined primarily based on the pH and bicarbonate concentrations at well locations. Seepage-impacted water is more prevalent toward the eastern limit of saturation and less prevalent toward the west. There is a central core of low pH water (5 to less than 3) in the main body of the seepage-impacted water, and the pH increases toward the margins of the impacted area as the ground water mixes with and is neutralized by the non-impacted background water. A significant drop in pH at the northern most downgradient well, Well NBL-01, in October 2011 from approximately 5.5 earlier in the year to less than 3.0 signaled the arrival of the tailings seepage at that location. The acidic pH core of the Zone 3 tailings seepage plume is represented by the orange-colored polygon in Figure 3. Seepage-impacted water in Zone 3, some of which exceeds the 1988 ROD cleanup standards, is contained within the property boundary in Section 36. The portion of seepage-impacted water that extends off the property in Section 1 (Figures 3 and 16) was eliminated as a POE because of limited saturation (Chester Engineers, 2013). The decision to eliminate the ground water in this area of Zone 3 as a POE is documented in a letter from the NRC (1999b). Overall, ground water quality in Zone 3 is variable and it has oscillated between degrading and improving trends since 2003.

Sulfate and TDS exceed the UNC Site cleanup standards because they are present at high concentrations in the seepage-impacted ground water and background water, and the physical action of removing water by pumping does not address the geochemical processes that occur in the water. The levels of TDS and sulfate in the Zone 3 are similar because sulfate is the dominant ion in the seepage-impacted water and it is present at similar levels in the background water. Sulfate concentrations in Zone 3 are also controlled by the geochemical equilibrium with gypsum (possibly anhydrite) and calcite, the same geochemical processes discussed for the SWA. The sulfate concentrations are highest in the area closest to the North Cell tailings area where the sulfuric acid levels are the strongest, but it quickly decreases in the downgradient direction. For instance, the sulfate level at Well 613 is approximately 9,000 mg/l and at Well NBL-01 the sulfate level is approximately 4,000 mg/l.

Zone 3 ground water monitoring well sample results for the 2008-2012 review period continues to show the presence of many COPCs at elevated concentrations. The monitoring data from a transect of seven Zone 3 monitoring wells along the ground water flow path from south to north (Wells 613, 517, EPA 14, 717, 420, 504B, and NBL-01) were examined to see how the COPC concentrations vary spatially in the down gradient direction toward the Section 36 boundary. The 2008-2012 period of data review indicates that the concentrations of 16 COPCs exceeded the EPA's cleanup levels. These are aluminum, arsenic, beryllium, cadmium, cobalt, manganese, molybdenum, nickel, vanadium, sulfate, TDS, TTHMs, combined radium, uranium, thorium-230, and gross alpha. The number of times a 1988 ROD COPC standard is exceeded is greatest in the southern half of Zone 3 (e.g. Well 613) and less frequent in the northern half (e.g. NBL-01). Most of the standards for metals are exceeded at the wells closest to the Tailings Disposal Cells. Standards for aluminum, cobalt, manganese, nickel, combined radium, lead-210, and gross alpha are the most commonly exceeded COPCs in the transect of wells from south to north.

Levels of metals including aluminum, arsenic, beryllium, cadmium, cobalt, manganese, molybdenum, nickel, uranium, and vanadium have historically exceeded the UNC Site 1988 ROD cleanup standards whether the source represents background or seepage-impacted water (Chester Engineers, 2013). However by 2012, only three metals (cobalt, manganese, and nickel) exceeded the 1988 ROD cleanup standards within the historic seepage-impacted area in all wells sampled in October 2012 except for Wells 613 and 420 which have elevated concentrations for multiple constituents.

Wells that have a strongly acidic pH (e.g. 613, EPA 14, 517, 504 B, and 717) are typically elevated in concentrations of trace metals and radionuclides like combined radium, uranium, vanadium, lead-210 and thorium-230 above Site standards. Well 613, which is closest to the North Disposal Cell, exceeded 15 standards during the review period for TDS, sulfate, TTHM, trace metals, and radionuclides. Well 613 has a persistent pH below 3.0 which supports an elevated uranium concentration of 0.989 mg/l in October 2012. Because the concentrations of hydrogen and sulfate ions are so high and the bicarbonate level is near zero, the uranium in Well 613 probably occurs in the form of a uranyl sulfate complex. This level of uranium is higher than the UCL95 of the background mean for uranium in Zone 3 at 0.107 mg/l (N.A. Water Systems, 2008f). Well 420, which has a higher pH level (pH = 6.72), only exceeded cleanup standards for uranium, combined radium, lead-210, and molybdenum during the 2008-2012 period. The metals concentration in some Zone 3 wells has stabilized at elevated levels due to the exhaustion of the neutralization capacity of the aquifer (e.g. Well 717 with no more bicarbonate). The levels of trace metals and radionuclides are present above the UNC Site cleanup standards because the sulfuric acid used in the milling process that was discharged to the tailings ponds and later infiltrated ground water is still very strong in the tailings seepage. The strong acidity of the seepage enables solublization and retention of trace metals and radionuclides as complexes of sulfate in the ground water as it migrates down gradient.

The concentration of combined radium exceeds the UNC Site standard for Zone 3 (5 pCi/L) in the background water and thus the radium in Zone 3 is never expected to meet the UNC Site standard. The UCL95 concentration of the background mean for combined radium is 10.66 pCi/L (N.A. Water Systems, 2008f, Table 5). At Well NBL-01 along the northern edge of the seepage- impacted water, the combined radium concentration in October 2012 was 11.5 pCi/L. This is the lowest value recorded since January 2005 over the 11 year period of monitoring since it was first installed in 2001. Well NBL-01 had a uranium concentration of 0.189 mg/l in October 2012 which is indicative of seepage-impacted water compared to the higher uranium concentration of 0.251 mg/l in October 2002 that represented the level in background water.

Seepage-impacted water began reaching NBL-01 in January 2004, and the sequence of geochemical processes that buffer the low pH water began. It appears the location of NBL-01 is in a position that contacts some of the strongest acidic seepage-impacted water because the October 2012 pH was 2.73 when in October 2011 it was 5.47.

Other COPCs that exceed Site standards include TTHM and lead-210. Only Well 613 had a TTHM concentration that exceeds the UNC Site standard of 0.080 mg/l in October 2012. Other Zone 3 wells (517, EPA-14, and 717) have detectable concentrations of TTHM in October 2012, but the low levels suggest the contaminant quickly attenuates in the downgradient direction. During the 2008-2012 period there were 36 detections of lead-210 in the transect of seven Zone 3 performance monitoring wells. The lead-210 standard is very close to the laboratory detection limit and most of the exceedances are likely due to a combination of laboratory quantitative analytical errors and reporting limits plus the naturally low background concentrations. The UCL95 background mean for lead-210 in Zone 3 is 1.618 pCi/L (N.A. Water Systems, 2008f, Table 5). At such low concentrations the exceedances are not inherently indicative of impact from the tailings seepage although at Well NBL-01 the 3.4 pCi/L of lead-210 in October 2012 is most likely considered to be from seepage since this well is deemed to be fully-impacted (Chester Engineers, 2013).

6.2.4 Zone 1

The Zone 1 seepage plume is estimated to contain 8.5 million gallons and occupy approximately 11 acres of area immediately east of the Central Cell. The plume currently extends approximately 700 ft east-west and approximately 1500 ft north-south based on the geochemical signature of chloride concentrations. Historically, parameters like pH, bicarbonate, sulfate, chloride, and TDS have been used collectively to track the presence and extent of seepage-impacted water in Zone 1. Based on the chloride concentrations in the ground water (greater than 50 mg/l), the overall extent of the seepage-impacted plume has gradually diminished since remediation began with the exception of the latest sampling event which included results from Wells 617 and 619. The Zone 1 performance monitoring system is comprised of 15 wells for water elevation measurement and eight wells for water quality sampling. Two additional wells, Wells 617 and 619 not included in the monitoring program since 2000, were sampled in October 2012 to provide supplemental information about ground water quality conditions close to the Central Cell where the concentrations of seepage-impacted water are greatest. Figure 17 presents a map of the Zone 1 seepage-impacted water, and 12 of the 15 performance monitoring well locations. Wells 412, 142, and 143 are located north of Well 504 A close to the northern boundary of Section 36. During the FYR period, eight wells in Zone 1 (Wells 142, 515A, 604, 614, EPA-2, EPA-4, EPA-5, and EPA-7) were monitored for water quality and comparison to cleanup standards.

The source of tailings seepage to Zone 1 is from the eastern part of the tailings Central Cell. The ground water flow direction in 1983 was generally east (azimuth 63°), but by October 2004 the flow direction was generally north (24° azimuth). This change in flow direction indicates the original ground water mound created by the Central Cell tailings seepage has dissipated due largely to the dewatering of Borrow Pit No. 2. The shift in the potentiometric surface reveals that the structural dip of the Zone 1 sandstone unit exerts the greater control on ground water flow direction. The hydraulic gradient from Well 614 to Well 142 is 0.013, or a one ft elevation drop for every 80 ft of distance. Most water levels elevations in Zone 1 continue to decrease, however, some down dip wells show a slight rise as ground water moves from an unconfined to a confined system under fully saturated conditions. The average water level decrease for Zone 1 during the current FYR is less than 0.5 ft. The rate of ground water drainage is also limited by the unit's relatively low transmissivity, and the very low transmissivity of the underlying aquiclude. In combination with the reduction in hydraulic head and the low transmissivity of the Zone 1 sandstone, the ground water velocity has dropped from approximately 93 ft/yr in 1983 to approximately 40 ft/yr in October 2007. A simple approximation of the ground water velocity required to extend the seepage-impact plume from Well 617 to Well 619 250 ft north in 12 years (2000 to 2012) yields a rate of 21 ft/yr.

The sampling of Wells 617 and 619 in October 2012 showed both wells exceeded 50 mg/l of chloride, and the seepage-impacted area depicted in Figure 17 was extended northward from Well 617 to include Well 619. At EPA-5, the chloride concentration has decreased from a maximum of 289 mg/l in 1992 to 40 mg/l in October 2012. The zone of seepage impact has migrated predominantly toward the northeast and the north-northeast. The eastward migration is limited by the proximity of the eastern edge of saturation. An acidic "core" of the seepage-impacted zone is assumed to exist close to the eastern edge of the Central Cell. Well 604 has persistently shown the lowest pH as it is the most highly seepage-impacted well in Zone 1. Starting in approximately 1990, acid neutralization and buffering resulted in substantial pH increases in Wells 515A, and EPA-7.

During the FYR period, all eight performance monitoring wells exceeded at least one of the 11 1988 ROD cleanup standards including TDS, sulfate, aluminum, cobalt, manganese, nickel, combined radium, lead-210, nitrate (above 30 mg/l), TTHM, and vanadium.

Sulfate and TDS concentrations exceeded the UNC Site standards in wells within the seepage-impacted ground water plume, and these COPCs concentrations were below standards downgradient of the plume (Wells 142 and EPA-2). The TDS within the plume typically ranged from 6,000 to 10,000 mg/l and sulfate ranged from 3,000 to 7,000 mg/l. At the downgradient wells TDS ranged from 1,000 to 3,000 mg/l and sulfate ranged from 550 to 1,900 mg/l. During this FYR period the 1988 ROD cleanup standard for nitrate (30 mg/l) was exceeded at Wells 604, 617, 614, 515A, and EPA-7. No wells in Zone 1 exceeded the NRC cleanup standard for nitrate (190 mg/l).

Three metals (manganese, cobalt and nickel) have historically exceeded the UNC Site standards within the seepage-impacted plume since the ground water extraction system was shutdown in

1999. Manganese concentrations exceeded the UNC Site standard in three wells (Wells 605, 515A, and EPA-7), but has continued to decrease overall since 1999. Manganese exceedances during the FYR period ranged from 2.66 mg/l to 18.8 mg/l (standard 2.6 mg/l). In October 2012, EPA-7 fell below the UNC Site manganese standard at 1.89 mg/l. At Well 604, the manganese concentration decreased from 9.12 mg/l in October 2008 to 5.36 mg/l in October 2012. At Well 515A, the manganese concentration decreased from 17.6 mg/l in October 2008 to 8.12 mg/l in October 2012.

Cobalt and nickel exceeded the UNC Site standards in three wells (Wells 604, 515A, and EPA-5) within the seepage–impacted plume when the ground water extraction system was shutdown in 1999. However, during this FYR period, cobalt was only detected above the UNC Site standard (0.05 mg/l) in Well 604 and has decreased from 0.22 mg/l in October 2008 to 0.15 mg/l in October 2012. Cobalt was also detected in the newly sampled well, Well 619, at 0.11 mg/l. Nickel concentrations ranged from 0.06 mg/l in Well EPA-5 to 0.25 mg/l in Well 604 in October 2012. Well 515A exceeded the standard for nickel throughout the current FYR period but decreased from a concentration of 0.02 mg/l in October 2008 to 0.013 mg/l in October 2012. Wells 617 and 619 exceeded the standard for nickel at 0.07 mg/l and 0.027 mg/l, respectively.

The Site standard for TTHM was exceeded at Wells 614 and 515A during this review period. During December 2008 UNC submitted to NRC an ACL application for TTHM and nickel in Zone 1 POC wells 614 and 604. NRC denied the request because the POE wells (EPA-5 and EPA-7) are located off the UNC property.

Sampling results for radionuclides during this FYR period indicated Wells 604, 617, 614, 619, 515A, EPA-2, EPA-5, and EPA-7 exceeded at least one Site standard. Combined radium exceeded the UNC Site standard of 5.0 pCi/L in wells within the seepage-impacted plume (Wells 604, 617, 614, 619, 515 A, and EPA-7) ranging in concentration from 5.06 pCi/L to 10.1 pCi/L. Combined radium exceeded the UNC Site standard at Well 614 in the first three quarters of 2012 but in October 2012 the level was 4.1 pCi/L. In addition, several wells close to or outside the plume (Wells EPA-5, EPA-4, and EPA-2) also had exceedances of combined radium ranging in concentration from 5.2 pCi/L to 8.9 pCi/L. Concentrations of lead-210 exceeded the UNC Site standard nine times among six wells. The highest detection of lead-210 was 6.1 pCi/L in Well 142 in January 2008, but this value is strongly suspected to be an outlier. Uranium, thorium-230 and gross alpha were not detected above the UNC Site standards in any well during this FYR period.

6.2.5 Conclusions

As concluded in the 2008 FYR, the 2013 FYR also concludes the remedy of ground water extraction and evaporation is not performing as designed because the remaining saturated thicknesses of the three hydrostratigraphic units and the low aquifer transmissivities do not support sustained pumping. Since mine dewatering ceased in 1986, there has been no recharge to Zones 1 and 3, and almost no recharge to the SWA. Sulfate and TDS levels within all three aquifers are not dependent on the continuation of pumping, but are controlled by natural geochemical reactions, primarily the equilibrium of gypsum or anhydrite. There is no known remedial technology to achieve the standards for sulfate and TDS, short of dewatering the aquifers. The operational results and performance monitoring data suggest that it is technically impracticable to achieve all of the cleanup levels within a reasonable time frame by the existing remedy because of geochemical conditions and physical limitations. Review of the performance monitoring data for the three UNC hydrostratigraphic units suggests the three units share commonalities with regard to reducing COPC levels to Site standards: NA; decreasing aquifer saturation; bicarbonate levels delineate seepage-impacted water; TDS; and sulfate are technically impracticable to remediate; most COPC Site standard exceedances are within the UNC Site boundary; and lead-210 increases are within background levels and do not necessarily reflect tailings seepage impact.

In the SWA, the only contaminants that exceed the current cleanup levels beyond the Tailings Disposal Area are sulfate, TDS, and manganese. However, these three constituents exceed the cleanup levels in both seepage-impacted and background wells. The SWA successfully attenuates the seepage-impacted water. Acidic seepage is being neutralized (buffered) by reactions with calcium carbonate, resulting in the attenuation of metals and radionuclides through chemical precipitation and adsorption. Uranium does not exceed the current cleanup level of 5 mg/l, but exceeds the newly promulgated EPA MCL of 0.03 mg/l throughout most of the seepage-impacted area. UNC has shown that uranium and bicarbonate concentrations are covariant in the SWA ground water (GE, 2006). UNC has concluded that uranium concentrations are not related to the migration of uranium in tailings fluids, but change when the bicarbonate levels within the alluvium change (i.e., uranium concentrations increase when bicarbonate levels increase). UNC has also concluded that the tailings solutions are far more depleted in uranium than are the post-mining/pre-tailings background waters (N.A. Water Systems, 2008). However, since the bicarbonate levels in the SWA increase when the acidic tailings liquid react with the carbonate-bearing minerals present within the alluvium, the resulting increase in uranium concentrations is nevertheless attributed to the seepage-impacted water.

Whether or not such seepage impact-related increases in uranium levels are relevant to remedial efforts for the SWA may depend on whether they exceed the post-mining, pre-tailings background uranium concentration or range of concentrations rather than the new MCL of 0.03 mg/l for uranium. UNC provided summary statistics for uranium and, based on those statistics, concluded that the post-mining, pre-tailings background range of uranium concentrations exceeds the new MCL and is similar to the range of the seepage-impacted water (GE, 2006). Subsequent statistical analysis by UNC in 2008 that is summarized and presented in Section 5 above indicates the background concentrations of uranium in the SWA exceeded the comparison values. UNC concluded that there is no further improvement in alluvial water quality that can be made with respect to uranium concentrations (Chester Engineers, 2013).

The shutdown of the SWA extraction well system for the NA test in January 2001 appears to have resulted in temporary increase of uranium levels at the GW series wells, the nearest down-gradient wells to the extraction wells. The uranium level in GW-3 displays an overall increasing trend with an initial increase after extraction well shut down (0.060 mg/l) then a leveling off from about 2004-2008 followed by an increasing trend since early 2009 through 2012 (0.150 mg/l). GW-1 and GW-2 uranium concentrations also indicate an initial increase after extraction well shut down (0.050 mg/l) then a leveling off followed by a slight increase or decrease depending on individual well location. The recommendations for the SWA in the 2012 Annual Review Report include: reducing the ground water sampling frequency from quarterly to annual; approving the TI waiver for TDS and sulfate; and adoption of the UPL95 BTVs as NTE values for future monitoring programs.

Since 1989 the saturated thickness of Zone 3 has declined by 75% on average and the hydrostratigraphic unit has been significantly dewatered by 23 years of remedial pumping (Chester Engineers, 2013). Once the saturated thickness decreases to approximately 25 ft or less, well efficiency pumping rates decline significantly to less than 1.0 gpm (Earth Tech, 2001). It is not surprising that the Zone 3 extraction system of wells has continued to decline in performance during the 2008-2012 period despite the efforts of UNC to maintain an active pumping operation. UNC attempts to the maintain the Zone 3 extraction system includes: a 2003 Phase I hydraulic fracture pilot study; installation of seven new recovery wells in late 2004; installation of five more new extraction wells in late 2008; injection well feasibility testing in early 2009; installation of three more new extraction wells in 2010; and addition of alkalinity-amended mill well water from April 2011 through July 2012. Currently the extraction system is operating using various wells with an average total flow rate of less 1 gpm.

The ground water quality in Zone 3 is variable and it has oscillated between degrading and improving trends since 2003. Seepage-impacted water is more prevalent toward the eastern limit of saturation and less prevalent toward the west. There is a central core of low pH water (5 to less than 3) in the main body of the seepage-impacted water, and the pH increases toward the margins of the impacted area as the ground water mixes with and is neutralized by the non-impacted background water. UNC has adjusted the extraction system to: minimize drawing in background water; pulling seepage-impacted water toward the west; and maximizing capture of the seepage-impacted water. The pumping configuration was adjusted in November 2009 and May 2012 to optimize capture of seepage-impacted ground water in the northern part of Zone 3. The efficiency of the Zone 3 extraction system is expected to decrease over time. Therefore, criteria needs to be developed for terminating pumping which could be based on a mixture of 60:40, seepage-impacted water to background water. When the ratio of seepage-impacted water drops and the contribution of background water rises beyond the 60:40 ratio, the pumping should be terminated.

Ground water monitoring data collected since the last FYR in 2008 for Zone 3 continues to show the presence of several contaminants at elevated concentrations. The 2007 ground water monitoring found that the concentrations of 16 contaminants exceeded the EPA's cleanup levels. These are aluminum, arsenic, beryllium, cadmium, cobalt, manganese, molybdenum, nickel, vanadium, nitrate, sulfate, TDS, radium-226 and radium-228, uranium, thorium-230, and gross alpha. Most of the standards for metals are exceeded at the wells closest to the Tailings Disposal Area. However, the concentrations of seven contaminants (cobalt, manganese, molybdenum, nickel, sulfate, TDS, and radium-226 and radium-228) exceeded the cleanup levels at monitoring well 504B, the furthest most down-gradient well within the seepage-impacted area.

In Zone 3 levels of metals including aluminum, arsenic, beryllium, cadmium, cobalt, manganese, molybdenum, nickel, uranium and vanadium have historically exceeded the UNC Site standards whether the source represents background or seepage-impacted water (Chester Engineers, 2013). UNC calculated background concentrations as the 95^{th} percentile upper prediction limits (UPL95s) for the constituents in the NRC License GWPSs and 1988 ROD contaminant standards (UNC, 2012; and Chester Engineers, 2012e). All wells sampled in October 2012 within the seepage-impacted area continue to show exceedances of cobalt, manganese, and nickel except for Well 420. Exhaustion of the neutralization capacity has stabilized the concentrations of metals at elevated levels in some wells (e.g. Well 717). Concentrations of uranium, vanadium, and thorium-230 are typically present above the UNC Site standards in Well 613 which has a persistent low pH and is located closest to the North Cell. The concentration of combined radium exceeded the UNC Site standard for Zone 3 (5 pCi/L) in the background water and thus the radium in Zone 3 is never expected to meet the UNC Site standard.

A Zone 3 ground water flow model simulation shows that the background water occupies a large area of Zone 3 between the down-gradient pre-mining water and the seepage-impacted ground water. The seepage-impacted water is marginalized between the eastern edge of the extent of saturation and the hydraulic mound on the west created as background ground water from mine dewatering discharge. The model is a predictive tool that can be used to predict the current and future dispositions of ground water especially for any hypothetical interactions with the tailings seepage-impacted water with pumped wells. Verification wells will need to be installed to reduce the uncertainty of the model and to inform the optimal locations for sentinel wells.

In Zone 1 the ground water flow direction in 1983 was generally to the east, but by 2007 the flow direction was generally to the north as the tailings seepage mound beneath the east side of the Central Cell dissipated. The shift in the potentiometric surface reveals that the structural dip of the Zone 1 sandstone unit exerts the greater control on ground water flow direction. Most water levels elevations in Zone 1 continue to decrease, however, some down dip well water levels are rising as ground water migrates from an unconfined to a confined system under fully saturated conditions. The Zone 1 seepage-impacted water quality is typically high in metals, radionuclides, and major ions like sulfate and chloride. The geochemical processes from neutralization, NA, and mixing have reduced many COPC concentrations below Site standards.

During the 2008 to 2012 period, Site standards are exceeded onsite in Zone 1 for TDS, sulfate, manganese, cobalt, nickel, TTHM and chloride. Contaminants that exceed the current cleanup levels outside of the Tailings Disposal Area boundary are cobalt, nickel, sulfate, TDS, and manganese. The only well that showed an exceedance outside the UNC Site boundary in October 2012 was Well EPA-5 with a nickel concentration of 0.06 mg/l when the NRC GWPS is 0.05 mg/l. The seepage-impacted water is being attenuated in Zone 1. Acidic seepage is being neutralized within the Zone 1 aquifer, resulting in attenuation of most metals and radionuclides. Since the Zone 1 extraction system was shut off in 1999, the water quality of Zone 1 has slowly improved, or stabilized, however, some of the seepage-impacted area has expanded for a couple of COPCs.

In summary, all of the cleanup levels established in the 1988 ROD have not been attained in the three hydrostratigraphic units and are not expected to be attained within a reasonable time frame. However, there is no known human exposure to contaminated ground water at the UNC Site. In Appendix A of the 1988 ROD, under Contingencies for Selected Remedy, it was anticipated that the remedy might not be effective at achieving the cleanup levels within a reasonable time frame. The 2003 FYR recognized the need to explore other contingencies or alternatives for remediating Site ground water and recommended a SFS. UNC completed Parts I and II of the SWSFS which included a screening analysis of remedial alternatives, a statistical review of the background and impacted monitoring data, and an updated baseline HHRA. Part III of the SWSFS is pending the 2012 NRC license amendment request for revised GWPSs based on the updated background concentrations from the ProUCL95 statistical analysis. Part III will evaluate the six GRAs that were retained from the screening analysis that includes: no further action; ICs; containment; extraction; passive treatment with wells; and hydraulic barriers. This SWSFS will be used to support future decision-making on remedy modification, revision to cleanup levels and invoking a TI waiver for certain chemical-specific ARARs, if appropriate. The current Zone 3 hydraulic control is temporary, and like the SWA and Zone 1 units, administrative regulatory tools are necessary to effectively manage the areas of seepage-impacted ground water including: ACLs; TI waivers; MNA, and ICs.

The 1988 ROD COPC levels for arsenic, cobalt, manganese, molybdenum, nickel, and uranium should be revised according to the background concentrations for these metals that are unique for each of the three hydrostratigraphic units. Future ground water performance compliance monitoring programs for the UNC Site should consider adoption of the UPL95 NTE values.

6.3 Site Inspection

The Site Inspection was conducted on April 18, 2013. Those in attendance included representatives from UNC, GE, NMED, and EPA. The Site Inspection Checklist and photographs documenting Site conditions are found at Attachments 5 and 6, respectively. The purpose of the UNC Site Inspection was to obtain familiarity with the UNC Site, review the records, examine the extraction and treatment systems and associated documentation, assess the protectiveness of the remedy, and conduct interviews with representatives of key stakeholders.

The following areas were visited; 1) the main office, 2) the Zone 3 wells, 3) the Zone 1 wells, 4) the Tailings Disposal area, 5) the SWA wells, and 6) the bedrock outcrop exposed within Pipeline Arroyo (known as the "Nickpoint"). It was noted that on-Site staff monitors visitors. They also take measures to identify livestock belonging to local residents that may enter the UNC Site looking for grazing. The existing fencing is intended to discourage livestock. There was no evidence of unauthorized development or construction activities. Monitoring and extraction wells appeared to be in good condition. Apart from Pipeline Arroyo there was no evidence of erosion or slope failure. Native vegetation has established itself on the radon barrier and protective rock cover placed on top the tailings disposal cells. A fence and locked gates surround the Tailings Disposal area. Barriers and warning signs surrounded the evaporation pond within the tailings impoundment area. Overall the UNC Site appears to be well managed.

Both full-time and part-time employees work at the UNC Site. One employee residence is located on the UNC Site near the former milling building. Both the residence and the UNC Site use bottled water for drinking. An on-Site well drilled into the Westwater Formation, well below the Gallup Formation, supplies other domestic uses.

6.4 Interviews

Interviews for this FYR were conducted by NMED and EPA. NRC, GE, NNEPA, DOE, and the local community were interviewed. Representatives of NRC, DOE, UNC and GE declined to be interviewed directly by NMED, but did provide written statements to EPA's interview questions with the exception of UNC. UNC felt their responses would be identical to GE's and thus they declined to duplicate those responses because they would be redundant. The information discussed below are based on the interviews and written responses. Those interviewed are listed Table 23.

Those interviewed expressed no indication of problems related to the current protectiveness of the remedy. But opinions were expressed regarding concerns and possible improvements.

Mr. Eugene Esplain with the NNEPA expressed that the cleanup of the NECR Mine Site was the priority concern for Navajo Nation and that the ground water issue at the UNC Mill Site has dropped significantly in priority and concern. Mr. Esplain suggested that greater effort should be devoted to community public education, outreach, and meetings with the local residents. The topic of in-situ uranium mining south of the UNC Site is a major concern to local residents and this can result in unfavorable impressions regarding the UNC Site activities.

Ms. Yolande Norman with the NRC also had a generally overall favorable impression of the project. She noted the Navajo community may have an unrealistic expectation that the remedy will completely remove all contamination from the ground water.

The DOE Office of Legacy Management expressed their role under the UMTRCA, and anticipates that they will become the general licensee under NRC for the UNC Site. After Site transfer, the DOE will perform long-term surveillance and maintenance within the UNC Site boundaries under UMTRCA and 10 CFR 40.28. DOE recognizes that the remedy to remediate contaminated ground water has not been successful, and that the Zone 3 plume is expected to migrate north of the Section 36 boundary. The UNC Site will need to achieve ground water compliance with EPA standards prior to site transfer, and active ground water remediation will not be required to maintain compliance. DOE is aware that the community is very concerned about the quality of drinking water and potential impacts from site operations, but there appears to be no complete exposure pathways to contaminated ground water at this time. DOE commends and appreciates efforts shown to-date by site regulators to provide the DOE with opportunities to become informed about the UNC Site's ground water cleanup activities and progress.

Mr. Roy Blickwedel with GE expressed the opinion that the existing remedy has generally been effective and it has been protective of human health and the environment. He also noted that the active ground water extraction systems as required in the 1988 ROD for all three hydrostratigraphic units has been discontinued with regulatory approval from both the NRC and the EPA because they were no longer effective. Alternative remedy enhancements have been utilized in Zone 3 but none have been successful in enhancing the effectiveness of the remedy for very long. UNC voluntarily continues pumping in Zone 3 although at consistently declining rate. In all three target areas, further ground water pumping will have no additional beneficial effect on achieving cleanup goals beyond the natural processes that are occurring.

Mr. Blickwedel also expressed concerns regarding the EPA's failure to act on UNC's TI waiver recommendation and NA proposal. He also suggested that it is time to focus the remedy on the tailings seepage, while bearing in mind the limits to what can be attempted with the ground water in Zone 3 due to the low permeability of the formation. Mr. Blickwedel encouraged the EPA to advance the process towards a conclusion. From GE's perspective, it is clear that the current remedy has reached the limits of effectiveness for Zone 1 and the SWA. UNC believes that EPA should complete the analysis of NA and TI Waivers for Zone 1 and the SWA, and make decisions with respect to their acceptability in accordance with NCP procedures. For Zone 3, it will be necessary to change the remedial goals and/or to invoke other administrative controls for the CERCLA process to attain closure and for the UNC Site to be transferred to the DOE for long-term stewardship. UNC believes it is time to re-invigorate discussions with Navajo Nation for ICs and the development of an alternative water supply should they not have access to viable supplies either for stock watering or domestic consumption because of the naturally poor water quality in the region.

The community members expressed concerns regarding the NECR Mine cleanup and proposed in-situ uranium mining industry in general. The EPA has met with local residents to discuss their concerns primarily related to the NECR Mine soil proposed cleanup plan. Regarding the UNC

Site, they lack confidence about the knowledge of the ground water contamination issues and they expressed the need for education sessions that work at their technical level to help them understand the UNC Site. Many residents feel that current health problems are linked to contamination from this or other sites in the area.

Interview record forms are provided in Attachment 6.

7.0 TECHNICAL ASSESSMENT

The FYR must determine whether the UNC Site remedy is protective of human health and the environment. The EPA guidance provides three questions that are used to organize and evaluate data and information, and to ensure that all relevant issues are considered when determining the protectiveness of a remedy. These questions are answered for the UNC Site in the following sections. Section 7 is concluded with a summary of the technical assessment.

7.1 Question A: Is the remedy functioning as intended by the decision documents?

7.1.1 Remedial Action Performance and Operations

No, the ground water remedy is not functioning as intended. The remedy was implemented and operated as specified in the 1988 ROD. The remedies for tailings and mill reclamation (described by the NRC Reclamation Plan), that support the ground water remedy, have been implemented as specified, with the exception of final closure and installation of the radon barrier over the South Cell that will occur after the ground water remediation is complete and the evaporation ponds are removed.

As discussed in Section 4, ground water extraction is no longer occurring, except in Zone 3, therefore the overall Site ground water remedial action is no longer operating and functioning as designed. The remedial action performed as expected until the ground water extraction well systems were determined to have reached the limit of their effectiveness. The ineffectiveness is due either to a loss in saturation from insufficient recharge (Zone 1 and Zone 3), or an inability to achieve some of the cleanup levels because contaminant levels are not dependent on pumping, but instead controlled by natural geochemical reactions. One geochemical reaction in particular is the pervasive equilibrium between the ground water and naturally occurring gypsum or anhydrite (Zone 1, Zone 3 and SWA). In light of these limitations, the extraction systems were turned off for the SWA and Zone 1 aquifers.

The Zone 3 extraction system was restarted in 2003 as part of the hydraulic fracturing pilot test and it has continued to be operated on a limited basis. The Zone 3 pumping configuration has been modified several times over the life of the system in an attempt to achieve hydraulic containment of the continually-advancing seepage-impacted front and removal of contaminated ground water at successively down-gradient locations at the edge of the advancing front. UNC recognizes that this effort will not completely stop the advance of the seepage-impacted front at this time, but hopes it will slow it down and lessen its impact to uncontaminated, down-gradient water. The pumping effort in 2005 and 2006 was found to temporarily arrest the advance of the seepage-impacted front and even reverse it, before pumping rates declined to levels which were ineffective at establishing hydraulic containment (N.A. Water Systems, 2008). It must be noted that the hydraulic head that drives the flow of ground water comprises the elevation head plus the pressure head. The elevation head is a result of the structural tilting (i.e., dipping) of the stratigraphic units to the north, which causes the ground water to flow northward. The long history of pumping in Zone 3 has reduced the pressure head, but cannot reduce the dip-related elevation head. The continued pumping has been helping in the short-term, but saturated thicknesses in this formation are quite low and there will eventually be no further reduction in the pressure head. As the well yields decrease to levels that do not support pumping, the reduction in head will gradually approach practical limits (N.A.Water Systems, 2008). At some time in the future, UNC estimates that a balance will be reached between the tendency for irreducible elevation head to drive the continued northward migration of the seepage-impacted water and the tendency for the seepage-induced permeability reductions from the alteration of feldspar minerals to kaolinitic clay to stop the movement of the ground water. However, although this condition should occur to stop the advancement of the seepage-impacted front, the exact timing and location for this critical balance to be achieved cannot be predicted (Chester Engineers, 2013). The ground water flow model should prove beneficial in predicting the disposition of seepage-impacted water into the future.

Although UNC concludes that uranium, as well as the other metals and radionuclides, are naturally attenuating within the SWA, based on the results of the NA system performance evaluation; the data show that the discontinuance of the pumping system has led to increases in uranium from levels observed before the extraction wells were shut off at some wells located down-gradient. Hence, the extraction system appears to have been somewhat effective at reducing uranium mass levels beyond the Tailings Disposal Area. Whether such effort could achieve the newly promulgated MCL for uranium of 0.03 mg/l, if established as an ARAR for the UNC Site by the EPA in future decision-making, must be assessed. In addition, whether or not the elevated uranium is background or related to seepage impact water must be considered in future decision documents.

The cleanup levels have not been achieved for all of the contaminants in any of the three aquifers, nor does UNC believe that they can be achieved with the existing remedy selected by the EPA for the reasons discussed above and in Section 6.

7.1.2 Opportunities for Optimization

While there may be opportunities to optimize the existing remedy, the geochemical and physical conditions and limitations of the aquifers which result in declining ground water levels and pumping rates, reduced permeability from alteration of the formation by acidic tailings seepage, and the elevated concentrations of sulfate and TDS associated with gypsum/anhydrite equilibrium reactions make it unlikely. It seems more likely that fundamental remedy changes, if any, will be addressed more holistically during completion of the SWSFS.

7.1.3 Implementation of Institutional Controls

The 1988 ROD did not formally establish any ICs; however certain enforcement documents, governmental controls, and informational controls are in place. UAO, Docket No. CERCLA 6-11-89 (issued on June 29, 1989), remains in force and it requires ground water remediation. In addition, the UNC Site Source Materials License No. SUA-1475 remains in effect. It requires that the UNC Site be managed to prevent contaminant exposure, including exposure to those contaminants in the ground water. Restrictions to the use of the on-site ground water will continue after the License is terminated by the NRC and the property is turned over to the DOE for long-term care and surveillance monitoring. However, there are currently no ICs restricting the use of seepage-impacted ground water that has advanced beyond the NRC Licensed Site boundary in Sections 2, 10, 3 and on Navajo Trust land to the north of Section 36. Informational controls such as signs are found near the Tailings Disposal Area. Barbed-wire fence (with “No Trespassing” signs) surround the UNC Site.

No proprietary controls establishing land use restrictions are in place. However, discussions continue regarding their potential utility and effectiveness. It is likely that some form of land and/or ground water use control will become necessary to ensure long-term protectiveness, by preventing exposure to contaminated ground water that has migrated off-Site.

It should be noted that UNC provided a Draft Resolution and Environmental Right-of-Way Procedures to the NNEPA and the U.S. Department of Justice (Davis, Graham & Stubbs, LLP, March 23, 2001). This document presented a draft Tribal Resolution to define ICs in certain seepage-impacted areas in the SWA in Section 3 and Section 10, and in Zone 1 of the Gallup Formation in Section 1. The draft resolution has not been acted upon.

The approximate areas covered by the proposed ICs are shown on Figure 18. The ICs would cover approximately 40 acres of Navajo Trust lands in Sections 3 and 10, and individual allotments, if necessary. The ICs for Section 1 would cover approximately 35 acres located in the northwest corner of the section. Grazing and surface activities would not be affected by the ICs. UNC also provided the procedures to establish an environmental right-of-way under the U.S. Department of Interior (DOI) regulations. The duration of the right-of-way would be 50 years, subject to right of renewal. In the Draft Resolution, UNC has proposed to drill a water supply well into the underlying Dakota formation. The Dakota is a higher yielding and better water-quality aquifer in comparison to the ground water aquifers in the Gallup Formation and the alluvium.

It is noted that in a letter to the EPA, dated September 3, 2003, the NNEPA stated that it did not recommend the use of ICs on any projects, especially Superfund activities where ground water is impacted. The NNEPA also stated that it does not have a mechanism in place to enforce the ICs and that a permanent staff would be required to oversee the project. Further, it stated that a lack of funds might hinder the establishment of such an oversight program for ICs. The EPA has since engaged in further substantial discussions with the NNEPA and BIA on the question of ICs; but as noted above, agreement on the utility and necessity of ICs has not been achieved. The EPA intends to continue to examine the IC issue, which it plans to address in the SWSFS.

7.2 Question B: Are the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives (RAOs) used at the time of remedy selection still valid?

As shown in the protectiveness evaluation (Attachment 8), changes have occurred in a number of MCLs. Additionally, background evaluations for select contaminants have been conducted post-1988 ROD by UNC and others. However there has been no formal EPA decision-making to change cleanup levels to reflect any proposed new background concentrations, so the original background concentrations remain in effect as cleanup levels for some contaminants. Criteria at the UNC Site are based on federal or New Mexico standards, and do not originate in a risk assessment. The MCLs or EPA Region 9 Preliminary Remedial Goals (PRGs) TBC health based criteria) for 12 contaminants have changed since the 1988 ROD was prepared. Eight of these values have been reduced and four have increased. Section 5 presents Contaminant Specific Ground Water Cleanup Levels and Other Comparison Values for the UNC Site and also presents comparison values for NMWQCC standards, EPA health based standards, EPA MCLs, NRC GWPS, the 1988 ROD standards, and other criteria.

There have been no changes to land use and no drinking water wells have been installed near the UNC Site. Therefore, there is no current exposure pathway and, hence, the remedy remains protective in the short term. However, the long-term protectiveness of the remedy is contingent upon achieving protective cleanup levels within the aquifers. The new federal MCLs and PRGs identified above are based on updated toxicological information and, therefore, are considered by the EPA to be protective. To ensure the long-term protectiveness of the remedy, it is recommended that these new MCLs and PRGs be evaluated for potential as revised ARARs and TBCs for this Site and lead to the modification of the cleanup levels in future EPA decision-making. It should be noted that some of the changes made to the federal MCLs and PRGs are, or may be, below Site background concentrations and would, therefore, not be appropriate requirements or TBC material. In such cases, the background concentration would be selected as the cleanup level in lieu of the new or revised standard or criterion.

The RAOs (Operable Unit Feasibility Study goals, EPA 1988) were described as follows:

- contain down-gradient contaminant migration within each target area;

- restore ground water down-gradient of the Tailings Disposal Area, to the maximum extent practicable, to meet the cleanup criteria; and

- restore ground water at the Tailings Disposal Area to a level that allows attainment of cleanup criteria at its boundary.

The RAOS are still considered to be valid objectives. However, as discussed above, it has not been possible to completely achieve the RAOs. For these and other reasons it will probably be necessary to modify the remedy to achieve the RAOs.

7.3 Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

No other information has come to light that could affect the protectiveness of the remedy. There are no new risks or previously unidentified risks that could affect performance or protectiveness of the remedy. There are no natural disasters that could affect performance or protectiveness of the remedy.

8.0 ISSUES

Issues related to the current Site operations, conditions, and activities that may prevent the remedy from being protective are listed in Table 24.

9.0 RECOMMENDATIONS AND FOLLOW-UP ACTIONS

Required and suggested Follow-up Action to current Site operations and activities are presented in Table 25.

10.0 PROTECTIVENESS STATEMENTS

The remedy at OU1 (the final source remedy) currently protects human health and the environment in the short term. Actions taken have minimized potential human exposures to contaminants found in the ground water and reduced the potential for the repository tailings to act as a source of ground water contamination. For the remedy to be protective in the long term, the following actions need to be taken:

1. Evaluate and revise the estimated background contaminant levels at the UNC Site and reevaluate UNC Site cleanup standards (*i.e.,* remediation goals) through the NCP decision-making process.

2. Complete the ongoing SWSFS Part III to develop and analyze remedial alternatives.

3. Continue the experimental efforts to create a subsurface hydraulic barrier in Zone 3 to slow down and contain the migration of the seepage-impacted water in the northern subsurface area.

4. Determine whether the Southwest Alluvium (SWA) extraction wells have provided improvement in ground water quality with respect to uranium contamination when compared to Natural Attenuation (NA).

5. Evaluate the use of various mechanism(s) of Natural Attenuation (NA) in the SWA for uranium as well as for other COCs in all hydrostratigraphic zones as part of the ongoing remediation effort to attain cleanup standards.

6. Renew efforts to establish ICs that will help protect human health by restricting the use of contaminated ground water on affected Navajo Nation, Tribal Trust, and Indian Allotment lands.

7. Evaluate whether a Technical Impracticability (TI) waiver is appropriate for the Applicable or Relevant and Appropriate Requirements (ARARs) related to sulfate and TDS. This evaluation would be done as part of the ongoing SWSFS, Part III.

8. Evaluate the anthropogenic origin and the transient nature of the artificially created ground water aquifers impact on future EPA ground water decision making.

The remedy at OU2 is expected to be protective of human health and the environment upon completion. In the interim, remedial activities completed to date have adequately addressed all exposure pathways that could result in unacceptable risks in these areas.

Because the remedial actions at both OUs are currently protective of human health and the environment, the UNC Site's remedy is and remains protective in the short term.

11.0 NEXT REVIEW

The next FYR will be due in September 2018.

TABLES

Table 1 - Chronology of Events for UNC and NECR Sites	
Event	**Date**
UNC & Kerr McGee mine discharge operations infiltrate Southwest Alluvium, and Gallup Sandstone Zone 1, & Zone 3 aquifer units. This ground water is designated “premining-premilling” water & it also functions as some of the “background” water for future comparisons & investigations.	1967-1986
UNC & Kerr McGee receives National Pollution Discharge Elimination Permits (NPDES) to release mine water to unnamed arroyo leading to Pipeline Canyon Arroyo. Estimated 37 billion gallons of water discharged & 600 tons of uranium released over life of mining operations.	January 1975
EPA 906/9/9-75-002 report released documenting NECR Mine discharge water elevated in radium & uranium above NPDES limits.	September 1975
UNC milling operations begin under license from state of New Mexico Radiation Protection Bureau	May-June 1977
New Mexico Environmental Improvement Division (NMEID) learned that seepage from UNC Mill Site posed a threat to ground water quality.	Prior to 1979
Retention dam on UNC south tailings disposal cell breached & released an estimated 93 million gallons of acidic mill tailings water & sediment to Pipeline Canyon / Rio Puerco River. EPA Region 6 and NMEID respond to contaminant release.	July 1979
NMEID orders UNC to perform cleanup of Rio Puerco contaminated areas to 3 pCi/g of Ra-226, Th-230, & Pb-210 where possible.	August 13, 1979
NMEID orders UNC to implement discharge plan to control contaminated Tailings seepage into subsurface around evaporation-disposal ponds	November 9, 1979
UNC sampled off site monitor well TWQ-124 & results indicated that Th-230 level exceeded NM Radiation Protection Regulations beyond the restricted area of the licensed facility. Other non-radiological constituents were degrading off site ground water quality.	October 28, 1980
EPA begins discussions with UNC over the need for a ground water investigation of tailings seepage from mill site that follows the CERCLA Process (Comprehensive, Environmental Response, Compensation and Liability Act or Superfund Act of 1980).	February 19, 1982
EPA informs UNC that the mill site has been placed on Interim Priority List for hazard ranking analysis, a measure that is used in the process to consider a site for the National Priority List (NPL) or Superfund. UNC milling operations begin under license from state of New Mexico Radiation Protection Bureau.	April 2, 1982
UNC announces mill closing due to depressed uranium market.	May 1982
EPA provides UNC with final AOC developed in coordination with NMEID. UNC did not sign the AOC.	November 8, 1982
EPA performs Field Investigation Team (FIT) inspection sampling of tailings solution, surface water, and ground water at UNC Site.	November 8 & 15, 1982
UNC mill site ground water plume placed on the National Priorities List (NPL) of Superfund Sites due to off-site migration of radionuclides and chemical constituents in ground water.	1983

Table 1 - Chronology of Events for UNC and NECR Sites	
Event	**Date**
EPA conducts Remedial Investigation (RI) field activities to determine the nature& extent of ground water contamination in the three water-bearing formations at the Site.	March 1984-August 1987
In 1984, UNC blocked EPA access to the Church Rock facility, and EPA brought an action to compel site access. UNC counterclaimed seeking declaratory and injunctive relief. U.S. District Court granted an EPA motion to dismiss the UNC counterclaims, &UNC provided access to the Site to EPA. *United States v. United Nuclear Corporation,* 610 F Supp. 527, 528 (D.N.M., 1985).	April 18, 1985
NMEID relinquishes regulatory program for uranium mill site licensing of the U.S. Nuclear Regulatory Commission (NRC).	June 1986
EPA and NRC sign Memorandum of Understanding (MOU) coordinating EPA's CERCLA ground water remedial action with NRC's reclamation & closure activities under the Source Materials License & the Uranium Mill Tailings Radiation Control Act (UMTRCA) for Title II sites.	August 26, 1988
EPA releases RI - Feasibility Study (FS) report along with proposed plan of action field sheet.	August 1988
EPA issues a Record of Decision (ROD) describing the remedy to address UNC contaminated water beyond the boundaries of the tailings disposal cells by extraction-evaporation of ground water.	September 30, 1988
UNC submits Remedial Design Report.	April 1989
Remedial action implemented in Zone 1 – Borrow Pit No. 2.	April 1989
EPA issues Unilateral Administrative Order (UAO) Docket No. CERCLA 6-11-89 to UNC requiring UNC to implement the Site CERCLA ground water operable unit remedy determined by the ROD.	June 29, 1989
Remedial action implemented in Zone 3 – 12 new extraction wells begin pumping.	August 1989
Remedial action implemented in Southwest Alluvium – 3 new extraction wells begin pumping.	October 1989
Ground Water Corrective Action Annual Review 1989 documents remedial action construction completion.	December 1989
United States had brought action against UNC in 1991 for response cost recovery under CERCLA; and in late 1992, the U.S. District Court issued an opinion and order granting a U.S. motion for partial summary judgment on the issue of costs and denying a UNC cross motion for summary judgment. *United States v. United Nuclear Corporation*, 814 F Supp. 1552 (D.N.M., 1992).	December 28, 1992
NRC issues a background water quality study that recommends higher concentrations of background constituents than presented in the ROD.	1996
GE completes acquisition of UNC Inc.	1997
First Five-Year Review completed.	September 24,

Table 1 - Chronology of Events for UNC and NECR Sites	
Event	**Date**
	1998
NRC, EPA, and NMED approve the decommissioning of 10 Zone 3 wells, 3 Zone 1 wells, and 1 Southwest Alluvium well because they meet the decommissioning criteria of producing less than 1 gallon per minute (gpm).	July 30, 1999
NRC approves eliminating the Section 1 portion of Zone 3 as a point of exposure.	September 16, 1999
UNC submits request to terminate all Zone 3 pumping and for Technical Impracticability waiver to EPA, NRC and NMED.	May 2000
All but three Zone 3 wells decommissioned in accord with criterion.	June 2000
EPA approves UNC's request to shut down remaining three Zone 3 wells to slow seepage migration rate.	November 2000
License Amendment No. 31 allows UNC to temporarily suspend the corrective action pumping in Zone 3.	December 29, 2000
UNC submits Draft Tribal Resolution and Environmental Right-of-Way to the Navajo Nation to form basis for ICs.	March 2001
EPA gives UNC approval to temporarily shut down Southwest Alluvium extraction wells and an 18-month Natural Attenuation Test is conducted.	February 2001 through July 2002
UNC submits Final Report and Technical Impracticability Evaluation – Southwest Alluvium Natural Attenuation Test to EPA, NRC and NMED.	November 2002
UNC submits proposal to conduct hydraulic fracturing pilot test.	May 21, 2003
UNC conducts the hydraulic fracturing pilot test in Zone 3.	June 2003
Second Five-Year Review completed.	September 18, 2003
UNC submits Final Report – Hydraulic Fracturing Pilot Test Results and Preliminary Full-Scale Design, United Nuclear Church Rock Facility.	December 2003
EPA comments on the Final Report – Hydraulic Fracturing Pilot Test Results and Preliminary Full-Scale Design and directs UNC to perform supplemental feasibility study (SFS) for Zone 3.	March 10, 2004 and March 19, 2004
EPA approves Final Report - Hydraulic Fracturing Pilot Test Results and Preliminary Full-Scale Design.	May 21, 2004
UNC conducts the Phase 1 full-scale hydraulic fracturing test in Zone 3.	September 2004
UNC installs well SBL-01 in Section 10, Southwest Alluvium.	October 2004
UNC submits the draft SFS for Zone 3 for review.	October 27, 2004
EPA disapproves draft SFS for Zone 3 and directs UNC to perform a Site-wide SFS (SWSFS) consistent with the NCP.	June 24, 2005
Meeting between EPA, UNC, NRC, NMED, and NNEPA to discuss the SWSFS. UNC generally	August 17, 2006

Table 1 - Chronology of Events for UNC and NECR Sites	
Event	**Date**
expresses its opposition to the feasibility study process.	
Meeting between EPA, NNEPA, BIA and NMED in Window Rock, AZ, to discuss feasibility of ICs restricting the use of contaminated ground water.	January 18, 2006
Meeting between EPA and NNEPA in Dallas, TX, to continue discussions on ICs.	March 16, 2006
EPA approves in-situ alkalinity stabilization pilot study for Zone 3.	May 12, 2006
EPA directs UNC to perform the SWSFS in writing, stating that the feasibility study is appropriate and necessary.	June 23, 2006
Meeting between EPA, NNEPA, BIA, and NMED in Albuquerque, NM to continue discussions on ICs.	August 21, 2006
UNC submits the draft List of Preliminary Assembled Remedial Alternatives for the SWSFS.	September 2006
UNC begins the in-situ alkalinity stabilization pilot study in Zone 3. The study is completed in February 2007.	October 2006
UNC submits the draft SWSFS, Part 1, Church Rock Remediation Standards Update.	February 2007
UNC submits In-Situ Alkalinity Stabilization Pilot Study Report.	June 2007
EPA disapproves SWSFS, Part 1, Church Rock Remediation Standards Update and requires revision to address written comments.	January 25, 2008
Meeting between EPA, NMED, NRC, NNEPA and UNC to discuss status of remedial activities. UNC notifies regulatory agencies that pumping of hydraulic fracture wells in Zone 3 was unsuccessful in stopping migration of seepage-impacted ground water. UNC proposes to submit a plan for additional extraction wells for Zone 3.	March 12, 2008
UNC submits summary of hydrogeologic analysis evaluation of ground water flow and recommended plan for additional extraction wells for interception and recovery of seepage-impacted ground water in Zone 3.	April 2008
UNC submits white paper on statistics to address some of EPA comments on the SWSFS, Part 1.	May 2008
EPA notifies NRC of approval of UNC's recommendation for additional extraction wells.	June 2008
UNC submits initial report on calculation of background statistics and comparisons to ARARs for the UNC Church Rock Mill and Tailings Site (aka revised SWSFS, Part I).	August 28, 2008
Third Five Year Review completed.	September 17, 2008
EPA accepts revised SWSFS Part I, Remediation Standards Update and gives approval for UNC to proceed with SWSFS Part II: Development and Screening of Remedial Alternatives.	February 11, 2009
EPA Region 6 conducts community meeting at Pinedale Chapter House to give an update on the UNC 2008 Five Year Review.	May 5, 2009
UNC-GE letter to NRC on Technical Impediments to Site Closure at the Church Rock Mill Site (lack of consensus, unattainable cleanup standards, & complex issues related to statistics and geochemistry).	May 20, 2009
EPA Region 9 releases Northeast Church Rock (NECR) Engineering Evaluation/Cost Analysis (EE/CA) report for non-critical time removal of NECR mine waste. The preferred	June 11, 2009

Table 1 - Chronology of Events for UNC and NECR Sites	
Event	**Date**
alternative for disposition of NECR Mine waste is disposal at an NRC-licensed facility namely the UNC Mill Site tailings disposal ponds.	
UNC submits report entitled, The Remedial Design: Conceptual Approach to Enhanced Remediation in Zone 3-New Injection Wells combined with Existing Extraction Wells.	May 17, 2010
UNC-GE submits NRC License SUA-1475 Amendment request for revised dates to complete ground water corrective actions (*12-31-2013*) & to install final radon barrier & erosion protection cover on tailings pond (*12-31-2014*).	September 1, 2010
EPA provides UNC-GE with combined agency comment-approval letter (EPA, NRC, NMED, NNEPA) on SWSFS Part II dated July 2009, and general considerations-requirements to proceed with Part III.	September 2, 2010
UNC submits revised version of the Updated Baseline Human Health Risk Assessment.	March 4, 2011
UNC submits revised versions SWSFS Part I and Part II.	April 26, 2011
EPA Region 9 provides regional assessment report on ground water quality in/around UNC-NECR Mill facilities.	September 2011
UNC provides report on the Hydrogeologic Assessment of Injection at Zone 3 Well IW-A through September 2011 to EPA and NRC.	November 1, 2011
UNC submits to NRC, "License Amendment Request Revised Ground Water Protection Standards Based On Updated Background Concentrations Source Material License SUA-1475 Ground Water Corrective Action Program United Nuclear Corporation Church Rock Tailings Site."	April 21, 2012
UNC provides Final Version of the Updated Baseline Human Health Risk Assessment for the Church Rock Site in order to: 1) update risk estimates for the Site using current risk assessment methods-information; 2) support reassessment of remediation levels; 3) compare remedial alternatives; & 4) identify Point of Compliance (POC) & Point of Exposure (POE) concentrations in accordance with NRC requirements.	August 2012
EPA Region 6 provides UNC with acceptance letter for Updated Baseline Human Health Risk Assessment (August 13, 2012 version).	September 11, 2012
UNC provides ground water flow model report of the Church Rock Site & local area for three genetic classes of ground water to support decision-making for future Zone 3 ACL applications.	October 2012
EPA issues Record of Decision (ROD) for the Site Surface Soil Operable Unit Alternative 2 preference for disposal of NECR mine waste at UNC Mill Site tailings evaporation ponds under NRC license SUA-1475.	March 2013
EPA issues technical memorandum letter regarding results for background water quality parameter levels using ProUCL.	March 2013

Table 2 - Projected Monitoring Well Dryness Dates for Each Hydrostratigraphic Unit				
Well Number	**Start Date of Monitoring**	**Ground elev. (ft)**	**Total depth (ft)**	**Projected Dry Date**
Southwest Alluvium				**Average = 2060**
0509 D	11/24/1981	6947.69	110	2049
0624	9/18/1984	6898.16	85	2057
0627	9/20/1984	6891.81	78	2038
0632	4/17/1985	6901.74	85	2046
0801	8/24/1989	6900.85	61.5	2025
0802	8/25/1989	6904.02	82	2062
0803	8/23/1989	6921.49	123	2085
0808	6/14/1991	6908.80	132	2114
EPA 23	2/14/1985	6923.06	140	2084
EPA 25	2/2/1985	6900.58	72	2044
EPA 28	2/12/1985	6915.16	90	2043
GW 1	11/15/1976	6914.46	80	2037
GW 2	11/15/1976	6910.37	95	2067
GW 3	11/11/1976	6908.97	80	2018
SBL-01	7/12/2004	6894.53	63.65	2125
Zone 3				**Average = 2046**
0420	3/25/1981	6981.72	170	2015
0504 B	11/12/1981	6999.98	172	2038
0517	4/14/1982	6968.02	111	2035
0613	8/11/1983	6958.38	96	2065
0708	5/24/1989	7010.38	172	2029
0711	5/9/1989	7040.00	206	2091
0717	5/30/1991	6970.16	153	2031
0719	6/7/1991	7000.40	178	2020
EPA 13	2/22/1985	7030.47	197	2117
EPA 14	2/8/1985	6962.61	145	2026
NBL-01	7/23/2001	6988.60	204	2040
NBL-02	3/27/07	6974.61	187.25	2027
Zone 1				**Average = 2050**
0142	9/7/1980	6981.50	320	Not Applicable
0515 A	11/23/1981	7007.08	116	2036
0604	4/15/1982	7004.33	121	2043
0614	8/2/1984	7011.03	126	2040
EPA 02	12/3/1984	7016.91	200	2079
EPA 04	1/12/1985	7066.30	240	2074
EPA 05	1/6/1985	7008.54	142	2044
EPA 07	2/23/1985	7008.66	172	2023
Notes: Projected dry dates represent the estimated year in which declining well water levels reach the base of the screen. Elevations are in feet above mean sea level. Total depths are in feet below ground.				

Table 3 - UNC 1988 ROD Clean-up Levels and Contaminants Exceeding Clean-up Levels					
Contaminant	**Value**	**Units**	**Exceeds ARARs**		
			SWA[1]	**Zone 3**	**Zone 1**
Aluminum	5	mg/L		X	X
Antimony	0.014	mg/L			
Arsenic	0.05	mg/L		X	X
Barium	1	mg/L			
Beryllium	0.017	mg/L			
Cadmium	0.01	mg/L	X	X	X
Chromium	0.05	mg/L			
Cobalt	0.05	mg/L	X	X	X
Copper	1	mg/L			
Iron	5.5	mg/L			
Lead	0.05	mg/L			
Manganese	2.6	mg/L	X	X	X
Mercury	0.002	mg/L			
Molybdenum	1	mg/L	X	X	X
Nickel	0.2	mg/L	X	X	X
Selenium	0.01	mg/L	X	X	X
Silver	0.05	mg/L			
Thallium	0.014	mg/L			
Vanadium	0.7	mg/L			
Zinc	10	mg/L			
Chloride	250	mg/L			
Sulfate	2160	mg/L			
Nitrate	30	mg/L	X	X	X
Total Dissolved Solids (TDS)	3170	mg/L	X	X	X
Radium 226 & radium-228	5	pCi/L		X	
Uranium-238	5 or 1645	mg/L pCi/L			
Thorium-230	15	pCi/L			
Gross Alpha	15	pCi/L	X	X	X

Notes:

1. SWA = Southwest Alluvium.
2. mg/L = milligram per liter, pCi/L = picocurie per liter.
3. EPA clean-up levels represent NMWQCC standards for Aluminum, Cobalt, Copper, Molydenum, Nickel, Zinc, Chloride, and Uranium.
4. EPA clean-up levels represent MCLs for Arsenic, Barium, Cadmium, Chromium, Lead, Mercury, Selenium, Silver, Radium-226, Radium-228, Thorium-230, and Gross Alpha; numerically identical NMWQCC standards existed for Barium, Cadmium, Chromium, Lead, Mercury, and Silver.
5. EPA clean-up levels represent background levels for Iron, Manganese Sulfate, Nitrate, and TDS.
6. EPA clean-up levels represent health-based criteria for Antimony, Beryllium, Thallium, and Vanadium.
7. Although some NMWQCC standards and MCLs are numerically identical, the state standards represent dissolved concentrations, while the federal MCLs represent total concentrations.

Table 4 - UNC ROD Clean-up Levels, NRC Standards, and Contaminant Exceedances Identified in UNC's 1989 Remedial Design Report						
Contaminant	**ROD Clean-up Level**	**NRC Standard**	**Units**	**Exceeds Clean-up Levels or Standards**		
				SWA[1]	**Zone 3**	**Zone 1**
Aluminum	5	None	mg/L	-/na	CL/na	CL/na
Antimony	0.014	None	mg/L	-/na	-/na	-/na
Arsenic	0.05	0.05	mg/L	-/-	CL/S	CL/S
Barium	1	None	mg/L	-/na	-/na	-/na
Beryllium	0.017	0.05	mg/L	-/-	-/S	-/S
Cadmium	0.01	0.01	mg/L	CL/-	CL/S	CL/S
Chromium	0.05	None	mg/L	-/na	-/na	-/na
Cobalt	0.05	None	mg/L	CL/na	CL/na	CL/na
Copper	1	None	mg/L	-/na	-/na	-/na
Iron	5.5	None	mg/L	-/na	-/na	-/na
Lead	0.05	0.05	mg/L	-/S	-/S	-/-
Manganese	2.6	None	mg/L	CL/na	CL/na	CL/na
Mercury	0.002	None	mg/L	-/na	-/na	-/na
Molybdenum	1	None	mg/L	CL/na	CL/na	CL/na
Nickel	0.2	0.05	mg/L	-/S	CL/S	CL/S
Selenium	0.01	0.01	mg/L	CL/S	CL/S	CL/S
Silver	0.05	None	mg/L	-/na	-/na	-/na
Thallium	0.014	None	mg/L	-/na	-/na	-/na
Vanadium	0.7	0.1	mg/L	-/-	-/S	-/-
Zinc	10	None	mg/L	-/na	-/na	-/na
Chloride	250	None	mg/L	-/na	-/na	-/na
Sulfate	2160	None	mg/L	-/na	-/na	-/na
Nitrate	30	None	mg/L	CL/na	CL/na	CL/na
Total Dissolved Solids (TDS)	3170	None	mg/L	CL/na	CL/na	CL/na
Radium 226 & radium-228	5	5	pCi/L	-/S	CL/S	-/S
Uranium	5	0.3	mg/L	-/-	-/S	-/-
Thorium-230	15	5	pCi/L	-/S	-/S	-/S
Gross Alpha	15	15	pCi/L	CL/S	CL/S	CL/S
Lead-210	None	1	pCi/L	na/-	na/S	na/S
Chloroform	None	0.001	mg/L	na/-	na/S	na/-
Cyanide	None	0.005	mg/L	na/S	na/S	na/S
Naphthalene	None	0.001	mg/L	na/-	na/S	na/-

Notes:

1. SWA = Southwest Alluvium.
2. Exceeds Clean-up Levels or Standards.

CL= exceeds EPA's clean-up level.
S = exceeds NRC's standard.
"-" = no exceedance.
"na" = no EPA clean-up level or NRC standard established.
mg/L milligram per liter
pCi/L = picoCurie per liter.

Table 5 - Comparison of UNC 1988 ROD Clean-up Levels and NRC Standards with Current Monitoring Program						
Contaminant	**ROD Clean-up Level**	**NRC Standard**	**Units**	**Current Monitoring Program**		
				SWA[1]	**Zone 3**	**Zone 1**
Aluminum	5	None	mg/L		X	X
Antimony	0.014	None	mg/L			
Arsenic	0.05	0.05	mg/L		X	X
Barium	1	None	mg/L			
Beryllium	0.017	0.05	mg/L	X	X	X
Cadmium	0.01	0.01	mg/L	X	X	X
Chromium	0.05	None	mg/L			
Cobalt	0.05	None	mg/L		X	X
Copper	1	None	mg/L			
Iron	5.5	None	mg/L			
Lead	0.05	0.05	mg/L	X	X	X
Manganese	2.6	None	mg/L	X	X	X
Mercury	0.002	None	mg/L			
Molybdenum	1	None	mg/L	X	X	X
Nickel	0.2	0.05	mg/L	X	X	X
Selenium	0.01	0.01	mg/L	X	X	X
Silver	0.05	None	mg/L			
Thallium	0.014	None	mg/L			
Vanadium	0.7	0.1	mg/L	X	X	X
Zinc	10	None	mg/L			
Chloride	250	None	mg/L	X	X	X
Sulfate	2160	None	mg/L	X	X	X
Nitrate	30	None	mg/L	X	X	X
Total Dissolved Solids (TDS)	3170	None	mg/L	X	X	X
Radium-226 & radium- 228	5	5.2 (SWA) 5.0 (Z-3) 9.4 (Z-1)	pCi/L	X	X	X
Uranium	5	0.3	mg/L	X	X	X
Thorium-230	15	5	pCi/L	X	X	X
Gross Alpha	15	15	pCi/L	X	X	X
Lead-210	None	1	pCi/L	X	X	X
TTHM	None	0.080	mg/L	X	X	X
Cyanide	None	0.005	mg/L			
Naphthalene	None	0.001	mg/L			

Notes:
1. SWA = Southwest Alluvium.
2. Chloroform replaced with total trihalomethane (TTHM). The TTHM MCL is 0.080 mg/L.
3. "X" = contaminant in the current monitoring program.
4. mg/L = milligram per liter, pCi/L = picoCurie per liter.

Table 6 - Summary of Early Well Series and Purpose for the UNC Site Prior to the 1985 EPA RI and 1988 ROD Remedy	
Well Series Designation	**Purpose**
TWQ-1	water quality & elevation monitoring
GW-1	permanent monitoring wells
300	observation
400	hydrologic barrier
500	observation
600	northeast pump back wells

Table 7 - Zone 3 Performance Monitoring Program, 2012 Operating Year (Table 9, 2012 Annual Review Report)

Well	Water Level	Water Quality	NRC POC	Purpose
Continue Monitoring				
420	X	X		Post mining-pretailings background, track plume.
711	X	X	Y	Track saturation and plume, replace 502 B based on results of low flow purge testing performed in January 2000.
504 B	X	X		Track saturation and plume, extensive data set.
517	X	X	Y	Track plume, extensive data set.
EPA 9	X			Extent of saturation, water quality not necessary.
EPA 13	X	X		Extent of saturation. Water quality added 2nd quarter 2001.
EPA 14	X	X		Post mining-pretailings background, track plume.
702	X			Water level only, track saturation.
710	X			Water level only.
712	X			Water level only.
713	X			Water level only.
714	X			Water level only.
613	X	X	Y	Extensive data set, track saturation and source.
701	X			Water level only (decommissioned pumper).
706	X			Water level only (decommissioned pumper).
707	X			Water level only (decommissioned pumper).
708	X	X	Y	Added to program 2nd quarter 2001.
717	X	X		Water level. Water quality added 2nd quarter 2001.
719	X	X		Water level. Water quality added 2nd quarter 2001.
Additional Wells, Not Included In Original Performance Monitoring Program				
402	X			Long-term water level for migration path.
424	X			Long-term water level for migration path.
446	X			Long-term water level for migration path.
NBL-01	X	X		Well drilled and installed June 2001. Water level and water quality to track downgradient extent of seepage.
Total	**23**	**11**		
Eliminated From Monitoring				**Reason For Elimination**
9 D				Dry
106 D				Dry
411				Oil, cannot get water level or sample.
501 B			Y	Dry
EPA 1				Dry
EPA 3			Y	Dry
EPA 11				Unusable since 1990 - water level below pump, pump cemented in well.
EPA 12				Dry
EPA 15				Dry
EPA 17				Dry
EPA 18				Dry
126				Dry
502 B				Failed low-flow test, use 711
518			Y	Failed low-flow test, use 517
608				Not needed (formerly water level only)
703				Not needed (formerly water level only)
715				Not needed (formerly water level only)
709				Not needed (decommissioned pumper)
716				Not needed (pumper)
718				Not needed (pumper)
720				Not needed (decommissioned pumper)

Notes:
NRC POC = Nuclear Regulatory Commission Point of Compliance well.
Source: Earth Tech, Dec. 2002, Table 3.2

Table 8 - Zone 1 Performance Monitoring Program, 2012 Operating Year (Table 15, 2012 Annual Review Report)				
Well[1]	Water Level[2]	Water Quality[2]	NRC POC	Purpose
Continue Monitoring				
515 A	X	X		Track transition area
604	X	X	Y	Track center of seepage
614	X	X	Y	Track transition area
EPA 2	X	X		Post mining-pretailings background water quality
EPA 4	X	X	Y	Post mining-pretailings background water quality
EPA 5	X	X	Y	Track transition area
EPA 7	X	X	Y	Track transition area, edge of saturation
EPA 8	X			Track edge of saturation
142	X	X		Premining background
143	X			Water level only, use 142
Additional Wells, Not Included In Original Performance Monitoring Program				
505 A	X			Long-term water level for migration path
502 A	X			Long-term water level for migration path
501 A	X			Long-term water level for migration path
504 A	X			Long-term water level for migration path
412	X			Long-term water level for migration path
Total	**15**	**8**		
Eliminated From Monitoring				**Reason For Elimination**
141				No longer useable, plugged during arroyo flooding
516 A			Y	Failed low-flow testing
619				Anomalous water quality and water level
615				Decommissioned pumper, not needed - use 515 A
616				Decommissioned pumper, not needed - use 604
617				Decommissioned pumper, not needed
Notes: 1. No wells within the tailings reclamation cap were included. 2. Water level and water quality monitored on a quarterly basis.				

Table 9 - SWA Performance Monitoring Program, 2012 Operating Year (Table 1B 2012 Annual Review Report)				
Well	**Water Level**	**Water Quality**	**NRC POC**	**Purpose**
Continue Monitoring				
420	X	X		Post mining-pretailings background, track plume.
711	X	X	Y	Track saturation and plume, replace 502 B based on results of low flow purge testing performed in January 2000.
504 B	X	X		Track saturation and plume, extensive data set.
517	X	X	Y	Track plume, extensive data set.
EPA 9	X			Extent of saturation, water quality not necessary.
EPA 13	X	X		Extent of saturation. Water quality added 2nd quarter 2001.
EPA 14	X	X		Post mining-pretailings background, track plume.
702	X			Water level only, track saturation.
710	X			Water level only.
712	X			Water level only.
713	X			Water level only.
714	X			Water level only.
613	X	X	Y	Extensive data set, track saturation and source.
701	X			Water level only (decommissioned pumper).
706	X			Water level only (decommissioned pumper).
707	X			Water level only (decommissioned pumper).
708	X	X	Y	Added to program 2nd quarter 2001.
717	X	X		Water level. Water quality added 2nd quarter 2001.
719	X	X		Water level. Water quality added 2nd quarter 2001.
Additional Wells, Not Included In Original Performance Monitoring Program				
402	X			Long-term water level for migration path.
424	X			Long-term water level for migration path.
446	X			Long-term water level for migration path.
NBL-01	X	X		Well drilled and installed June 2001. Water level and water quality to track downgradient extent of seepage.
Total	23	11		
Eliminated From Monitoring				**Reason For Elimination**
9 D				Dry
106 D				Dry
411				Oil, cannot get water level or sample.
501 B			Y	Dry
EPA 1				Dry
EPA 3			Y	Dry
EPA 11				Unusable since 1990 - water level below pump, pump cemented in well.
EPA 12				Dry
EPA 15				Dry
EPA 17				Dry
EPA 18				Dry
126				Dry
502 B				Failed low-flow test, use 711
518			Y	Failed low-flow test, use 517
608				Not needed (formerly water level only)
703				Not needed (formerly water level only)
715				Not needed (formerly water level only)
709				Not needed (decommissioned pumper)
716				Not needed (pumper)
718				Not needed (pumper)
720				Not needed (decommissioned pumper)

Notes:
NRC POC = Nuclear Regulatory Commission Point of Compliance well. Source: Earth Tech, December 2002, Table 3.2.

Table 10 – Southwest Alluvium Saturated Thickness, October 2012 (Table 3, 2012 Annual Review Report)				
Well	**Water Level Measurement Date**	**SWA Unsaturated Thickness**	**SWA Saturated Thickness**	**SWA Percentage Saturated**
0509 D	10/8/2012	78.70	31.30	28%
0624	10/9/2012	51.89	23.11	31%
0627	10/9/2012	59.29	11.71	16%
0632	10/8/2012	44.55	22.45	34%
0801	10/8/2012	50.03	10.47	17%
0802	10/8/2012	47.88	33.62	41%
0803	10/8/2012	62.96	55.04	47%
0805	10/18/2012	50.25	69.75	58%
0807	10/18/2012	55.84	44.16	44%
0808	10/8/2012	49.53	82.47	62%
EPA 23	10/8/2012	53.90	66.10	55%
EPA 25	10/9/2012	52.40	17.60	25%
EPA 28	10/9/2012	61.80	16.20	21%
GW 1	10/8/2012	61.30	15.70	20%
GW 2	10/8/2012	55.09	34.91	39%
GW 3	10/9/2012	53.68	3.32	6%
SBL-01	10/9/2012	48.92	16.08	25%

Table 11 – Zone 3 Saturated Thickness, October 2012 (Table 10, 2012 Annual Review Report)				
Well	Water Level Measurement Date	Zone 3 Unsaturated Thickness	Zone 3 Saturated Thickness	Zone 3 Percentage Saturated
0402	10/19/2012	47.56	15.44	25%
0420	10/16/2012	46.84	4.16	8%
0424	10/30/2012	8457.31	15.69	21%
0446	10/18/2012	58.18	6.82	10%
0504 B	10/16/2012	NA	<1.73[1]	NA
0517	10/15/2012	51.88	10.12	16%
0613	10/9/2012	49.04	18.96	28%
0701	10/18/2012	48.46	15.54	24%
0702	10/18/2012	72.64	8.36	10%
0703	10/18/2012	73.35	18.65	20%
0706	10/18/2012	62.47	15.53	20%
0707	10/18/2012	76.79	11.21	13%
0708	10/15/2012	71.95	13.05	15%
0709	10/18/2012	65.67	11.33	15%
0710	10/18/2012	70.12	10.88	13%
0711	10/15/2012	66.95	18.05	21%
0712	10/18/2012	81.57	4.43	5%
0713	10/18/2012	64.69	8.31	11%
0714	10/19/2012	23.44	14.56	38%
0715	10/18/2012	26.12	8.88	25%
0716	10/18/2012	48.51	15.49	24%
0717	10/16/2012	52.93	18.07	25%
0718	10/18/2012	33.12	1388	30%
0719	10/16/2012	39.22	5.78	13%
EPA 09	10/15/2012	46.27	3.73	7%
EPA 13	10/15/2012	56.61	7.39	12%
EPA 14	10/9/2012	49.35	23.65	32%
MW-2	10/18/2012	49.83	10.60	18%
MW-3	10/19/2012	50.09	10.83	18%
MW-4	10/19/2012	NA	<2[1]	NA
MW-5	10/19/2012	NA	<2[1]	NA
MW-6	10/17/2012	40.90	6.81	14%
MW-7	10/16/2012	36.35	18.12	33%
NBL-01	10/16/2012	33.75	10.56	24%
NBL-02	10/16/2012	53.47	24.10	31%
NW-1	10/16/2012	40.51	3.78	9%
NW-2	10/16/2012	37.47	13.65	27%
NW-3	10/16/2012	35.22	22.59	39%
NW-4	10/16/2012	42.76	7.60	15%
NW-5	10/16/2012	35.09	22.92	40%
PB-02	10/16/2012	38.96	8.64	18%
PB-03	10/16/2012	34.52	12.45	27%
PB-04	10/16/2012	36.18	10.82	23
RW-11	10/16/2012	49.91	11.93	19
RW-15	10/18/2012	NA	<4.9[1]	NA
RW-16	10/18/2012	59.68	3.42	5

Table 11 – Zone 3 Saturated Thickness, October 2012 (Table 10, 2012 Annual Review Report)				
Well	**Water Level Measurement Date**	**Zone 3 Unsaturated Thickness**	**Zone 3 Saturated Thickness**	**Zone 3 Percentage Saturated**
RW-17	10/18/2012	68.71	4.52	6
RW-A	10/16/2012	55.72	12.15	18
Z3 M-01	10/18/2012	43.13	2.71	6
Z3 M-02	10/18/2012	43.89	2.38	5
IW-A	10/15/2012	38.69	9.02	19
NA = not available [1] = Dry Well.				

Table 12 – Zone 1 Saturated Thickness, October 2012 (Table 16, 2012 Annual Review Report)				
Well	**Water Level Measurement Date**	**Zone 1 Unsaturated Thickness**	**Zone 1 Saturated Thickness**	**Zone 1 Percentage Saturated**
TWQ-142	10/16/2012	0.00	55.00	100%
TWQ-143	10/19/2012	0.00	52.00	100%
0412	10/19/2012	0.00	76.00	100%
0501 A	10/18/2012	10.38	54.62	84%
0502 A	10/18/2012	0.00	59.00	100%
0504 A	10/18/2012	7.56	60.44	89%
0505 A	10/18/2012	0.00	46.00	100%
0515 A	10/10/2012	28.55	12.45	30%
0604	10/10/2012	25.98	19.02	42%
0614	10/10/2012	23.67	21.33	47%
0617	10/10/2012	39.31	6.69	15%
0619	10/16/2012	26.90	38.10	59%
EPA 02	10/15/2012	21.32	28.68	57%
EPA 04	10/15/2012	19.01	35.99	65%
EPA 05	10/15/2012	30.05	18.95	39%
EPA 07	10/15/2012	30.60	52.40	63%
EPA 08	10/15/2012	27.73	38.27	58%

Table 13 - Annual System Operations/O&M Costs	
Year	**Annual O&M Cost**
2008	$582,000
2009	$537,000
2010	$595,000
2011	$1,092,000
2012	$1,145,000

Table 14 – 1988 Record of Decision ARARs and the Current NRC License Ground Water Protection Standards			
Contaminant	**ROD Concentration (mg/L) unless noted**	**Source of ARAR Identified in ROD**	**NRC GWPS (mg/L) unless noted**
Aluminum	5	NMWQA	
Antimony	0.014	HEALTH-BASED	
Arsenic	0.05	MCL	0.05
Barium	1	MCL, NMWQA	
Beryllium	0.017	HEALTH-BASED	0.05
Cadmium	0.01	MCL, NMWQA	0.01
Chromium	0.05	MCL, NMWQA	
Cobalt	0.05	NMWQA	
Copper	1	NMWQA	
Iron	5.5	BACKGROUND	
Lead	0.05	MCL, NMWQA	
Manganese	2.6	BACKGROUND	
Mercury	0.002	MCL, NMWQA	0.05
Molybdenum	1	NMWQA	
Nickel	0.2	NMWQA	0.05
Selenium	0.01	MCL	0.01
Silver	0.05	MCL, NMWQA	
Thallium	0.014	HEALTH-BASED	
Vanadium	0.7	HEALTH-BASED	0.1
Zinc	10	NMWQA	
Chloride	250	NMWQA	
Sulfate	2,160	BACKGROUND	
Nitrate	30	BACKGROUND	
TDS	3,170	BACKGROUND	
Radium-226 And 228	5 [a]	MCL	
Uranium-238	5	NMWQA	
Uranium-238	Or 1,645 [a]		
Thorium-230 [b]	15 [a]	MCL	5 [a]
Gross Alpha	15 [a]	MCL	15 [a]
Lead 210	NA	NA	1 [a]
TTHMs [c]	NA	NA	0.08

Notes:
[a] pCi/L
[b] based on 15 pCi/L Gross Alpha
[c] Total trihalomethanes - include chloroform; TTHMs MCL = 0.08 mg/L; in addition, chloroform has an MCLG = 0.07 mg/L

MCL – Maximum Contaminant Level;
NA = Not Applicable
NMWQA – New Mexico Water Quality ARAR (Applicable or Relevant and Appropriate Requirement)
Source: Chester Engineers, April 2011, Table 15.

Table 15 – Record of Decision ARARs and Current ARARs Standards						
Contaminant	**1988 ROD Concentration (mg/L) unless noted**	**ARAR Source Identified in ROD**	**2013 NMWQCC GW Standard**	**2013 MCL, TT or Secondary DW Standard [a]**	**NRC GWPS (mg/L) unless noted**	**NRC GW Protection List [b]**
Aluminum	5	NMWQA [f]	5	0.05 to 0.2		
Antimony	0.014	HEALTH-BASED		0.006		
Arsenic	0.05	MCL	0.1	0.01	0.05	0.05
Barium	1	MCL, NMWQA [f]	1	2		1
Beryllium	0.017	HEALTH-BASED		0.004	0.05	
Cadmium	0.01	MCL, NMWQA [f]	0.01	0.005	0.01	0.01
Chromium	0.05	MCL, NMWQA [f]	0.05	0.1		0.05
Cobalt	0.05	NMWQA [f]	0.05			
Copper	1	NMWQA [f]	1	1.3		
Iron	5.5	BACK-GROUND	1	0.3		
Lead	0.05	MCL, NMWQA [f]	0.05	0.015		0.05
Manganese	2.6	BACK-GROUND	0.2	0.05		
Mercury	0.002	MCL, NMWQA [f]	0.002	0.002	0.05	0.002
Molybdenum	1	NMWQA [f]	1			
Nickel	0.2	NMWQA [f]	0.2		0.05	
Selenium	0.01	MCL	0.05	0.05	0.01	0.01
Silver	0.05	MCL, NMWQA [f]	0.05	0.1		0.05
Thallium	0.014	HEALTH-BASED		0.002		
Vanadium	0.7	HEALTH-BASED			0.1	
Zinc	10	NMWQA [f]	10	5		
Chloride	250	NMWQA [f]	250	250		
Sulfate	2,160	BACK-GROUND	600 [g]	250		
Nitrate	30	BACK-GROUND	10 [g]	10		
TDS	3,170	BACK-GROUND	1000 [g]	500		
Radium-226 And 228	5 [c]	MCL	30 [c]	5 [c]		5 [c]
Uranium - 238	5	NMWQA [f]	0.03	0.03		
Uranium - 238	Or 1,645 [c]					
Thorium-230 [d]	15 [c]	MCL			5 [c]	
Gross Alpha	15 [c]	MCL		15 [c]	15 [c]	15 [c]
Lead – 210	NA	NA			1 [c]	
TTHMs [e]	NA	NA	0.1	0.08	0.08	

Notes: Current standards less than the 1988 ROD ARAR are highlighted in light blue and current standards greater than a 1988 ROD ARAR are highlighted in light green.

[a] Federal Maximum Contaminant Level, Treatment Technology Action Level (TT), or Secondary Drinking Water Standard

[b] 10 CFR Appendix A to Part 40 - 5C-Maximum Values for Ground Water Protection

Table 15 – Record of Decision ARARs and Current ARARs Standards
[c] pCi/L [d] based on 15 pCi/L Gross Alpha [e] Total trihalomethanes - include chloroform; TTHMs MCL = 0.08 mg/L; in addition, chloroform has an MCLG = 0.07 mg/L [f] ROD Identifies NMWQA as Source for State of NM ARARs - NM numerical standards are from the NM Water Quality Control Commission Regulations. Establishment of ground water standards is required by the NMWQA. [g] NMED Recommended Background Values according to a letter to EPA January 1998 differs from current NMWQCC Standards (Sulfate 2125, Nitrate 190, and TDS 4800).

Table 16 – 2013 ARAR Selected Comparison Values

Contaminant	2013 Comparison Value	Units	2013 NMWQCC GW Standard	2013 MCL, TT or Secondary DW Standard [a]	NRC GWPS (mg/L) unless noted	NRC GW Protection List [b]
Aluminum	5	mg/L	5 [e]	0.05 to 0.2		
Antimony	***0.006***	mg/L		0.006		
Arsenic	**0.01**	mg/L	0.1	0.01	0.05	0.05
Barium	1	mg/L	1 [e]	2		1
Beryllium	***0.004***	mg/L		0.004	0.05	
Cadmium	***0.005***	mg/L	0.01 [e]	0.005	0.01	0.01
Chromium	0.05	mg/L	0.05 [e]	0.1		0.05
Cobalt	0.05	mg/L	0.05 [e]			
Copper	1	mg/L	1 [e]	1.3		
Iron	***1***	mg/L	1	0.3		
Lead	**0.015**	mg/L	0.05 [e]	0.015		0.05
Manganese	***0.2***	mg/L	0.2	0.05		
Mercury	0.002	mg/L	0.002 [e]	0.002	0.05	0.002
Molybdenum	1	mg/L	1 [e]			
Nickel	0.2	mg/L	0.2 [e]		0.05	
Selenium	0.01	mg/L	0.05	0.05	0.01	0.01
Silver	0.05	mg/L	0.05 [e]	0.1		0.05
Thallium	***0.002***	mg/L		0.002		
Vanadium	***0.1***	mg/L			0.1	
Zinc	10	mg/L	10 [e]	5		
Chloride	250	mg/L	250 [e]	250		
Sulfate	***600***	mg/L	600 [f]	250		
Nitrate	***10***	mg/L	10 [f]	10		
TDS	***1000***	mg/L	1000 [f]	500		
Radium-226 And 228	5	pCi/L	30	5		5**
Uranium - 238	***0.03***	mg/L	0.03 [e]	0.03		
Uranium - 238	Or 1,645	pCi/L				
Thorium-230 [c]	***5***	pCi/L			5**	
Gross Alpha	15	pCi/L		15	15**	15**
Lead – 210	1**	pCi/L			1**	
TTHMs [d]	***0.08***	mg/L	0.1	0.08	0.08	

Comparison ROD Concentration Values are generally based on the lowest current standard identified in Table 15. Differences between the 2013 Comparison Value in Table 16 and from the 1988 ROD values presented in Table 15 are shown in ***bold, italic, red*** font. The specific ARAR source for the selected comparison value is shown in the gray-shaded cells. Gray-shaded cells also correspond to the light green cells in Table 15, Attachment 9 of 2013 UNC FYR and in N.A. Water Systems report: Calculation of Background Statistics with Comparison Values, 2008 (Tables 7 to 9).

Table 16 – 2013 ARAR Selected Comparison Values
[a] Federal Maximum Contaminant Level (MCL), Treatment Technology Action Level (TT), or Secondary Drinking Water Standard [b] 10 CFR Appendix A to Part 40 - 5C-Maximum Values for Ground Water Protection [c] BASED ON 15 pCi/L GROSS ALPHA. [d] Total trihalomethanes - include chloroform; TTHMs MCL = 0.08 mg/L; in addition, chloroform has an MCLG = 0.07 mg/L [e] ROD Identifies NMWQA as Source for State of NM ARARs - NM numerical standards are from the NM Water Quality Control Commission Regulations. Establishment of ground water standards is required by the NMWQA. [f] NMED Recommended Background Values according to a letter to EPA January 1998 differs from current NMWQCC Standards (Sulfate 2125, Nitrate 190, and TDS 4800).

Table 17 - SWA, Zone 1, and Zone 3 Wells and Sample Dates Representative of Background Quality at the UNC Site that were Used for the UCL95 Statistical Analysis					
Southwest Alluvium (SWA) Wells	**SWA Well sample dates**	**Zone 1 Wells**	**Zone 1 Well sample dates**	**Zone 3 Wells**	**Zone 3 Well sample dates**
29A	July 1989 - October 2007	619	July 1989 - October 2007	411	July 1989 – January 1998
629	July 1989 - October 1995	EPA 2	July 1989 - October 2007	504 B	July 1989 – April 1992
627	July 1989 - October 2007	EPA 4 (POC)	July 1989 - October 2007	517 (POC)[a]	July 1989 – April 1991
639	July 1989 - October 2007	EPA 8	July 1989 - October 2007	EPA 01	July 1989 – October 1997
642	July 1989 - October 2007	EPA 5 *	July 1989 - October 2007	EPA 03	July 1989 – October 1991
645	July 1989 - October 2007			EPA 11	July 1989 – April 1990
EPA 22A	July 1989 - October 2007			EPA 12	July 1989 – April 1992
EPA 25	July 1989 – October 1995			EPA 14	July 1989 – April 1995
EPA 27	July 1989 - October 2007			EPA 15	July 1989 – April 1995
EPA 28 (POC) [a]	July 1989 - October 2007			EPA 17	July 1989 – April 1992
SBL 1	July 1989 - October 2007			NBL -01	August 2001 – April 2004
GW 4 *	July 1989 - October 2007				
623*	July 1989 - October 2007				

Note that the variation in well background sample dates is designed to include data up through October 2007 exclusive of the time when the wells went dry or when sample results indicated the wells became impacted by tailings seepage.

[a] (POC) Point-of-Compliance Well

* Wells were included only for the pre-July 1989 metals results.

Table 18 - Summary of UNC Site Background UCL95 Statistics and EPCs Calculated for Each Hydrostratigraphic Unit with Emphasis on Background Values Greater Than Comparison Values

Parameter	Units	2013 Comparison Values	Southwest Alluvium		Zone1		Zone 3	
			Background UCL95	EPC	Background UCL95	EPC	Background UCL95	EPC
Al	mg/L	5	0.107	0.0109[a]	0.117	0.44	0.231	39.15
As	mg/L	0.01	0.0016	0.00256	0.00117	0.00145	0.175[b]	0.412
Be	mg/L	0.004	N/A	N/A	N/A	N/A	N/A	0.0202
Cd	mg/L	0.005	0.0108	N/A	0.0051	N/A	0.0113	0.0075
Co	mg/L	0.05	0.0121	N/A	0.0112	0.0557	0.0877	0.439
Pb	mg/L	0.015	0.0502	N/A	N/A	N/A	0.0701	N/A
Mn	mg/L	0.2	0.414	2.8	2.519	1.95	3.436	10.89
Mo	mg/L	1	N/A	N/A	0.132	N/A	17.43	0.739
Ni	mg/L	0.2	0.0613	N/A	0.0602	0.0519	0.14	0.489
Se	mg/L	0.01	0.00516	N/A	0.00107	N/A	0.00159	0.0014
V	mg/L	0.1	N/A	N/A	N/A	N/A	N/A	0.111
Cl	mg/L	250	83.72	199.6	39.03	214.3	32.65	48.01
SO4	mg/L	600	2,468	2,867	2,773	4,049	2,674	3,717
NO3 as N	mg/L	10	137.4	94.42	1.754	152	15.61	16.09
U	mg/L	0.03	0.0459	0.128	0.0255	0.00174	0.107	0.0431
Chloroform	mg/L	0.08	N/A	0.00338	N/A	0.00064	N/A	0.00326
Lab TDS	mg/L	1,000	4,745	6,250	4,319	6,843	4,239	5,441
Ra-226	pCi/L	5	0.798	0.268	1.314	1.213	4.996	11.14
Ra-228	pCi/L	5	1.611	0.86	2.946	2.087	4.509	17.84
Ra-total	pCi/L	5	1.621	0.828	3.841	2.8	10.66	29.14
Th-230	pCi/L	5	0.509	0.29	0.403	0.621	1.426	0.259
Pb-210	pCi/L	1	1.513	N/A	1.579	N/A	1.618	2.287
Gross Alpha	pCi/L	15	1.693	1.141	2.361	2.319	8.217	14.28
Sb	mg/L	0.006	N/A	N/A	N/A	N/A	N/A	N/A
Ba	mg/L	1	N/A	N/A	0.091	N/A	N/A	N/A
Cr	mg/L	0.05	N/A	N/A	N/A	N/A	N/A	N/A
Cu	mg/L	1	N/A	N/A	N/A	N/A	0.06	N/A
Fe	mg/L	1	0.275	N/A	8.701	N/A	12.16	N/A
Hg	mg/L	0.002	N/A	N/A	N/A	N/A	N/A	N/A
Ag	mg/L	0.05	N/A	N/A	N/A	N/A	N/A	N/A
Tl	mg/L	0.002	N/A	N/A	N/A	N/A	N/A	N/A
Zn	mg/L	10	0.0949	N/A	3.583	N/A	3.539	N/A

Notes:
UCL95 statistics = upper confidence limit on the mean at the 95% confidence level calculated using ProUCL.
EPC = exposure point concentrations = UCL95 for seepage-impacted water.

[a] Yellow cells = EPC values based on UCL95 statistics having questionable reliability because of few detections.
[b] Light Red cell = background UCL95's are greater than comparison values.
N/A = Insufficient data to make an estimate.
[-] = no comparison value.

Table 18 - Summary of UNC Site Background UCL95 Statistics and EPCs Calculated for Each Hydrostratigraphic Unit with Emphasis on Background Values Greater Than Comparison Values								
Parameter	Units	2013 Comparison Values	Southwest Alluvium		Zone1		Zone 3	
			Background UCL95	EPC	Background UCL95	EPC	Background UCL95	EPC

See Table 16 (above) for 2013 Comparison Value and ARAR source (light gray cells) and Table 15 in Attachment 9 (2013 UNC FYR) for Comparison Values in light green cells.

All background UCL95 values are from NA Water Systems (October 2008); all seepage-impacted EPC's are from NA Water Systems (December 2008) except for cadmium in Zone 3 which was revised to the corrected value shown (Erratum Sheet, Revised Submittal Estimated UCL95 Statistics and EPCs in Impacted Groundwater UNC Church Rock Mill & Tailings Site, Church Rock, New Mexico, December 5, 2008).

Table 19 - Summary of UNC Site Background UCL95 Statistics and EPCs Calculated for Each Hydrostratigraphic Unit with Emphasis on EPC Values Greater Than Background UCL95 and/or Comparison Values								
Parameter	Units	Comparison Values	Southwest Alluvium		Zone 1		Zone 3	
			Background UCL95	EPC	Background UCL95	EPC	Background UCL95	EPC
Al	mg/L	5	0.107	0.0109	0.117	0.44[a]	0.231	**39.15**[b]
As	mg/L	0.01	0.0016	0.00256	0.00117	0.00145	0.175[c]	***0.412***
Be	mg/L	0.004	N/A	N/A	N/A	N/A	N/A	0.0202
Cd	mg/L	0.005	0.0108	N/A	0.0051	N/A	0.0113	*0.0075*
Co	mg/L	0.05	0.0121	N/A	0.0112	***0.0557***	0.0877	**0.439**
Pb	mg/L	0.015	0.0502	N/A	N/A	N/A	0.0701	N/A
Mn	mg/L	0.2	0.414	***2.8***	2.519	1.95	3.436	***10.89***
Mo	mg/L	1	N/A	N/A	0.132	N/A	17.43	0.739
Ni	mg/L	0.2	0.0613	N/A	0.0602	0.0519[d]	0.14	***0.489***
Se	mg/L	0.01	0.00516	N/A	0.00107	N/A	0.00159	0.0014
V	mg/L	0.1	N/A	N/A	N/A	N/A	N/A	0.111
Cl	mg/L	250	83.72	199.6	39.03	214.3	32.65	48.01
SO4	mg/L	600	2,468	***2,867***	2,773	***4,049***	2,674	***3,717***
NO3 as N	mg/L	10	137.4	94.42	1.754	***152***	15.61	***16.09***
U	mg/L	0.03	0.0459	***0.128***	0.0255	0.00174	0.107	0.0431
Chloroform	mg/L	0.08	N/A	0.00338	N/A	0.00064	N/A	0.00326
Lab TDS	mg/L	1,000	4,745	***6,250***	4,319	***6,843***	4,239	***5,441***
Ra-226	pCi/L	5	0.798	0.268	1.314	1.213	4.996	***11.14***
Ra-228	pCi/L	5	1.611	0.86	2.946	2.087	4.509	***17.84***
Ra-total	pCi/L	5	1.621	0.828	3.841	2.8	10.66	***29.14***
Th-230	pCi/L	5	0.509	0.29	0.403	0.621	1.426	0.259
Pb-210	pCi/L	1	1.513	N/A	1.579	N/A	1.618	***2.287***
Gross Alpha	pCi/L	15	1.693	1.141	2.361	2.319	8.217	14.28
Sb	mg/L	0.006	N/A	N/A	N/A	N/A	N/A	N/A
Ba	mg/L	1	N/A	N/A	0.091	N/A	N/A	N/A
Cr	mg/L	0.05	N/A	N/A	N/A	N/A	N/A	N/A
Cu	mg/L	1	N/A	N/A	N/A	N/A	0.06	N/A
Fe	mg/L	1	0.275	N/A	8.701	N/A	12.16	N/A
Hg	mg/L	0.002	N/A	N/A	N/A	N/A	N/A	N/A
Ag	mg/L	0.05	N/A	N/A	N/A	N/A	N/A	N/A
Tl	mg/L	0.002	N/A	N/A	N/A	N/A	N/A	N/A
Zn	mg/L	10	0.0949	N/A	3.583	N/A	3.539	N/A

Notes:
UCL95 statistics = upper confidence limit on the mean at the 95% confidence level calculated using ProUCL.
EPC = exposure point concentrations = UCL95 for seepage-impacted water.

[a] Blue cell = EPC > background UCL95.
[b] Blue cell with Bold Italic results = EPC > comparison value & background UCL95 value.
[c] Light Red cell = background UCL95's are greater than comparison values.
[d] Yellow cells = EPC values based on UCL95 statistics having questionable reliability because of few detections.

Table 19 - Summary of UNC Site Background UCL95 Statistics and EPCs Calculated for Each Hydrostratigraphic Unit with Emphasis on EPC Values Greater Than Background UCL95 and/or Comparison Values

Parameter	Units	Comparison Values	Southwest Alluvium		Zone 1		Zone 3	
			Background UCL95	EPC	Background UCL95	EPC	Background UCL95	EPC

N/A = Insufficient data to make an estimate.
[-] = no comparison value.

See Table 16 (above) for 2013 Comparison Value and ARAR source (light gray cells).

All background UCL95 values are from NA Water Systems (October 2008); all seepage-impacted EPC's are from NA Water Systems (December 2008) except for cadmium in Zone 3 which was revised to the corrected value shown (Erratum Sheet, Revised Submittal Estimated UCL95 Statistics and EPCs in Impacted Groundwater UNC Church Rock Mill & Tailings Site, Church Rock, New Mexico, December 5, 2008).

Table 20 - Summary of EPA Comments, October 2011 on SWSFS Part I and II Document (April 2011)	
No.	**Comment**
1	Need to include conclusions from revised human health risk assessment in Part III.
2	Need to evaluate each remedial alternative against compliance & performance criteria including RAOs; current, new, & proposed ARARs.
3	Need to include NRC, state, tribal & community acceptance as criteria in the evaluation of remedial alternatives.
4	Suggest use of ground water flow & solute transport model to help evaluate remedial alternatives.
5	Discuss use of zero valence iron (ZVI) in Zone 3 pilot hydraulic barrier water injection project to possibly help mitigate seepage impact.
6	Need to consider & discuss how SWSFS will impact requirements of 10 CFR Part 40 Appendix A, Criterion 5B(6).
7	Need to address Source Material License requirements in 10 CFR Part 40 for POC & POE locations: will the SWSFS Part III address GPS & Zone 3 compliance?
8	Need more discussion of NM WQCC standards for ground water, & how they could be addressed with remedial alternatives or technical variance.
9	NMED has concerns about the sample data in total ion form versus dissolved ion form when it comes to NM WQCC standards & solute transport modeling.
10	Need for more detailed analysis of monitored natural attenuation (NMA) since it is cited as a remedial alternative technology for many COPCs
11	Consider a table that chronologically documents history of site remediation activities since 1977 through 2011.
12	Specify the range of depths from ground surface to the top & base of each the three hydrostratigraphic units (SWA, Zone 1 & Zone 3).
13	Figures 8 & 18-20 do not appear to be consistent with respect to some well depths to bedrock based on addition of depth to water plus saturated thickness.
14	Revisions to paragraphs 2 & 3 in Section 3.1.
15	Revisions to paragraph 2 in Section 3.2.
16	Need to note in Section 3.5 that for some COPCs the detection limits exceed the potentially new or revised ARARs.
17	Appears references in Section 3.8 were excluded & need to be included.
18	Revisions to Section 3.9 related to Updated Human Health Risk Assessment & background & impacted water quality.
19	Correction to Section 4.1 about Zone 1 compliance with ROD clean-up levels.
20	Need for more discussion in Section 4.1 about screening out of grout barriers as a viable remedial technology for Zones 1 & 3.
21	Need for more discussion in Section 4.1 about screening out of hydraulic barriers as a viable remedial technology for SWA & Zone 1.
22	Table 13: Include more information about COPCs in Revised Human Health Risk Assessment.
23	Table 22: Clarification about levels of Radium-226 &-228.
24	Table 30: need to add column for preliminary new & revised ARARs.
25	Table 31: levels listed for Radium-226 & -228 should be blank cells since EPA has not accepted NRC License concentrations as background.
26	Editorial corrections in Sections 2 & 3 of document.

Table 21 - Summary of UNC Site Background Water Upper Prediction Limit 95th Percentile (UPL95) Statistic Values Calculated for Each Hydrostratigraphic Unit

Parameter	Units	Current ROD Standard	Current NRC Standard	Southwest Alluvium Background UPL95	Zone 1 Background UPL95	Zone 3 Background UPL95
Al	mg/L	5	*no standard*	0.226	0.285	1.055
As	mg/L	0.05	0.05	0.0039	0.00259	0.757
Be	mg/L	*no standard*	0.05	N/A	N/A	N/A
Cd	mg/L	0.01	0.01	0.0251	0.00642	0.0315
Co	mg/L	0.05	*no standard*	0.0347	0.0257	0.391
Pb	mg/L	0.05	0.05	0.0536	N/A	0.0601
Mn	mg/L	2.6	*no standard*	2.103	5.3920	9.149
Mo	mg/L	1	*no standard*	0.0426	0.0984	66.1
Ni	mg/L	0.2	0.05	0.0781	0.0634	0.569
Se	mg/L	0.01	0.01	0.0699	0.0021	0.0074
V	mg/L	0.7	0.1	N/A	N/A	N/A
Cl	mg/L	250	*no standard*	244.5	109.3	69.84
SO4	mg/L	2,160	*no standard*	5,815	5,539	5,693
NO3 as N	mg/L	30	*no standard*	536.6	16.01	57.78
U	mg/L	5	0.3	0.205	0.238	0.3950
Chloroform	mg/L	*no standard*	0.08	N/A	N/A	N/A
Lab_TDS	mg/L	3,170	*no standard*	10,376	8,020	8,592
Radium-226	pCi/L	*no standard*	*no standard*	4.34	3.499	5.132
Radium-228	pCi/L	*no standard*	*no standard*	6.09	9.877	17.58
Radium Total	pCi/L	5	*****	8.118	12.06	35.18
Th-230	pCi/L	15	5	4.518	1.1619	16.99
Pb-210	pCi/L	*no standard*	1	5.94	4.569	5.674
Gross Alpha	pCi/L	15	15	9.768	8.984	39.73

UPL95 statistics = 95th percentile upper prediction limit calculated using ProUCL; these are a type of background threshold value. Olive green highlight indicates background UPL95 exceeds current ROD and/or NRC standard.

*****Combined radium NRC ground water protection standard = 5.2 pCi/L for Southwest Alluvium; 9.4 pCi/L for Zone 1; and 5.0 pCi/L for Zone 3.

N/A – insufficient data to make an estimate. All background UPL95 values are from UNC (2012) and Chester Engineers (2012b).

Table 22 - Recommendations from the 2008 Five-Year Report and Current Action Taken and Outcome

Item #	Party Responsible	Milestone Date	Date Action Taken
1	PRP	Not Defined in 2008 FYR	TBD pending completion of NRC License Amendment for GWPS
Recommendations			**Action Taken and Outcome**
Complete SWSFS to: develop remedial alternatives; provide support for waiving ARARS due to TI; document whether it is appropriate to adopt the NRC revisions to the License GWPS; and monitoring program by identifying or updating COCs, preliminary remediation goals, including background water quality estimations, and performance monitoring requirements in support of future EPA decision making. The SWSFS should also include a screening-level reassessment of risk, based on more recent toxicological information.			Part 1 of the SWSFS was approved in 2009. Revised SWSFS Parts I and II (April 2011) was determined complete provided that the comments on the revised SWSFS Part I and II were addressed in the SWSFS Part III. In the October 14, 2011, letter, the EPA provided UNC with a Notice to Proceed with development of the SWSFS Part III.
Item #	**Party Responsible**	**Milestone Date**	**Date Action Taken**
2	PRP	Not Defined in 2008 FYR	Evaluation and adjustment to be continued as needed
Recommendations			**Action Taken and Outcome**
In interim, prior to completion of SWSFS, continue effort to minimize advancement of the Zone 3 seepage-impacted water northward, and continue to extract contaminated ground water to the maximum extent practicable by installing and operating additional extraction wells at the leading edge of the seepage-impacted front.			A pilot study conducted between 10/24/2006 to 2/15/2007 concluded that the use of alkalinity rich solutions to remediate the Zone 3 seepage-impacted ground water in-situ was infeasible (ARCADIS BBL, 2007). Five new extraction wells were installed during September 2008. The revised Zone 3 pumping system has been declining in performance with the majority of these Zone 3 wells having reduced yields that are below 0.5 gpm. Injection testing was undertaken in 2009 and 2010. The injection capacity declined over time. On June 29, 2012, the injection at IW-A was terminated because of the decline in injection capacity and because Well MW 6 showed increasing levels of uranium.
Item #	**Party Responsible**	**Milestone Date**	**Date Action Taken**
3	PRP	Not Defined in 2008 FYR	TBD
Recommendations			**Action Taken and Outcome**
As part of SWSFS, determine post-mining/ pre-tailings background concentrations of uranium for comparison to the seepage-impacted uranium levels and assess whether uranium concentrations can further be reduced in the SWA.			Post-mining/pre-tailings background concentrations of uranium and seepage-impacted concentrations of uranium in the SWA have been determined and analyzed with comparison values as described in the SWSFS Part I (2008). The SWSFS Part III will determine if uranium concentrations can be reduced further to meet revised standards using

Table 22 - Recommendations from the 2008 Five-Year Report and Current Action Taken and Outcome			
			alternative remedial technologies.
Item #	**Party Responsible**	**Milestone Date**	**Date Action Taken**
4	PRP	Not Defined in 2008 FYR	TBD
Recommendations			**Action Taken and Outcome**
Reassess the effectiveness of the SWA extraction wells to improve ground water quality with respect to uranium.			Since the shutdown of the SWA extraction system in 1999, the remedial action has defaulted to monitoring the natural attenuation of uranium and whether or not there has been any improvement of ground water quality as a result.
Item #	**Party Responsible**	**Milestone Date**	**Date Action Taken**
5	EPA	Not Defined in 2008 FYR	TBD
Recommendations			**Action Taken and Outcome**
Identify COCs, RAOs, and preliminary clean up levels and codify in a decision document. As part of SWSFS, identify COCs, RAOs, and preliminary clean up levels and codify in a decision document.			Determination of if a new Decision Document is needed is dependent on the results of the SWSFS Part III which is dependent on the April 2012 NRC License Amendment for revised ground water standards.
Item #	**Party Responsible**	**Milestone Date**	**Date Action Taken**
6	EPA	Not Defined in 2008 FYR	TBD
Recommendations			**Action Taken and Outcome**
After the COCs and clean up levels are modified in EPA decision-making, the ground water monitoring program should be updated to ensure that it is consistent with the revised COCs and clean up levels, and at the appropriate well locations and aquifers.			No action at this time. We are awaiting the outcome of the NRC license amendment process, and the completion of SWSFS Part III.
Item #	**Party Responsible**	**Milestone Date**	**Date Action Taken**
7	EPA	Not Defined in 2008 FYR	TBD
Recommendations			**Action Taken and Outcome**
EPA requirements in a decision document as appropriate to be consistent with NRC License requirements.			No action at this time. We are awaiting the outcome of the NRC license amendment process, and the completion of SWSFS Part III.
Item #	**Party Responsible**	**Milestone Date**	**Date Action Taken**
8	EPA, NNEPA, BIA,	Not Defined in 2008 FYR	TBD

Table 22 - Recommendations from the 2008 Five-Year Report and Current Action Taken and Outcome

	PRP		
Recommendations			**Action Taken and Outcome**
A renewed effort should be made to establish ICs that will restrict the use of contaminated ground water on Navajo, Tribal Trust and Indian Allotment lands.			ICs are one of several alternative remedial strategies that are being analyzed for consideration in the SWSFS Part III.
Item #	**Party Responsible**	**Milestone Date**	**Date Action Taken**
9	PRP	Not Defined in 2008 FYR	TBD
Recommendations			**Action Taken and Outcome**
As part of the SWSFS, include an evaluation of remedial technologies and process options to achieve the clean up levels for sulfate and TDS, or provide a basis for EPA to invoke a waiver of those standards for sulfate and TDS due to TI.			On hold pending completion of NRC License Amendment for GWPS and SWSFS Part III.
Item #	**Party Responsible**	**Milestone Date**	**Date Action Taken**
10	PRP	Not Defined in 2008 FYR	TBD
Recommendations			**Action Taken and Outcome**
As part of the SWSFS, complete the reassessment of post-mining/pre-tailings background water quality based on ground water monitoring data.			The reassessment of post-mining/pre-tailings background ground water quality was completed in the SWSFS Part I (2008) for each of the three hydrostratigraphic units. The reassessment recommends that some of the 1988 ROD cleanup standards be revised and designated separately for each unit.
Item #	**Party Responsible**	**Milestone Date**	**Date Action Taken**
11	EPA, PRP, NRC	Not Defined in 2008 FYR	Ongoing
Recommendations			**Action Taken and Outcome**
Increase effort to share information with community regarding the ground water remedy.			CIP completed in December 2012. Monthly EPA R6/R9 communications with the local community. Public meetings noticed and conducted locally. Public meeting for FYR tentatively scheduled for November 2013. R6 hosting a UNC Site website that provided information targeted to the communities' requests.
Item #	**Party Responsible**	**Milestone Date**	**Date Action Taken**
12	PRP	Not Defined in 2008 FYR	TBD

Table 22 - Recommendations from the 2008 Five-Year Report and Current Action Taken and Outcome

Recommendations	Action Taken and Outcome
Develop a schedule for completion of the SWSFS.	On hold pending completion of NRC License Amendment for GWPS and SWSFS Part III.

Table 23 – Interviewees	
Name	**Affiliation**
Yolande Norman	NRC
Eugene Esplain	NNEPA
Roy Blickwedel	GE
Deborah Steckley	DOE
Red Water Pond Road Community Association	Local Residential Group
Tommy Nez	Local Resident

Table 24 – Issues		
Issues	**Affects Current Protectiveness (Y/N)**	**Affects Future Protectiveness (Y/N)**
1. The 1988 ROD did not provide a clear evaluation of the post-mining/pre-tailings background water quality in establishing the UNC Site cleanup standards. The COCs or cleanup levels for the UNC Site were not specifically identified in the 1988 ROD. UNC addressed cleanup levels in the UNC SWSFS Part I investigation report that included: 1) a thorough review and update of the UNC Site COCs based on screening with current EPA Maximum Concentration Levels (MCLs), health based criteria, background water quality; and 2) an update and recommendation for revision of the UNC Site cleanup levels. Parts I and II of the SWSFS have been reviewed and accepted by the EPA but has not yet modified the COC list and monitoring program. The NRC has approved several revisions to License standards, COCs, and monitoring programs recommended by UNC. EPA has discussed those revisions with the NRC but has not modified the cleanup levels or remedy set forth in the 1988 ROD to be consistent with NRC revisions. Such consistency, where appropriate, would help to integrate and coordinate the ground water and source control/surface reclamation activities to achieve comprehensive reclamation and remediation of the UNC Site, which is called for in the MOU between the EPA and the NRC.	N	Y
2. The ground water remedy cannot attain the cleanup levels within a reasonable time frame because the source of anthropogenic recharge to the ground water system is no longer available and has resulted in a significant loss of aquifer saturated thicknesses. By loss of saturated thickness, we mean that, if you measured a cross section of the wet part of the subsurface layer, measuring from the top to the bottom, the part of the layer containing the ground water would be smaller than it used to be. Losing saturated thickness, in this case means that there is less ground water to pump. In fact the aquifer is so depleted that ground water levels do not support extraction of contaminated water at pumping flow rates that are efficient and maintainable. In short, since the mines no longer discharge water, there is not enough water to pump from this aquifer, which was essentially created by the discharge of ground water from the mine.	N	Y
3. One of EPA's goals in Zone 3 is to reduce the subsurface migration of contaminated ground water that is contaminated by seepage from tailings. To accomplish this reduction, EPA has been pumping the ground water to reduce the hydraulic head moving this contamination. The Zone 3 extraction well system cannot hydraulically control the migration of tailings seepage-impacted water northward toward and	N	Y

Table 24 – Issues		
Issues	**Affects Current Protectiveness (Y/N)**	**Affects Future Protectiveness (Y/N)**
eventually on to the Navajo Nation lands. All current extraction and hydraulic barrier implementation and any future pumping to reduce the pressure head will only yield short-term results. Because the structural tilting or dip of the impacted hydrostratigraphic strata also drives ground water flow northward, there is an irreducible elevation head that cannot be decreased by pumping. Counteracting this hydraulic force is the clogging of the formation's pore spaces by the seepage-induced chemical alteration of feldspar to kaolinite clay in the aquifer matrix. This alteration-clogging action reduces the formation's permeability and impedes the flow of seepage-impacted ground water. Eventually, there will be a balance between the irreducible hydraulic head and the trapping of seepage-impacted ground water from loss of permeability. In short, while pumping cannot completely reduce the hydraulic head that is causing the northward subsurface migration of contaminants, eventually it appears that clogging of the pores in the subsurface will impede the ground water that has been contaminated by seepage from the tailings and the subsurface migration will cease. The 2012 Ground Water Flow Model will be able to predict when this condition will occur.		
4. UNC has indicated in its 2007 and 2012 Annual Review Report that there is no significant difference between the SWA uranium concentration levels in ground water and uranium concentration level trends that existed before the shutoff of the extraction wells and after shutoff of the extraction wells in 2001. The SWA extraction well system was temporarily shut off in 2001 to conduct an 18-month Natural Attenuation (NA) test and the wells have remained off since then. The conclusion reached by UNC is that NA is as effective as extraction of contaminated water in the reduction of uranium levels in the SWA. Although review of the 2012 Annual Review Report indicates that UNC's conclusion appears valid for most wells in the SWA, for some wells the levels of uranium have shown increasing trends since the extraction system was shut off. Consequently, the question still remains as to whether or not the operation of the extraction system in the SWA is effective for improving ground water quality with respect to uranium and whether NA can be relied upon as part of the remedy to mitigate tailings seepage impacts on ground water. One factor that makes it difficult to determine whether NA could be as effective as extraction is that the UNC report relies on a 2006 statistical analysis of background contaminant concentration levels that does not agree with the 2008 Pro Upper Confidence Limit (ProUCL) statistical finding. The 2008 ProUCL findings were developed by N.A. Water Systems for UNC.	N	Y

Table 24 – Issues		
Issues	**Affects Current Protectiveness (Y/N)**	**Affects Future Protectiveness (Y/N)**
5. Uranium concentrations in the SWA ground water do not exceed the uranium cleanup level of 5.0 milligrams per Liter (mg/l) called for in the 1988 ROD. However, they do exceed the 2003 promulgated EPA Safe Drinking Water Act (SDWA) Maximum Contaminant Level (MCL) for uranium of 0.030 mg/l.	N	Y
6. In light of the technical difficulties of achieving Site ground water cleanup levels using engineering controls, Institutional Controls (ICs) may have to play a larger role in protecting human health at the UNC Site. Consequently, ICs should be evaluated in the SWSFS Part III.	N	Y
7. Sulfate and TDS concentrations are not dependent on continued operation of extraction systems in the hydrostratigraphic units at the UNC Site, but rather these constituent concentrations are controlled by natural geochemical reactions, primarily the chemical equilibrium with gypsum and/or anhydrite. UNC's conclusion that concentrations of sulfate and TDS will continue to exceed cleanup levels as long as the SWA and Zone 1 are saturated appears to be well supported. UNC has performed a TI evaluation and recommended that EPA invoke a TI waiver of the sulfate and TDS standards as well as for the manganese standard.	N	N
8. The definition of background water at the UNC Site is not a natural water source but instead an anthropogenic artificial aquifer created by mine water effluent that was pumped from the Westwater Canyon Member of the Morrison Formation, which contains the uranium ore body. This water is also referred to as the ground water beneath the UNC Site which has been contaminated by the seepage-impacted water from the tailings. Thirty years of water level records have confirmed that this "ground water" aquifer is also transient in nature as the source of artificial recharge has been eliminated.	N	Y

Table 25 - Recommendations and Follow-up Actions						
Issue	**Recommendations and Follow-up Actions**	**Party Responsible**	**Oversight Agency**	**Milestone Date**	**Affects Protectiveness (Y/N)**	
					Current	**Future**
1	Evaluate and incorporate revisions to the background levels and cleanup standards through the decision making process. Pending NRC License Amendment acceptance; revise Site background levels, the COCs and cleanup standards to ensure that they are consistent with the revised COCs and cleanup levels, and at the appropriate well locations and aquifers. If appropriate and consistent with the NCP, adopt NRC revisions to the License Amendment ground water protection standards and monitoring programs to be consistent with NRC's source control and surface reclamation activities.	UNC	EPA, NRC	TBD	N	Y
2	Complete the ongoing Site Wide Supplemental Feasibility Study (SWSFS) Part III to develop and analyze remedial alternatives.	UNC	EPA, NMED	TBD	N	Y
3	Continue the experimental efforts to create a hydraulic barrier in Zone 3 to slow down and contain the migration of the seepage-impacted water in the northern area. Use the 2012 ground water flow model for the Church Rock area to help define how far the contaminated water would move on to lands of the Navajo Nation for proper location of additional monitoring wells.	UNC	EPA, NRC, NMED	TBD	N	Y
4	Reassess the effectiveness of the SWA extraction wells to improve ground water quality with respect to uranium compared to NA and determine if there are any increasing trends of uranium in wells since the shut off of the extraction wells in 2001.	UNC	EPA, NRC	TBD	N	Y
5	Evaluate mechanism(s) of Natural Attenuation (NA) in the SWA for uranium as well as for other COCs in all hydrostratigraphic zones as part of the ongoing remediation effort to attain cleanup standards.	UNC	EPA, NRC	TBD	N	Y
6	Renew efforts to establish ICs that will restrict the use of contaminated ground water on Navajo Nation, Tribal Trust, and Indian Allotment lands.	UNC, Navajo Nation Council, and BIA	EPA, NRC	TBD	N	Y
7	Evaluate TI for sulfate and TDS as part of the ongoing SWSFS, Part III.	UNC	EPA, NRC	TBD	N	N
8	Evaluate the anthropogenic origin and the transient nature of the artificially created ground water aquifers impact on future EPA ground water decision making	EPA	EPA, NRC	TBD	N	N

FIGURES

Figure 1 – Site Location Map

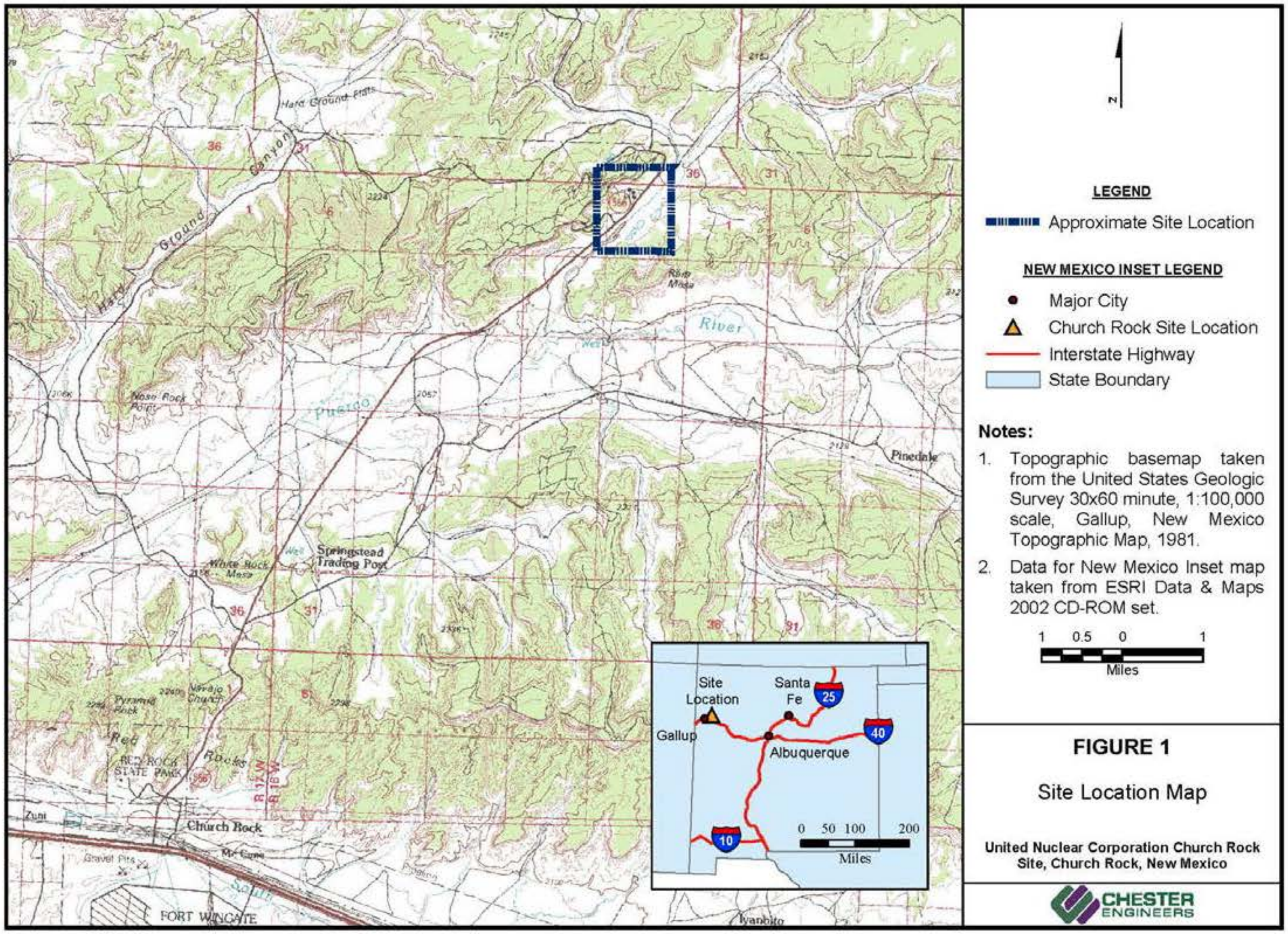

Figure 2 – Site Layout and Performance Monitoring Wells Locations 2012 Operating Year

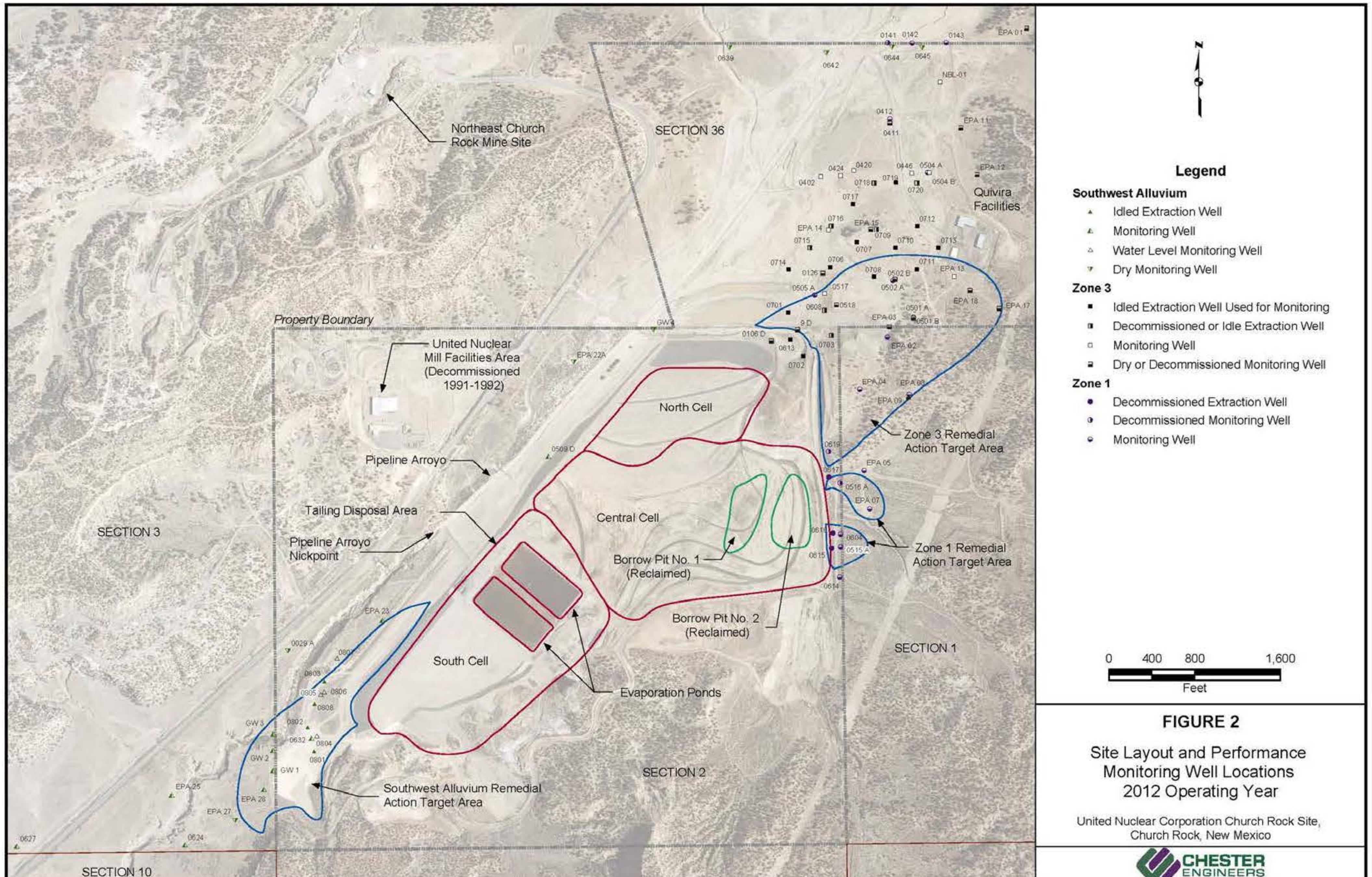

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Figure 3 – Extent of Seepage-Impacted Ground Water, October 2012

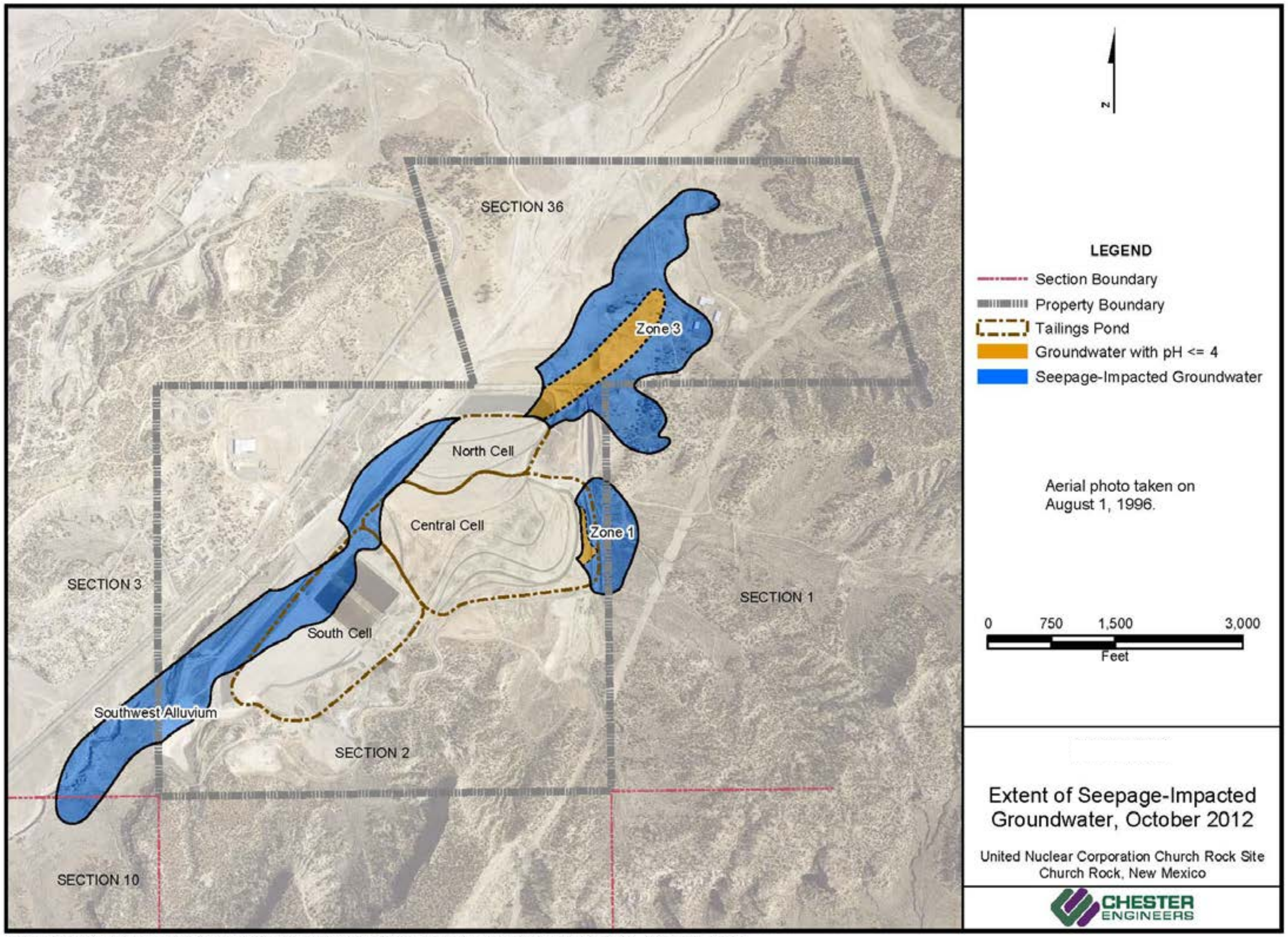

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Figure 4 - Zone 3 Approximate Extent of Seepage Impacts, October 2012

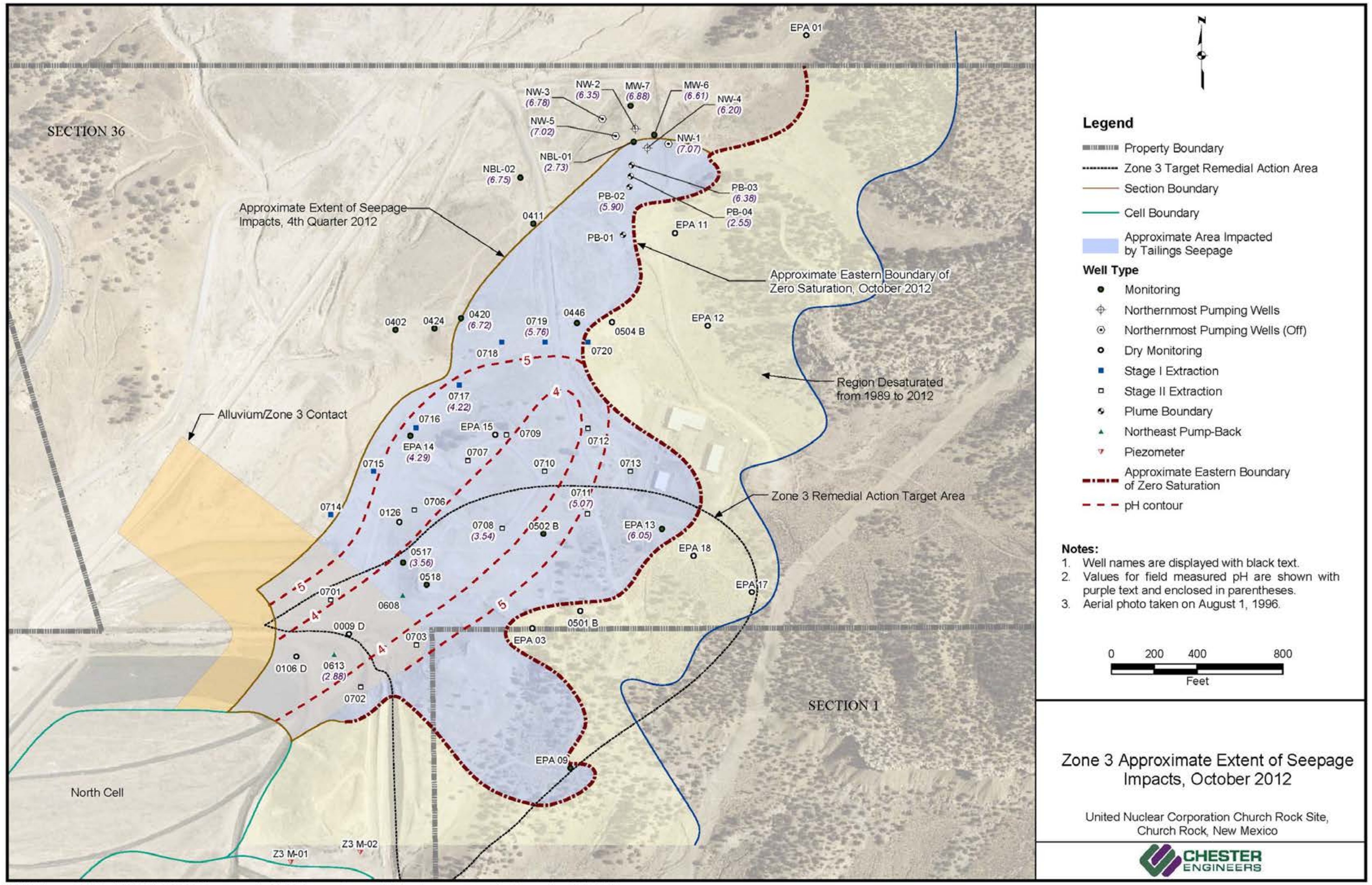

Figure 5 – Zone 1 2012 Monitoring Locations

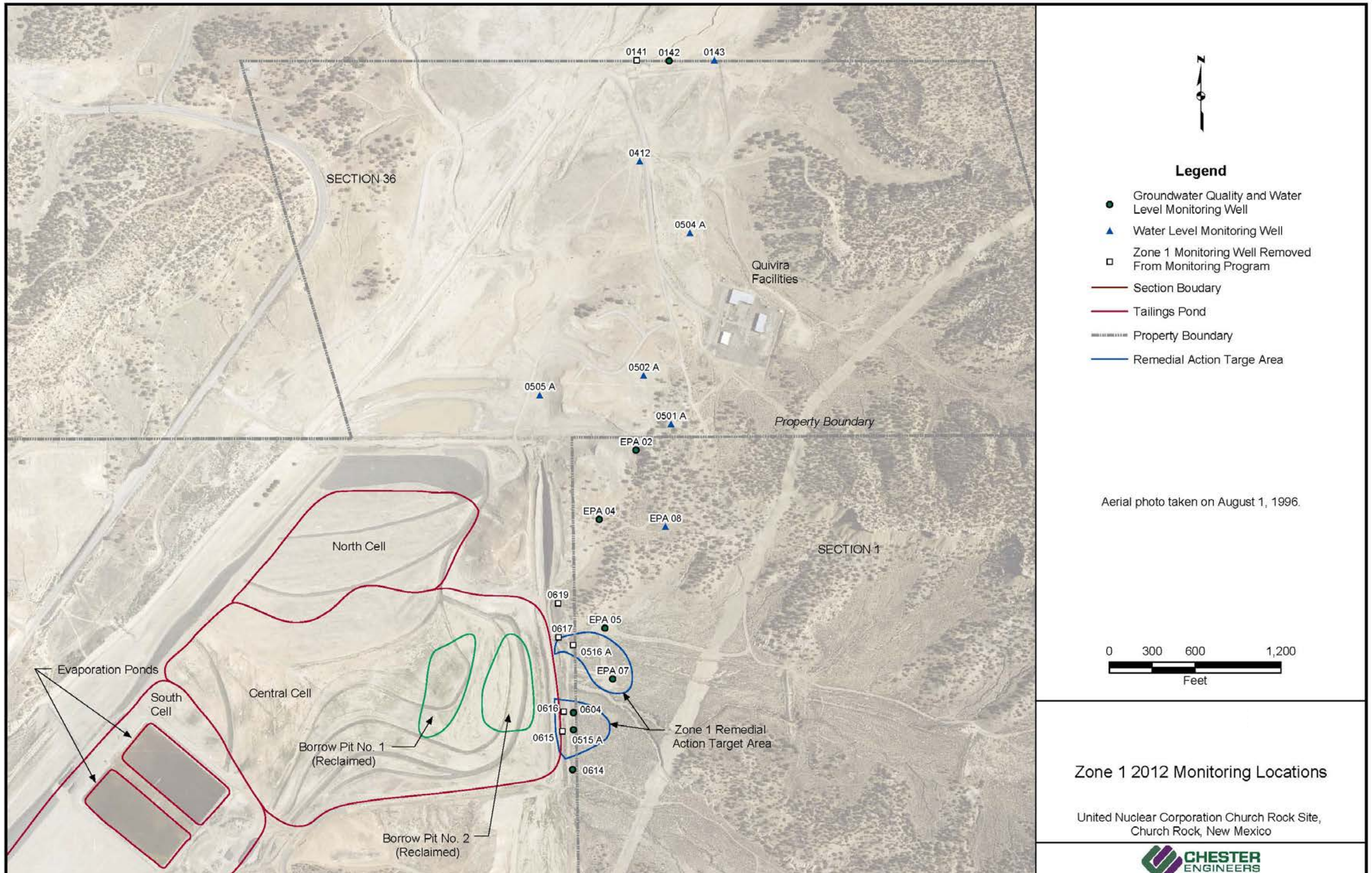

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Figure 6 – Southwest Alluvium Potentiometric Surface Map October 2012

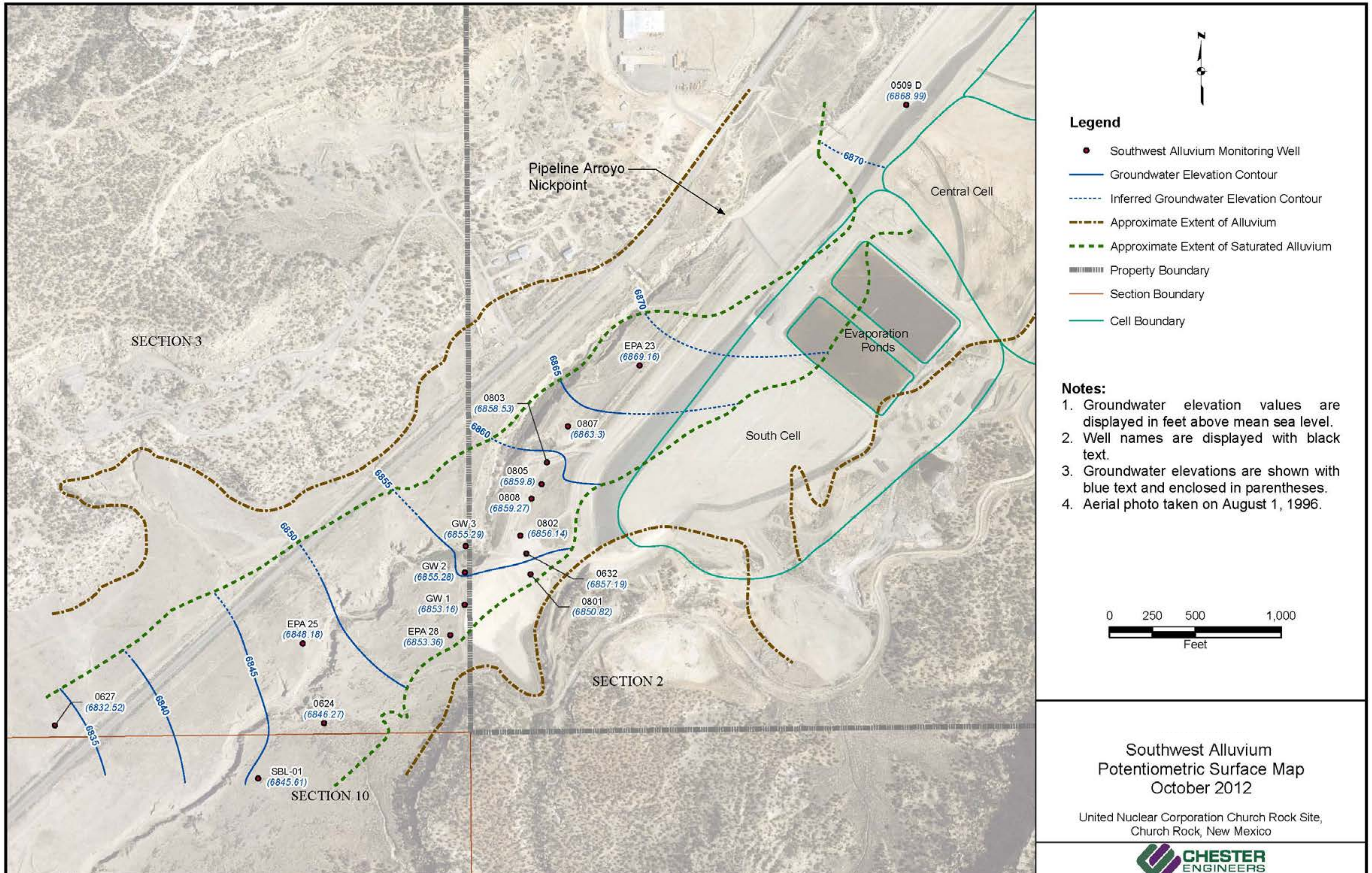

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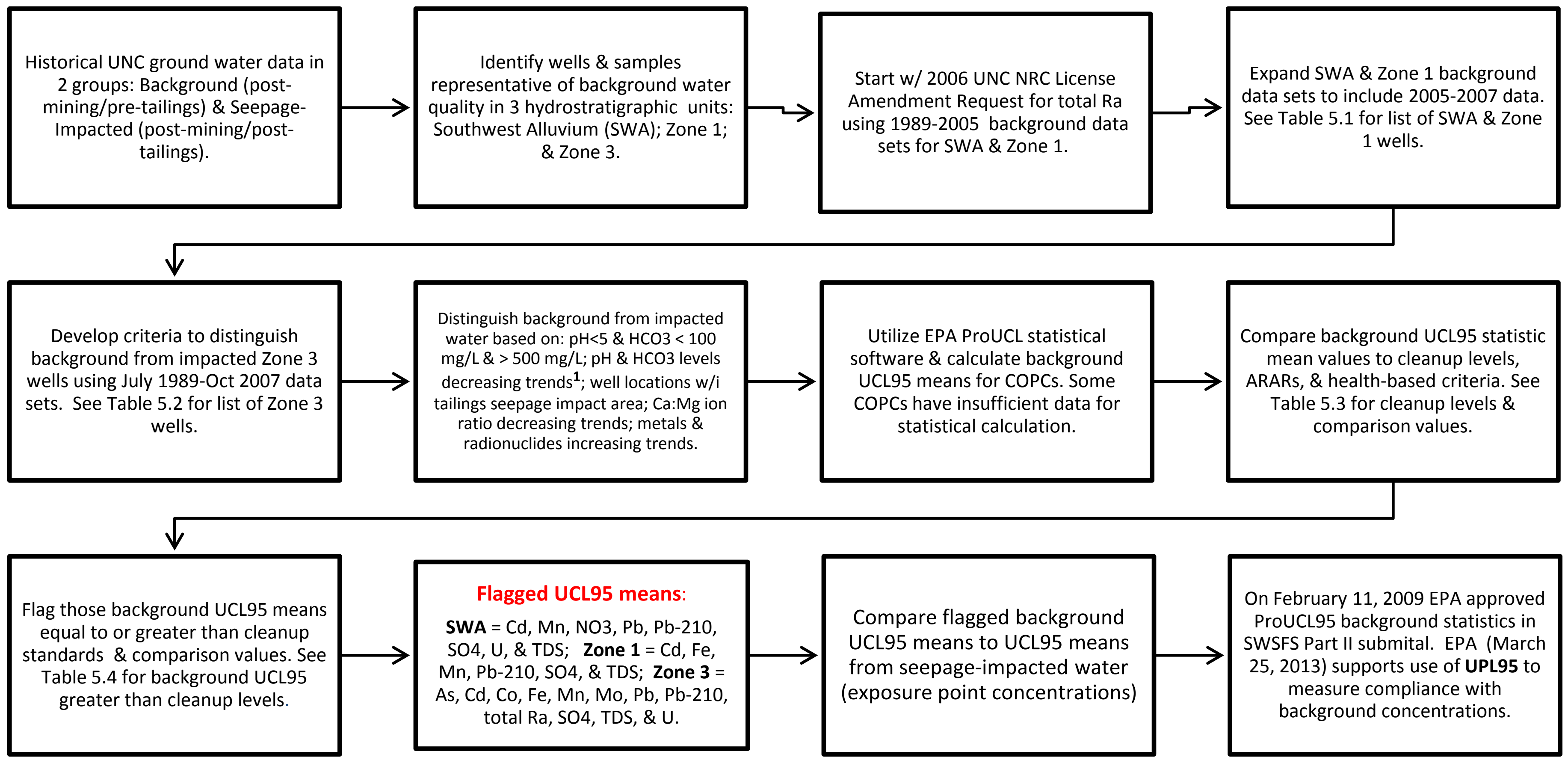
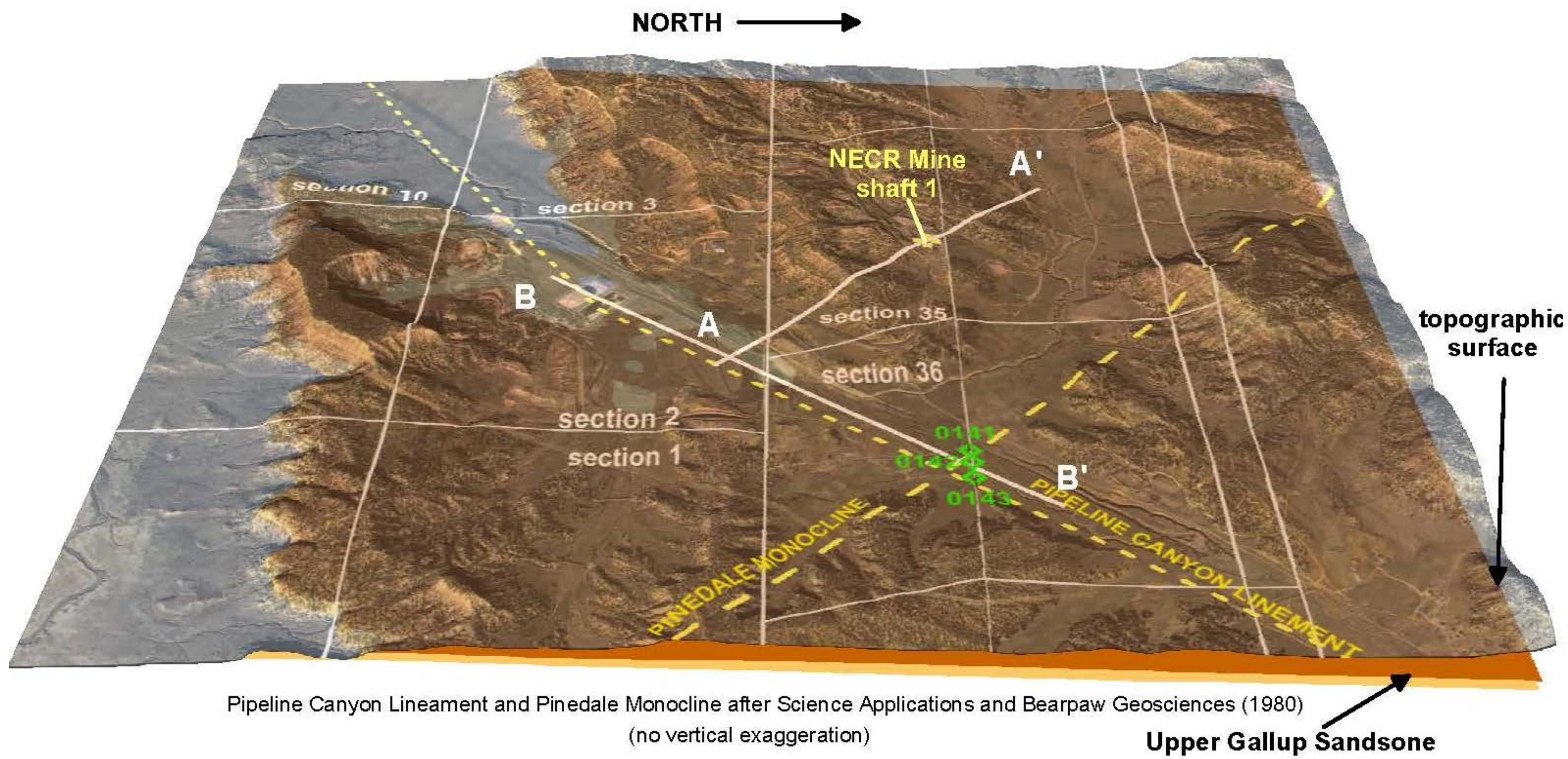
Figure 7 – Process Chart of the Development and Usage of UNC Site Background Water UCL95 Statistics



1: pH & HCO3 decreasing concentration trends are not always certain indicators of acidic tailings seepage impact across all three hydrostratigraphic zones. The water quality impact-buffering cycle in well time-series graphs typically show increasing bicarbonate then a rapid decline, which can also occur to a lesser degree with pH, as the seepage front advances and the buffering capacity is used up (see Zone 3 well EPA-14 in Figure 39 from UNC 2012 Annual Report).

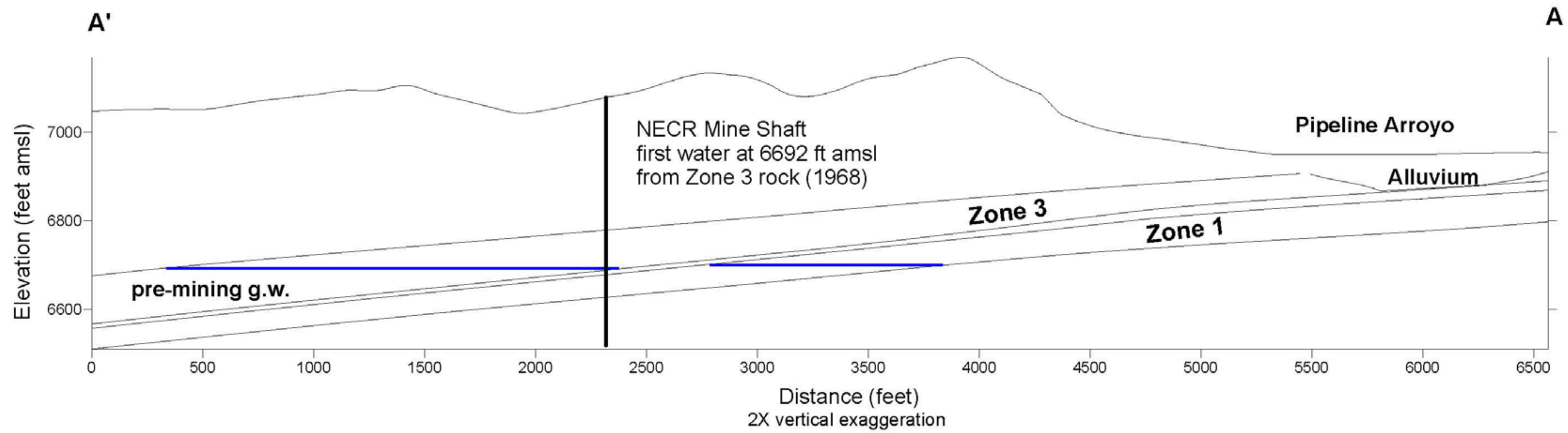
Figure 8 – Pipeline Canyon Lineament and Pinedale Monocline



Pipeline Canyon Lineament and Pinedale Monocline after Science Applications and Bearpaw Geosciences (1980)
(no vertical exaggeration)

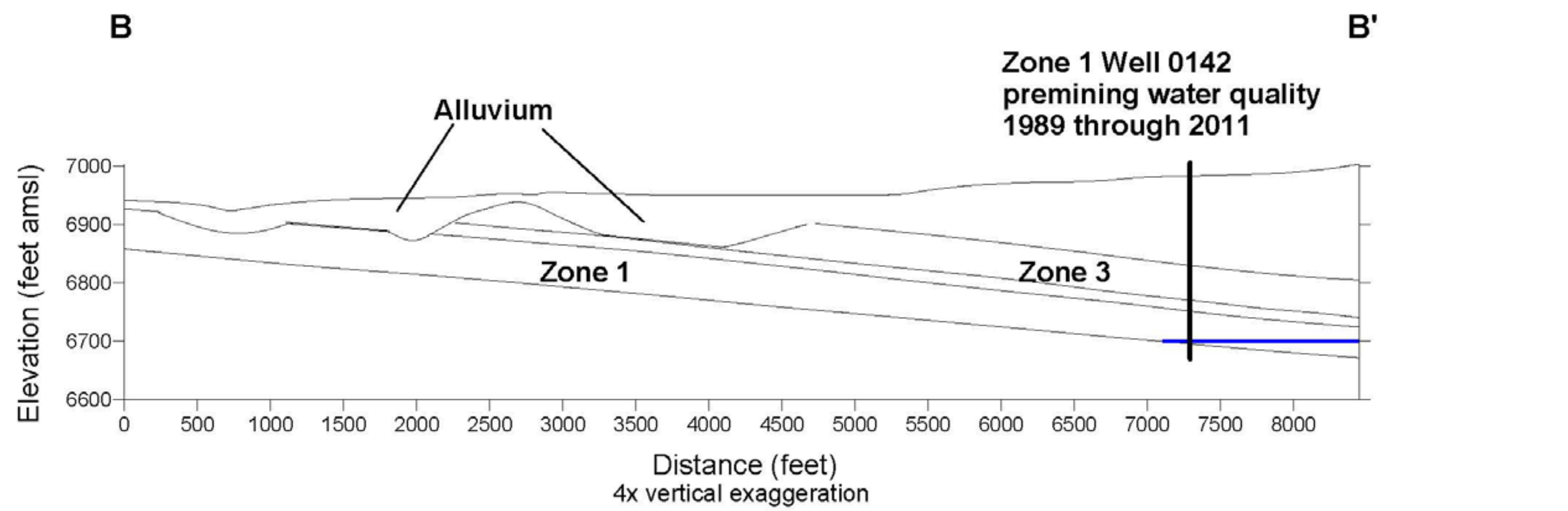
West-looking perspective view of topographic surface and north-dipping Upper Gallup Sandstone, showing locations of Pipeline Canyon Lineament, Pinedale Monocline, cross sections A-A', B-B' and associated features. Surface imagery (NAIP 2009 orthophoto) rendered semi-transparent to show underlying Upper Gallup Sandstone.

Figure 9 – Geologic Cross-Sections A-A’ and B-B’



Northeast-looking view of cross section A-A' (see Figure 8 for location)

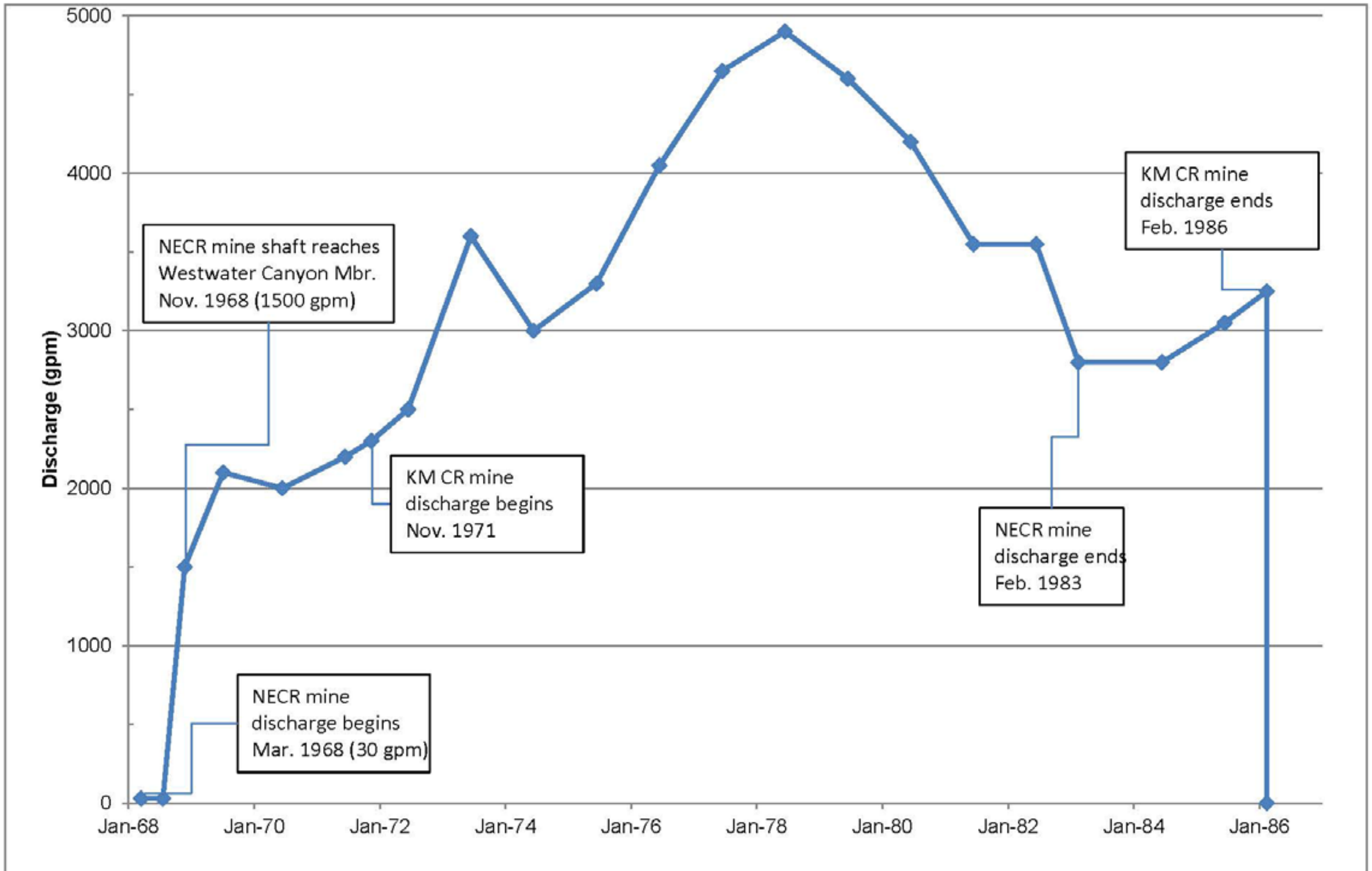
Pre-mining water table shown in Zone 3 where encountered in NECR mine shaft in 1968 (at elevation 6692 ft amsl). Elevation of pre-mining water table shown in Zone 1 is interpreted by analogy, but is also consistent with sample data from Zone 1 monitoring wells.



Northwest-looking view of cross section B-B' (see Figure 8 for location)

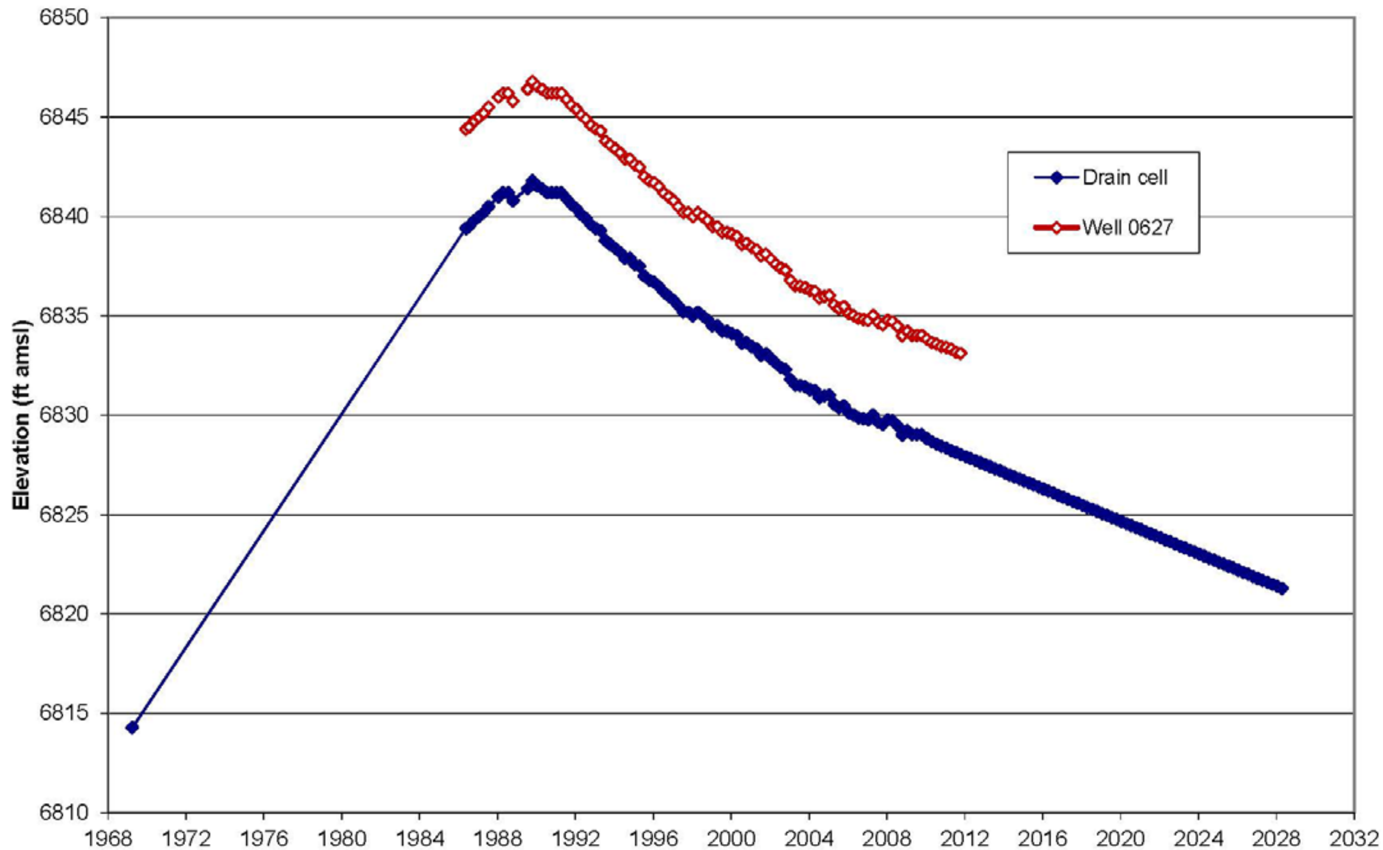
Zone 1 pre-mining water table depicted by blue line is consistent with early sample data from Zone 1 monitoring wells 0141, 0142, and 0143. These wells are screened at the base of Zone 1. The persistence of pre-mining water quality in these wells (through 2011 in 0142) demonstates little or no displacement of pre-mininggroundwater by background groundwater.

Figure 10 – Combined Rate of Discharges from Northeast Church Rock and Kerr McGee Mines



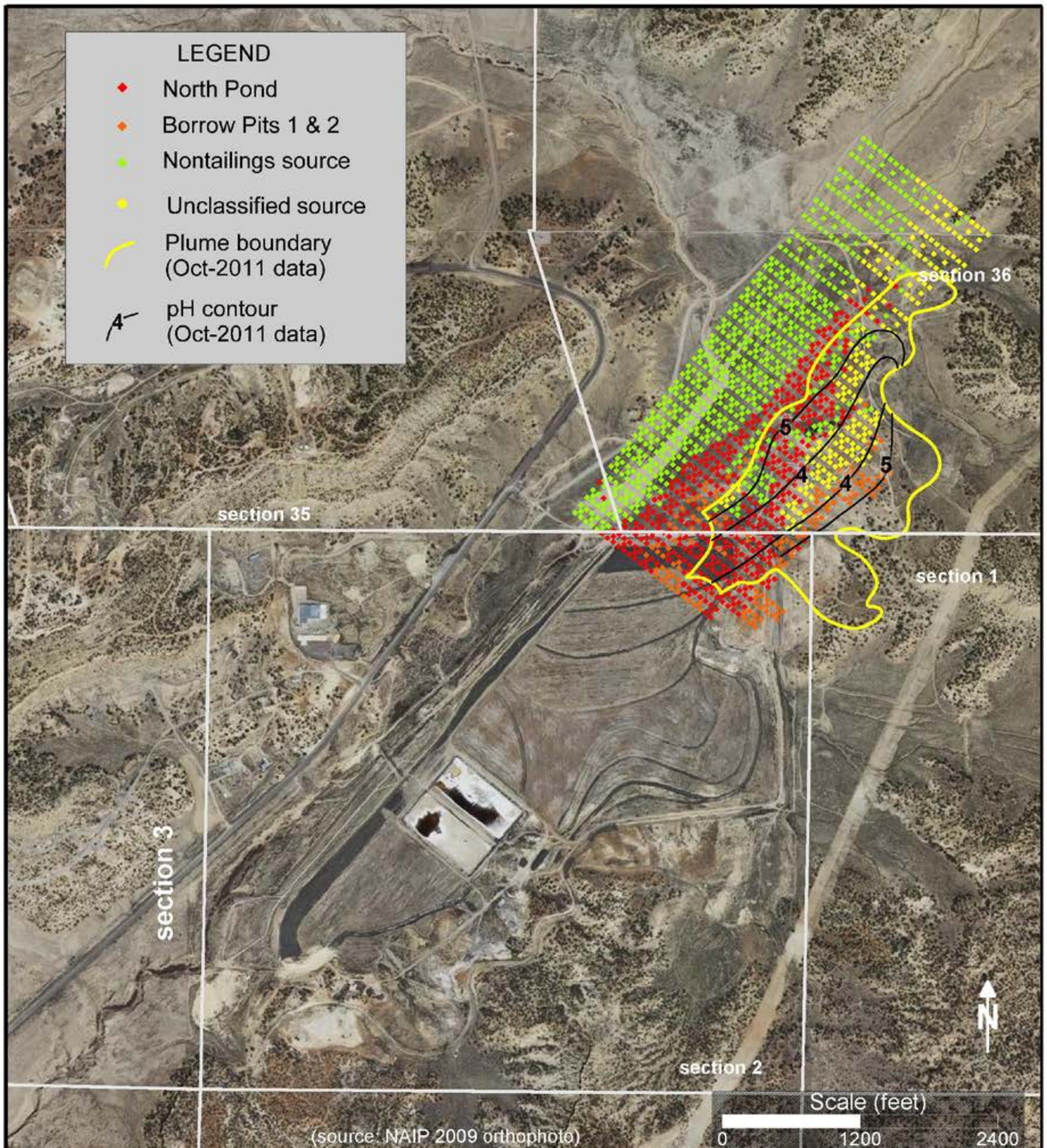
Combined rate of discharges from NE Church Rock (NECR) and Kerr McGee (KM CR) Mines
(after Canonie file figure, Mar. 1989; Figure 4 in EPA , Sep., 1998, p.37)

Figure 11 – Comparison of Extrapolated Flow Model Drain Cell Hydrograph for Well 0627



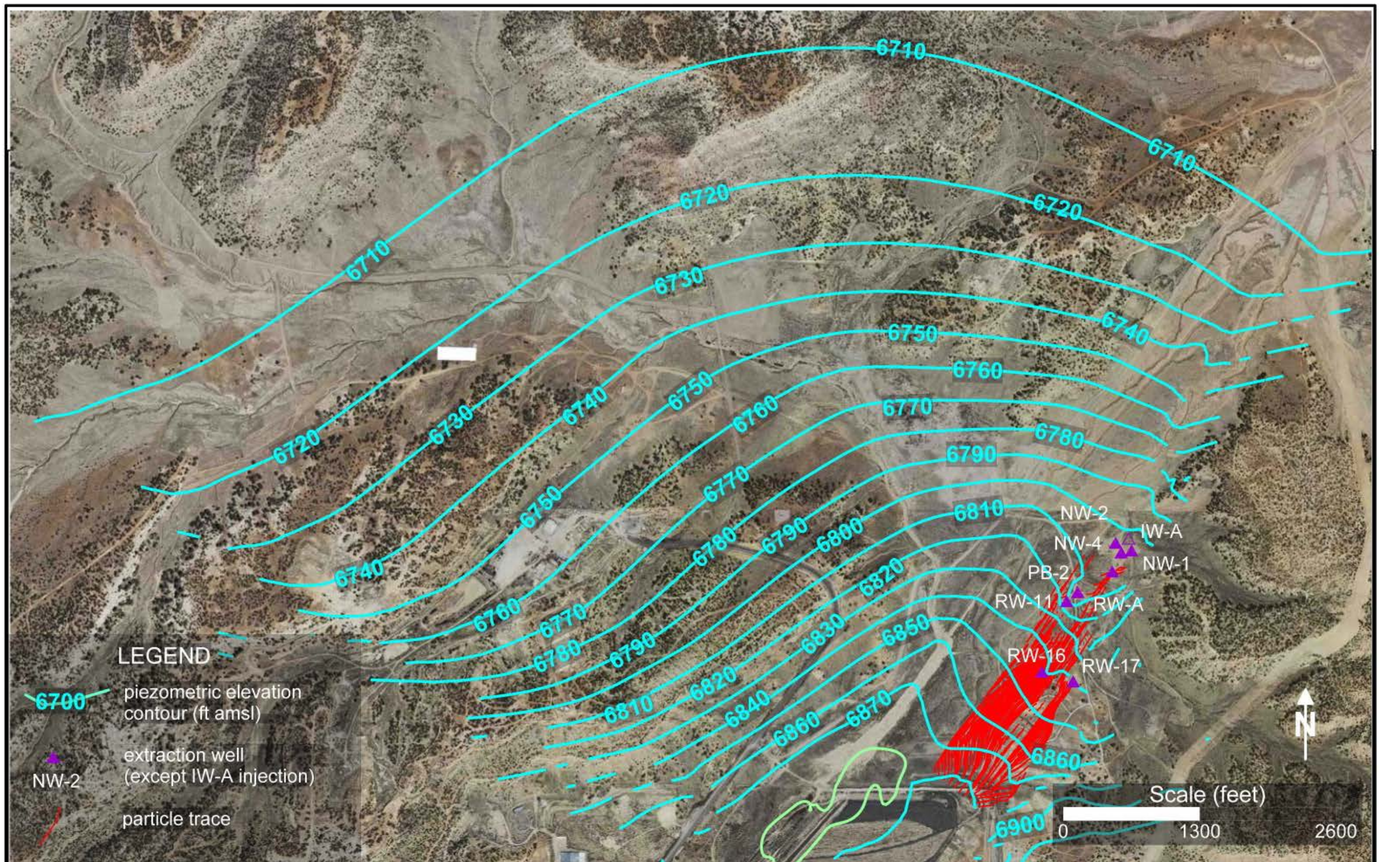
Comparison of extrapolated Flow Model drain cell hydrograph with measurements made in upgradient alluvium Well 0627 (see Figure A-1 for locations)

Figure 12 – Ground Water Flow Model Particle Track End Points for Simulation Date 10/16/2011



Particle track end points for simulation date October 15, 2011,
Classified by source locations analyzed by backward tracking,
Tracks stopped short of sources are unclassified,
Base of Zone 3, model layer 4,
Seepage impact plume and pH contours based on Oct 2011 data

Figure 13 – Ground Water Flow Model Years 2011-2026 Particle Traces of Tailing Seepage Impact



2011-2026 particle traces (red) from area of tailings seepage impact,
Model layer 4 piezometric elevation contours for October 2026,
representing base of Zone 3 and alluvium (within areas delimited in green)

Figure 14 – Southwest Alluvium Bicarbonate Isoconcentration and Distribution of Sulfate, October 2012

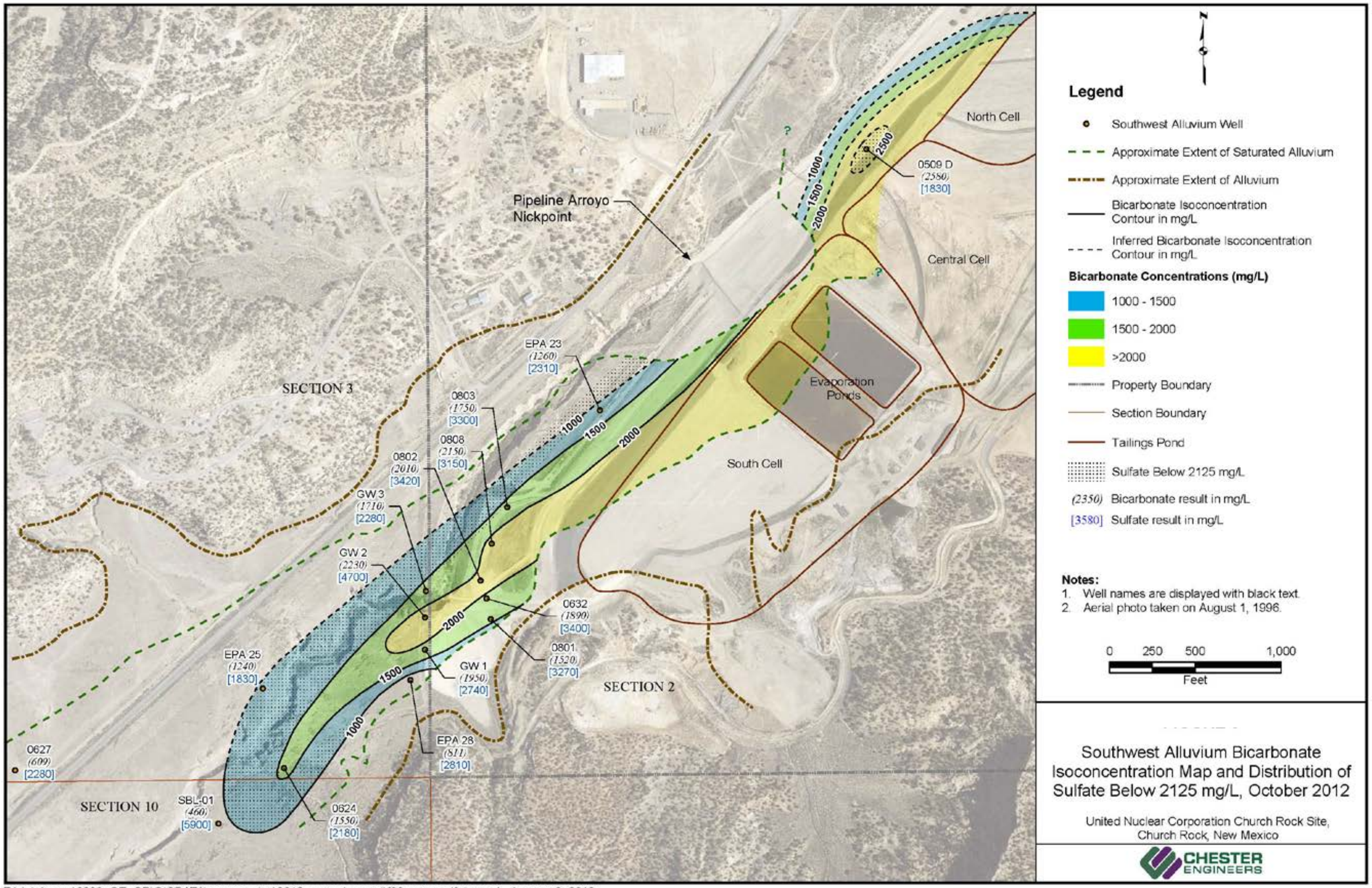


Figure 15 – Southwest Alluvium Water Level over Time

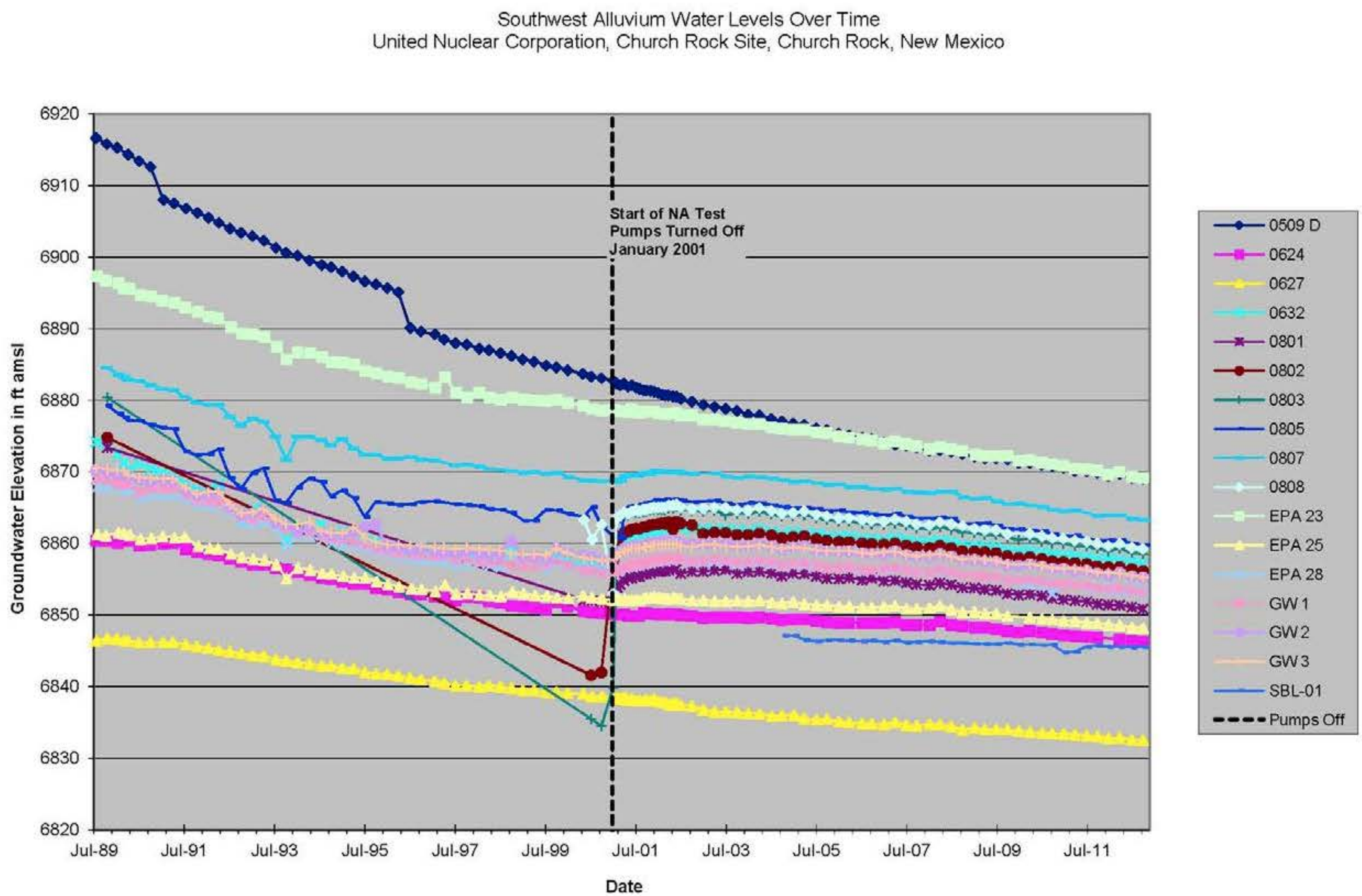


Figure 16 – Zone 3 Approximate Extent of Seepage Impacts, October 2012

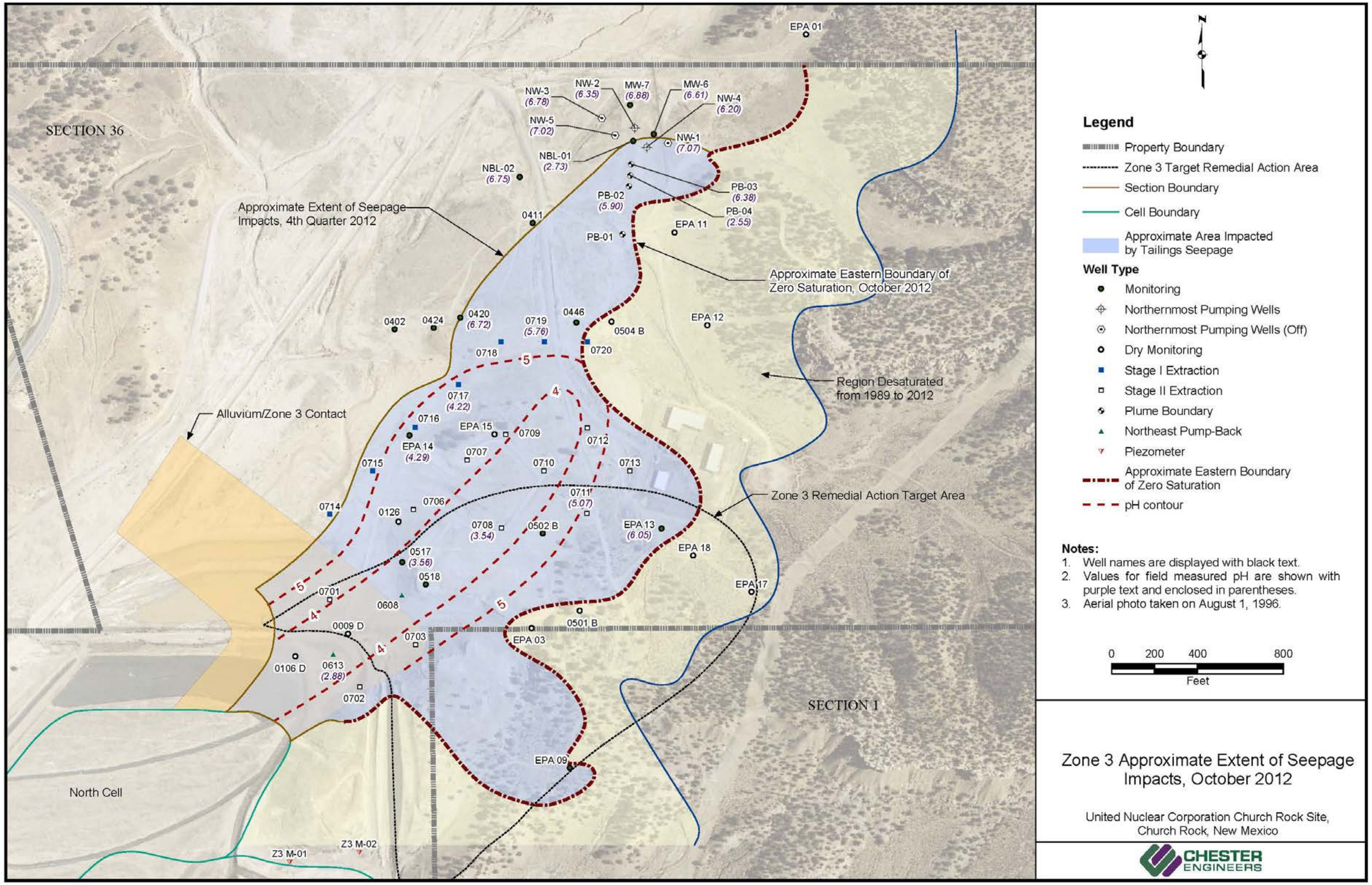


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Figure 17 – Zone 1 Extent of Seepage Impacts, October 2012

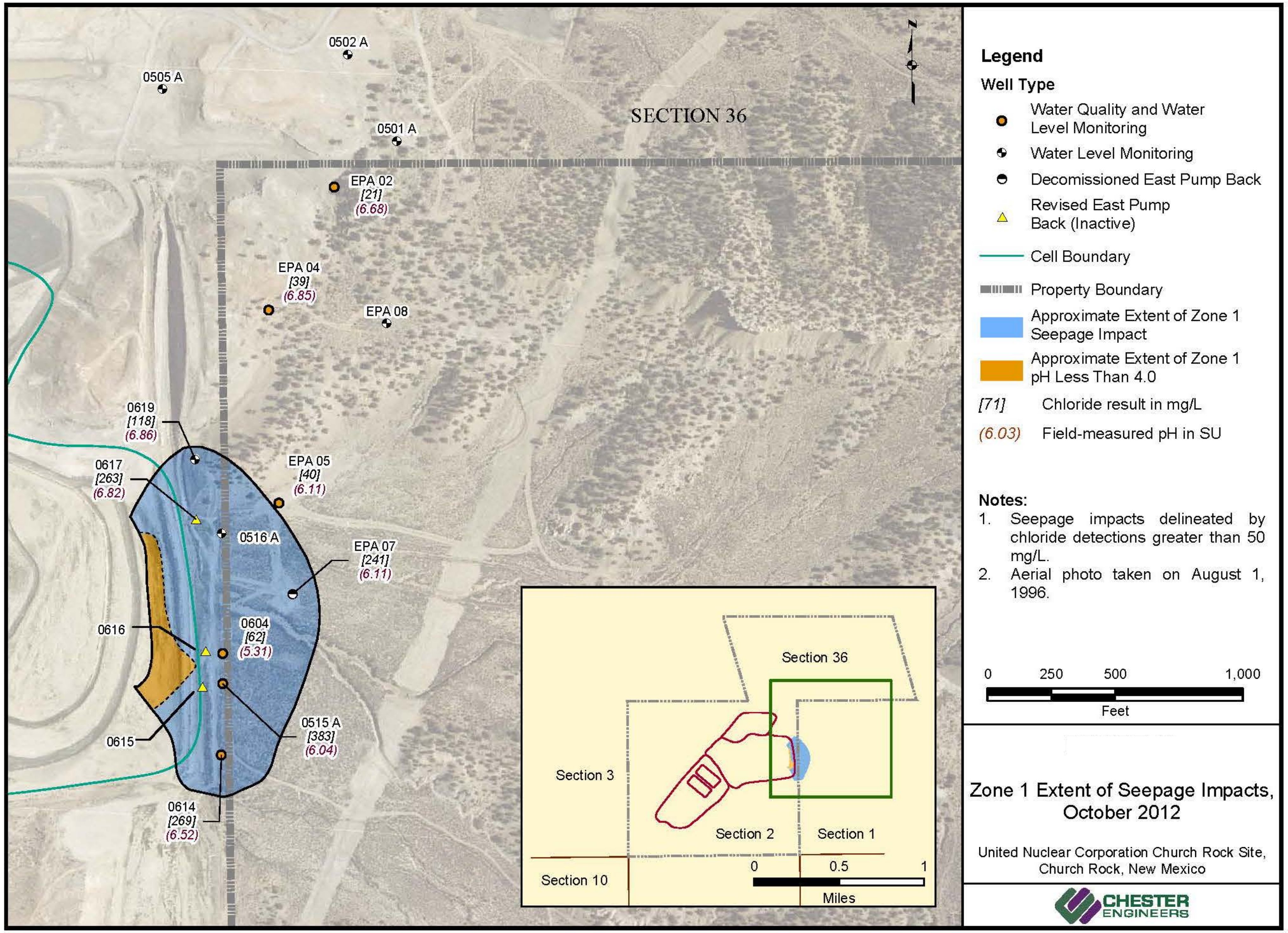

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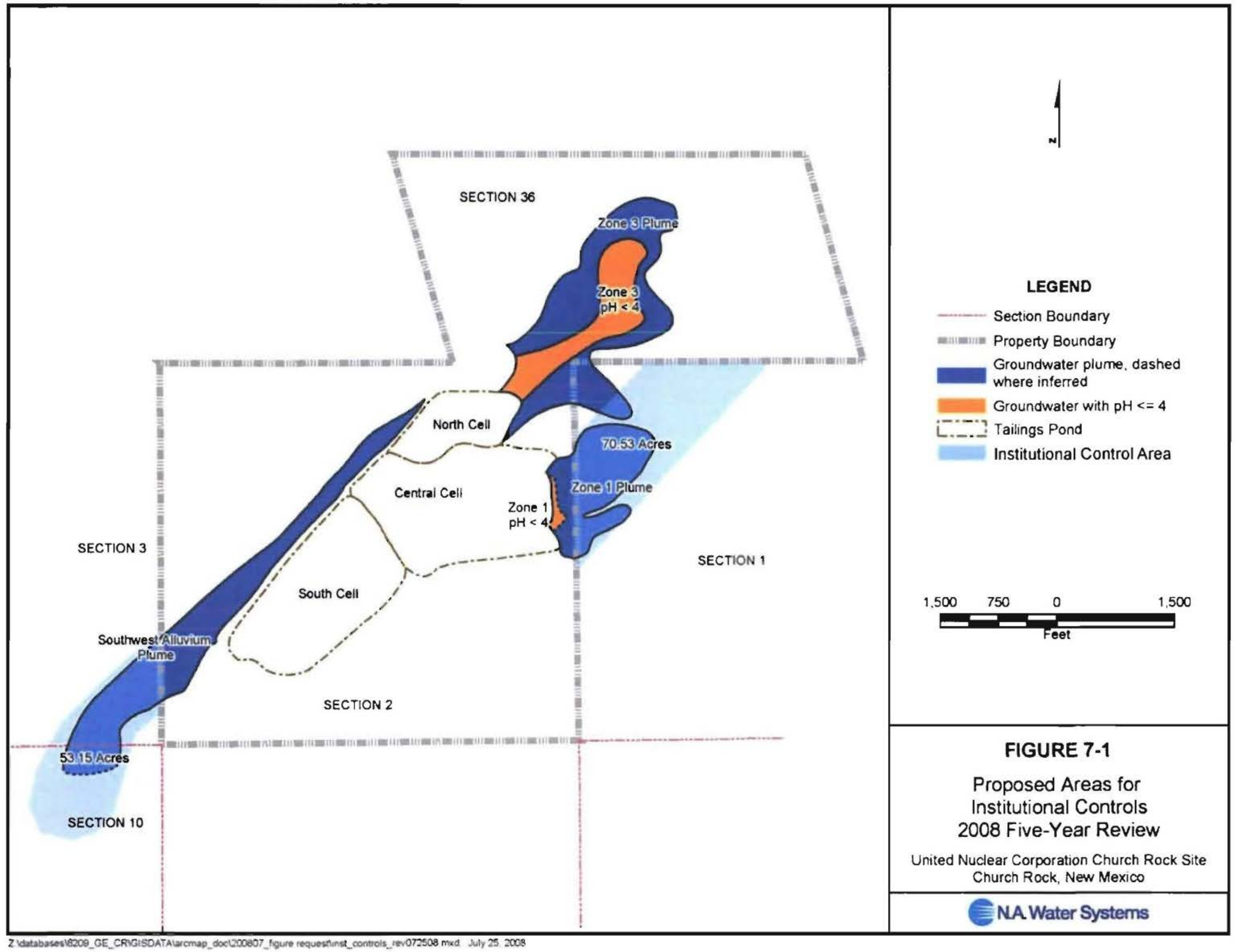
Figure 18 – Proposed Areas for Institutional Controls 2008 Five-Year Review



ATTACHMENTS

ATTACHMENT 1

LIST OF DOCUMENTS REVIEWED

Documents Reviewed

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Higgins-Coltrain (EPA); Subject: Support Info for Tomorrow's (Thurs) Conference Call UNC Church Rock Tailings Site. Two Attachments: (1) Key Technical References, United Nuclear Corporation Church Rock Mill Tailings Site (by Mark Jancin, Chester Engineers, June 6, 2012); and (2) Overview of Draft Attached Tables, Summary Comparisons of Upper Prediction Limits for Parameter Concentrations in Background Groundwater to Site Clean-up Standards and Potential ARARs for All Three Hydrostratigraphic Units at the Church Rock Mill Tailings Site (Chester Engineers, June 6, 2012). June 6, 2012. Minor revisions to the second attachment sent from Mark Jancin to Katrina Higgins-Coltrain on June 7, 2012.

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ATTACHMENT 2

FACT SHEET

EPA Signs Record of Decision for the United Nuclear Corporation Superfund Site

United Nuclear Corporation
McKinley County, New Mexico **March 29, 2013**

United States Environmental Protection Agency

This fact sheet will tell you about:

- The Record of Decision (ROD) for the Surface Soil Operable Unit
- Site History
- For More Information
- On the Web

Introduction

In July 2012, the U.S. Environmental Protection Agency (EPA) accepted public comment on the Surface Soil Operable Unit (OU02) Proposed Plan for the United Nuclear Corporation Superfund (UNC) Site. The comment period began on July 20, 2012, and ended on September 21, 2012. On March 29, 2013, EPA, in consultation with the New Mexico Environment Department (NMED), signed the Record of Decision for the remedy for the OU02.

Details of the Selected Remedy

The selected remedy (Alternative 2) includes the transportation, receipt, consolidation, and disposal of NECR Site mine waste at the UNC Site within the Tailings Disposal Area (Figure 1). EPA identified Alternative 2 as EPA's preferred remedy in the Surface Soil Operable Unit Proposed Plan for the UNC Site. Principal threat waste is not a part of this selected remedy and principal threat waste from the Northeast Church Rock Site will not be disposed of at the UNC Site. The O&M cost is estimated at $100K year which was calculated as a percentage of the remedy. The net present worth of O&M for 30 years was $1,230,000 (rounded). This was part of the $41.5 million estimated for the entire project. The design and license approval could take between two and four years; construction is projected to take an additional four years.

EPA selected the Preferred Alternative presented in the Proposed Plan because it is expected to be protective of human health and the environment, complying with regulations, and utilize permanent solutions and alternative treatment technologies to the maximum extent practicable.

Site History

The UNC Site includes a historic uranium mill that was licensed to operate by the State of New Mexico in May 1977. The mill operated from 1977 to 1982, and processed ore primarily from two of United Nuclear Corporation's nearby mines: Northeast Church Rock and Old Church Rock. Uranium ore was processed at the facility using a combination of crushing, grinding, and acid-leach solvent extraction methods. The milling operation produced acidic slurry of ground rock and fluid (tailing) that was pumped into the tailings area which consists of three cells. An estimated 3.5 million tons of tailings were disposed in the tailings impoundments (EPA, 1988a).

EPA placed the UNC Site onto the National Priorities List (NPL) of Superfund sites in 1983 [48 Fed. Reg. 40658 (Sept. 8, 1983)] because contaminated liquids had seeped from the tailings at the UNC Site and contaminated the underlying ground water, and because there were toxic emissions to surface water and air (EPA, 1988b). Acidic liquids had seeped from the tailings located in the unlined disposal cells into the underlying alluvium deposits (referred to as the Southwest Alluvium) and also into two deeper zones (Zones 1 and 3) of the Upper Gallup Sandstone Formation, contaminating the ground water with heavy metals, radionuclides such as uranium and radium, and other chemical constituents.

In 1988, EPA and the Nuclear Regulatory Commission (NRC) signed a Memorandum of Understanding (MOU) regarding the UNC Site [53 Fed. Reg. 37887 (September 28, 1988)]. The EPA and the NRC have overlapping authority in connection with the UNC Site, and the MOU

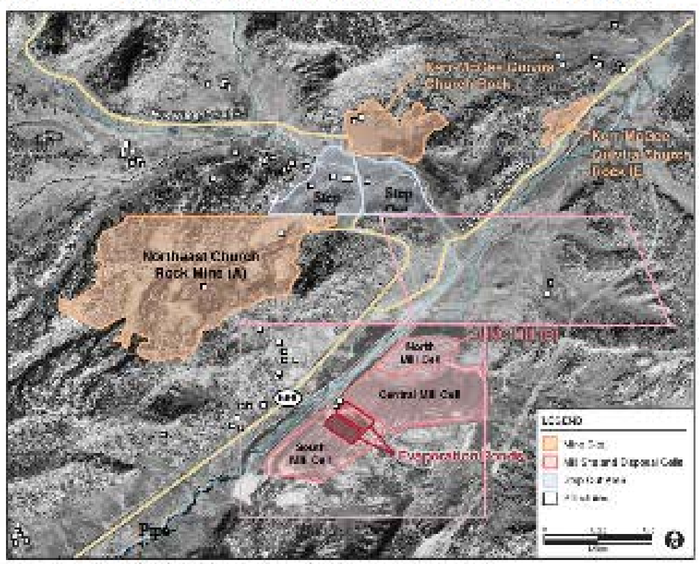


Figure 1: Northeast Church Rock Mine and United Nuclear Corporation site map

was developed to help assure that remedial actions occur in a timely and effective manner.

EPA issued a Ground Water Operable Unit ROD in September 1988 selecting a remedy for the contaminated ground water that included extraction of the ground water and treatment by evaporation. Under the oversight of EPA, United Nuclear Corporation constructed the remedy in 1989 and continues to address ground water contamination under the 1988 ROD. Ground water monitoring and extraction wells are located at the boundary and down-gradient of the Tailings Disposal Area. Ground water monitoring and remediation of the contaminant plumes are ongoing.

United Nuclear Corporation submitted a final reclamation plan to NRC which was approved in March 1991. Between 1988 and 1996, United Nuclear Corporation cleaned up the tailings disposal area including decommissioning of the mill facility, remediation of radium contaminated soil, capping of the tailings cells, installation of extraction wells, and construction of evaporation ponds and an evaporation system. All of these activities were completed under NRC oversight, and maintenance of the soil cleanup action continues.

For More Information

Janet Brooks
EPA Region 6, Remedial Project Manager
Tel: 214.665.7598 or 1.800.533.3508 (toll free)
brooks.janet@epa.gov

Jason T. McKinney
EPA Region 6, Community Involvement Coordinator
Tel: 214.665.8132 or 1.800.533.3508 (toll free)
Mckinney.jason@epa.gov

Earle Dixon
Project Manager
New Mexico Environment Department
Tel: 505.827.2890
Earle.dixon@state.nm.us

For press inquiries, please call the EPA Press Office at 214.665.2200.

Information Repositories are available at:

Octavia Fellin Public Library
115 West Hill Avenue
Gallup, NM 87310
Tel: 505.863.1291

Navajo Nation Superfund Office
Highway 264/43 Crest Road
St. Michaels, AZ 86511
Tel: 928.871.6859

On the Web

On the internet, the Record of Decision can be found at:

http://www.epa.gov/region6/6sf/6sf-decisiondocs.htm

Information about U.S. EPA Region 6 and the Superfund Program can be found at:

http://www.epa.gov/region6/6sf/6sf.htm

Call U.S. EPA at 1.800.533.3508 (toll free) to receive a Spanish translation of this fact sheet.

Para recibir una traducción en español de esta Hoja de Datos, comunicase con la Agencia de Protección del Medio Ambiente de los EEUU (la EPA) al número de teléfono 1.800.533.3508 (llamada gratis).

EPA
United States
Environmental Protection
Agency

Region 6
1445 Ross Ave. (6SF-VO)
Dallas, TX 75202

ATTACHMENT 3

PUBLIC NOTICE

BERNARD HODES GROUP.
220 East 42nd Street, , NY 10017
(212) 999-9999

PROOF OF INSERTION

IN 01205

CLIENT: CH2MHILL

PUBLICATION:NAVAJO TIMES

INSERTION DATE: NOV. 08, 2012

U.S. Environmental Protection Agency Region 6
Public Notice
United Nuclear Corporation (UNC) Superfund Site
2013 Five-Year Review of Site Remedy
October 2012

The Environmental Protection Agency (EPA) will evaluate the performance of the ground-water remedy for the United Nuclear Corporation (UNC) Site in Church Rock, New Mexico during the fourth five-year review and determine if it is still protective. Efforts to enhance the remedial system program through monitoring, natural attenuation, hydraulic injection-pumping, updated risk assessment, and feasibility studies are also included and will be evaluated. The EPA will work with the Nuclear Regulatory Commission (NRC), the New Mexico Environment Department (NMED) and the Navajo EPA (NNEPA) to conduct the 2013 five-year review. The EPA will evaluate the performance monitoring data generated si.. : the first five-year review in 1998 and since the last review in 2008. Those data are contained in UNC Annual Review Reports for groundwater remedial action. unnual Groundwater Reviews will be evaluated since tac third five-year review in 2008 to the latest Annual Review Report – 2011.

The EPA's fourth five-year review is scheduled to be completed in the fall of 2013. During the review, the EPA will conduct a Site inspection. The EPA plans to conduct interviews with key individuals or groups associated with the Site cleanup, including the Site Manager for UNC, representatives of regulatory agencies, the Navajo Pinedale Chapter, Site neighbors, and other stakeholders. A Five-Year Review Report will be prepared documenting the results of the EPA's review. As part of its community outreach effort, the EPA will notify the community when the Five-Year Review Report is complete, prepare and distribute a brief summary of the results in an informational bulletin, and place a copy of the Five-Year Review Report in the Site information repositories. The EPA also plans to hold an Open House meeting to present a summary of the five-year review results to the community.

FOR MORE INFORMATION

The following resources are available to make sure that you can locate the information you need to become involved in the Superfund Process at the United Nuclear Corporation Superfund Site.

If yo...

Janet Brooks, Remedial Project Manager
USEPA Region 6
1445 Ross Avenue (6SF-LP)
Dallas, TX 75202
Tel: 214.665.7598 or 800.533.3508 (toll-free)
Email: brooks.janet@epa.gov

For more information about the public involvement process, please contact:

Jason McKinney, Community Involvement Team
USEPA, Region 6
1445 Ross Avenue (6SF-VO)
Dallas, TX 75202
Tel: 214.665.8132 or 800.533.3508 (toll free)
Email: mckinney.jason@epa.gov

INFORMATION REPOSITORIES

If you would like more information about this Site, you may consult the Administrative Record File and other documents contained in the information repositories listed below.

Octavia Fellin Public Library
115 West Hill Avenue
Gallup, NM 87310
Tel: 505.863.1291

Navajo Nation, Navajo Superfund Office
Highway 264/43 Crest Road
St. Michaels, AZ 86511
Tel: 520.871.6859

New Mexico Environment Department
Harold Runnels Bldg.
1190 St. Francis Dr.
Santa Fe, NM 87505
Tel: 505.827.2855 or 800.879.3421 (toll free)

ON THE WEB:

USEPA Headquarters: *www.epa.gov*
USEPA Region 6: *www.epa.gov/region6*
USEPA Region 6 Superfund Program:
www.epa.gov/region6/superfund

ATTACHMENT 4

SITE INSPECTION CHECKLIST

2013 UNC Five Year Review Site Inspection Checklist

I. SITE INFORMATION	
Site name: United Nuclear Corporation	**Date of inspection: April 18, 2013**
Location and Region: McKinley County, Region 6	**EPA ID: NMD030443303**
Agency, office, or company leading the five-year review: New Mexico Environment Department	**Weather/temperature: Clear-partly cloudy & cold, about 30°F, occasional snow showers**

Remedy Includes: (Check all that apply)

- ☐ Landfill cover/containment
- **X** Access controls
- **X** Institutional controls
- **X** Groundwater pump and treatment
- **X** Surface water collection and treatment
- ☐ Other____
- **X** Monitored natural attenuation
- **X** walls Groundwater containment
- ☐ Vertical barrier

Attachments: X Inspection team roster attached ☐ Site map attached

II. INTERVIEWS (Check all that apply)

1. **O&M site manager** _____Larry Bush__________________ _UNC President___ __April 18, 2013__
   Name Title Date
   Interviewed ☐ at site **X** at office ☐ by phone Phone no. _______________
   Problems, suggestions; ☐ Report attached ____

2. **O&M staff** ______________________________ ________________________ _____________
   Name Title Date
   Interviewed at site ☐ at office ☐ by phone Phone no. _______________
   Problems, suggestions; ☐ Report attached ____

3.	**Local regulatory authorities and response agencies** (i.e., State and Tribal offices, emergency response office, police department, office of public health or environmental health, zoning office, recorder of deeds, or other city and county offices, etc.) Fill in all that apply. Agency _NM Environment Department________________ Contact ____Earle Dixon____________ ___Geoscientist_____ 4/18/2013 505-827-2890___ Name Title Date Phone no. Problems; suggestions; □ Report attached ____ ________Not interviewed since person is an author of the 2013 UNC Five Year Review Report______ Agency __Navajo Nation Superfund Program_________ Contact ___Eugene Esplain___________ _Project Manager__ 4/18/2013__ 928-871-7331__ Name Title Date Phone no. Problems; suggestions; X Report attached See interview form for Navajo Nation_______________ ____ Agency _____________________________ Contact _____________________________ ___________________ ________ ____________ Name Title Date Phone no. Problems; suggestions; □ Report attached ____ ____ Agency _____________________________ Contact _____________________________ ___________________ ________ ____________ Name Title Date Phone no. Problems; suggestions; □ Report attached ____ ____
4.	**Other interviews** (optional) □ Report attached.

	III. ON-SITE DOCUMENTS & RECORDS VERIFIED (Check all that apply)
1.	**O&M Documents** □ O&M manual X Readily available □ Up to date □ N/A □ As-built drawings X Readily available □ Up to date □ N/A □ Maintenance logs □ Readily available □ Up to date X N/A Remarks: UNC has all available documentation in the office and it is kept up to date. Annual reports show maps of wells in each zone and facility features.____ ____
2.	**Site-Specific Health and Safety Plan** X Readily available X Up to date □ N/A □ Contingency plan/emergency response plan X Readily available X Up to date □ N/A Remarks: Documents are available in the office.____ ____
3.	**O&M and OSHA Training Records** X Readily available □ Up to date □ N/A Remarks: Radiation Safety Officer is on site.____ ____

4.	**Permits and Service Agreements** □ Air discharge permit □ Readily available □ Up to date **X** N/A □ Effluent discharge □ Readily available □ Up to date **X** N/A □ Waste disposal, POTW □ Readily available □ Up to date **X** N/A □ Other permits: NRC Source Material License SUA-1475_______ **X** Readily available **X** Up to date □ N/A Remarks____
5.	**Gas generation Records** □ Readily available □ Up to date **X** N/A Remarks____
6.	**Settlement Monument Records** □ Readily available □ Up to date **X** N/A Remarks____
7.	**Groundwater Monitoring Records** **X** Readily available □ Up to date □ N/A Remarks____
8.	**Leachate Extraction Records** □ Readily available □ Up to date **X** N/A Remarks____
9.	**Discharge Compliance Records** □ Air □ Readily available □ Up to date **X** N/A □ Water (effluent) **X** Readily available □ Up to date □ N/A Remarks____
10.	**Daily Access/Security Logs** **X** Readily available □ Up to date □ N/A Remarks_ The UNC Site staff very closely monitor site access & visitors must sign-in at office in log book. ___________________________

IV. O&M COSTS	
1.	**O&M Organization** □ State in-house □ Contractor for State □ PRP in-house **X** Contractor for PRP □ Federal Facility in-house □ Contractor for Federal Facility □ Other______AMEC is the contractor for UNC.________________________

2. **O&M Cost Records**
X Readily available **X** Up to date
□ Funding mechanism/agreement in place
Original O&M cost estimate____________________ □ Breakdown attached

Total annual cost by year for review period if available

From___2008___ To___2009___ ___$582,000_______ □ Breakdown attached
Date Date Total cost
From___2009___ To___2010___ ___$537,000_______ □ Breakdown attached
Date Date Total cost
From___2010___ To___2011___ ___$595,000_______ □ Breakdown attached
Date Date Total cost
From___2011___ To___2012___ ___$1,092,000______ □ Breakdown attached
Date Date Total cost
From___2012___ To___2013___ ___$1,292,000______ □ Breakdown attached
Date Date Total cost

3. **Unanticipated or Unusually High O&M Costs During Review Period**
Describe costs and reasons: ________none identified.____

V. ACCESS AND INSTITUTIONAL CONTROLS **X** Applicable □ N/A

A. Fencing

1. **Fencing.** □ Location shown on site map □ Gates secured X N/A
Remarks: Fencing is in place & well maintained. Final fence will be installed at site closure._____
___Gates maintained with chains & locks.____

B. Other Access Restrictions

1. **Signs and other security measures** □ Location shown on site map □ N/A
Remarks: No trespassing signs are visibly posted in conspicuous places._________________

C. Institutional Controls (ICs)

1. **Implementation and enforcement**

Site conditions imply ICs not properly implemented X Yes □ No □ N/A

Site conditions imply ICs not being fully enforced X Yes □ No □ N/A

Type of monitoring (*e.g.*, self-reporting, drive by) _UNC self reports & agencies frequently visit UNC & NECR Sites.____

Frequency _no less than monthly____

Responsible party/agency ____

Contact ______________________________ ___________________ ________ ____________

Name Title Date Phone no.

Reporting is up-to-date X Yes □ No □ N/A

Reports are verified by the lead agency X Yes □ No □ N/A

Specific requirements in deed or decision documents have been met □ Yes □ No X N/A

Violations have been reported □ Yes □ No X N/A

Other problems or suggestions: □ Report attached

____Institutional Controls (ICs) will require EPA, BIA, Navajo Nation, community, and UNC discussion and agreements to see what will work, what is required, and what is acceptable.________

2. **Adequacy** □ ICs are adequate X ICs are inadequate □ N/A

Remarks: ICs will be required to close & transfer the mill site to Department of Energy Legacy Management.____

D. General

1. **Vandalism/trespassing** □ Location shown on site map □ No vandalism evident

Remarks: Occasionally there is trespassing on to site for livestock grazing. There has been some vandalism of signs.____

2. **Land use changes on site** □ N/A

Remarks: No land use changes on site.____

3. **Land use changes off site** □ N/A

Remarks: No land use changes off site. ____

VI. GENERAL SITE CONDITIONS

A. Roads X Applicable □ N/A

1. **Roads damaged** □ Location shown on site map X Roads adequate □ N/A

Remarks____

B. Other Site Conditions

Remarks ____
____
____
____
____
____

VII. LANDFILL COVERS □ Applicable **X** N/A

A. Landfill Surface

1. **Settlement** (Low spots) □ Location shown on site map □ Settlement not evident
Areal extent______________ Depth____________
Remarks____
____

2. **Cracks** □ Location shown on site map □ Cracking not evident
Lengths____________ Widths___________ Depths__________
Remarks____
____

3. **Erosion** □ Location shown on site map □ Erosion not evident
Areal extent______________ Depth____________
Remarks____
____

4. **Holes** □ Location shown on site map □ Holes not evident
Areal extent______________ Depth____________
Remarks____
____

5. **Vegetative Cover** □ grass □ Cover properly established □ No signs of stress
□ Trees/Shrubs (indicate size and locations on a diagram)
Remarks____
____

6. **Alternative Cover (armored rock, concrete, etc.)** □ N/A
Remarks____
____

7. **Bulges** □ Location shown on site map □ Bulges not evident
Areal extent______________ Height____________
Remarks____
____

8.	**Wet Areas/Water Damage** ☐ Wet areas/water damage not evident ☐ Wet areas ☐ Location shown on site map Areal extent______________ ☐ Pending ☐ Location shown on site map Areal extent______________ ☐ Seeps ☐ Location shown on site map Areal extent______________ ☐ Soft sub grade ☐ Location shown on site map Areal extent______________ Remarks____ ____
9.	**Slope Instability** ☐ Slides ☐ Location shown on site map ☐ No evidence of slope instability Areal extent______________ Remarks____ ____
B. Benches	☐ Applicable ☐ N/A (Horizontally constructed mounds of earth placed across a steep landfill side slope to interrupt the slope in order to slow down the velocity of surface runoff and intercept and convey the runoff to a lined channel.)
1.	**Flows Bypass Bench** ☐ Location shown on site map ☐ N/A or okay Remarks____ ____
2.	**Bench Breached** ☐ Location shown on site map ☐ N/A or okay Remarks____ ____
3.	**Bench Overtopped** ☐ Location shown on site map ☐ N/A or okay Remarks____ ____
C. Letdown Channels	☐ Applicable ☐ N/A (Channel lined with erosion control mats, riprap, grout bags, or gabions that descend down the steep side slope of the cover and will allow the runoff water collected by the benches to move off of the landfill cover without creating erosion gullies.)
1.	**Settlement** ☐ Location shown on site map ☐ No evidence of settlement Areal extent______________ Depth____________ Remarks____ ____
2.	**Material Degradation** ☐ Location shown on site map ☐ No evidence of degradation Material type_______________ Areal extent_____________ Remarks____ ____
3.	**Erosion** ☐ Location shown on site map ☐ No evidence of erosion Areal extent______________ Depth____________ Remarks____ ____
4.	**Undercutting** ☐ Location shown on site map ☐ No evidence of undercutting Areal extent______________ Depth____________ Remarks____ ____

5. **Obstructions** Type______________________ □ No obstructions
□ Location shown on site map Areal extent______________
Size_____________
Remarks____
____

6. **Excessive Vegetative Growth** Type_____________________
□ No evidence of excessive growth
□ Vegetation in channels does not obstruct flow
□ Location shown on site map Areal extent______________
Remarks____
____

D. Cover Penetrations □ Applicable □ N/A

1. **Gas Vents** □ Active□ Passive
□ Properly secured/locked □ Functioning □ Routinely sampled □ Good condition
□ Evidence of leakage at penetration □ Needs Maintenance
□ N/A
Remarks____
____

2. **Gas Monitoring Probes**
□ Properly secured/locked □ Functioning □ Routinely sampled □ Good condition
□ Evidence of leakage at penetration □ Needs Maintenance □ N/A
Remarks____
____

3. **Monitoring Wells** (within surface area of landfill)
□ Properly secured/locked □ Functioning □ Routinely sampled □ Good condition
□ Evidence of leakage at penetration □ Needs Maintenance □ N/A
Remarks____
____

4. **Leachate Extraction Wells**
□ Properly secured/locked □ Functioning □ Routinely sampled □ Good condition
□ Evidence of leakage at penetration □ Needs Maintenance □ N/A
Remarks____
____

5. **Settlement Monuments** □ Located □ Routinely surveyed □ N/A
Remarks____
____

E. □ as Collection and Treatment □ Applicable □ N/A

1. **Gas Treatment Facilities**
□ Flaring □ Thermal destruction □ Collection for reuse
□ Good condition □ Needs Maintenance
Remarks____
____

2.	**Gas Collection Wells, Manifolds and Piping** □ Good condition □ Needs Maintenance Remarks____ ____
3.	**Gas Monitoring Facilities** (*e.g.*, gas monitoring of adjacent homes or buildings) □ Good condition □ Needs Maintenance □ N/A Remarks____ ____
F. Cover Drainage Layer	□ Applicable □ N/A
1.	**Outlet Pipes Inspected** □ Functioning □ N/A Remarks____ ____
2.	**Outlet Rock Inspected** □ Functioning □ N/A Remarks____ ____
G. Detention/Sedimentation Ponds	□ Applicable □ N/A
1.	**Siltation** Areal extent_______________ Depth_____________ □ N/A □ Siltation not evident Remarks____ ____
2.	**Erosion** Areal extent_______________ Depth_____________ □ Erosion not evident Remarks____ ____
3.	**Outlet Works** □ Functioning □ N/A Remarks____ ____
4.	**Dam** □ Functioning □ N/A Remarks____ ____

H. Retaining Walls	□ Applicable □ N/A
1.	**Deformations** □ Location shown on site map □ Deformation not evident Horizontal displacement_____________ Vertical displacement________________ Rotational displacement_____________ Remarks____ ____
2.	**Degradation** □ Location shown on site map □ Degradation not evident Remarks____ ____
I. Perimeter Ditches/Off-Site Discharge	□ Applicable □ N/A

1.	**Siltation** □ Location shown on site map □ Siltation not evident Areal extent_______________ Depth_____________ Remarks____ ____	
2.	**Vegetative Growth** □ Location shown on site map □ N/A □ Vegetation does not impede flow Areal extent_______________ Type_____________ Remarks____ ____	
3.	**Erosion** □ Location shown on site map □ Erosion not evident Areal extent_______________ Depth_____________ Remarks____ ____	
4.	**Discharge Structure** □ Functioning □ N/A Remarks____ ____	
	VIII. VERTICAL BARRIER WALLS □ Applicable **XX** N/A	
1.	**Settlement** □ Location shown on site map □ Settlement not evident Areal extent_______________ Depth_____________ Remarks____ ____	
2.	**Performance Monitoring** Type of monitoring ___________________________ □ Performance not monitored Frequency________________________________□ Evidence of breaching Head differential___________________________ Remarks____ ____	

	IX. GROUNDWATER/SURFACE WATER REMEDIES **X** Applicable □ N/A
A. Groundwater Extraction Wells, Pumps, and Pipelines **X** Applicable □ N/A	
1.	**Pumps, Wellhead Plumbing, and Electrical** □ Good condition □ All required wells properly operating **X** Needs Maintenance □ N/A Remarks: Only Zone 3 extraction wells operational, but they require constant maintenance. Pumps fail & burn out on a regular basis. Clay coating on pump impellers requires disassembly & cleaning to restore operational efficiency.
2.	**Extraction System Pipelines, Valves, Valve Boxes, and Other Appurtenances** **X** Good condition □ Needs Maintenance Remarks: Equipment is maintained in good condition (Zone 3 extraction system only).___________ ____
3.	**Spare Parts and Equipment** **X** Readily available □ Good condition □ Requires upgrade □ Needs to be provided Remarks____ ____
B. Surface Water Collection Structures, Pumps, and Pipelines □ Applicable **X** N/A	

1.	**Collection Structures, Pumps, and Electrical** □ Good condition □ Needs Maintenance Remarks____	
2.	**Surface Water Collection System Pipelines, Valves, Valve Boxes, and Other Appurtenances** □ Good condition □ Needs Maintenance Remarks____	
3.	**Spare Parts and Equipment** □ Readily available □ Good condition □ Requires upgrade □ Needs to be provided Remarks____	

. **Treatment System**	**X** Applicable □ N/A	
1.	**Treatment Train** (Check components that apply) □ Metals removal □ Oil/water separation □ Bioremediation □ Air stripping □ Carbon adsorbers □ Filters____ □ Additive (*e.g.*, chelation agent, flocculent)_______________________ □ Others____ **X** Good condition □ Needs Maintenance □ Sampling ports properly marked and functional □ Sampling /maintenance log displayed and up to date **X** Equipment properly identified **X** Quantity of groundwater treated annually: See UNC Annual Review Report for Zone 3 only.____ □ Quantity of surface water treated annually________________________ Remarks____	
2.	**Electrical Enclosures and Panels** (properly rated and functional) □ N/A **X** Good condition □ Needs Maintenance Remarks____	
3.	**Tanks, Vaults, Storage Vessels** **X** N/A □ Good condition □ Proper secondary containment □ Needs Maintenance Remarks____	
4.	**Discharge Structure and Appurtenances** □ N/A **X** Good condition □ Needs Maintenance Remarks: Evaporative spray guns have not operated since about 2001, but there is no excess water to evaporate.___________________________________	
5.	**Treatment Building(s)** **X** N/A □ Good condition (esp. roof and doorways) □ Needs repair □ Chemicals and equipment properly stored Remarks____	

6.	**Monitoring Wells** (pump and treatment remedy) **X** Properly secured/locked **X** Functioning **X** Routinely sampled **X** Good condition **X** All required wells located □ Needs Maintenance □ N/A Remarks____ ____
D. Monitoring Data	
1.	Monitoring Data **X** Is routinely submitted on time **X** Is of acceptable quality
2.	Monitoring data suggests: see 2013 UNC FYR Report Section 6 discussion. □ Groundwater plume is effectively contained **X** Contaminant concentrations are declining

D. Monitored Natural Attenuation	
1.	**Monitoring Wells** (natural attenuation remedy) □ Properly secured/locked **X** Functioning □ Routinely sampled □ Good condition □ All required wells located □ Needs Maintenance □ N/A Remarks: Natural attention of metals & radionuclides occurring in all three hydrostratigraphic zones. NA not occurring at rates & concentrations that will meet Site cleanup standards in a reasonable amount of time. See 2013 UNC FYR Report Section 6 for discussion.______________________________ ____
X. OTHER REMEDIES	
	If there are remedies applied at the site which are not covered above, attach an inspection sheet describing the physical nature and condition of any facility associated with the remedy. An example would be soil vapor extraction.
XI. OVERALL OBSERVATIONS	
A.	**Implementation of the Remedy**

Describe issues and observations relating to whether the remedy is effective and functioning as designed. Begin with a brief statement of what the remedy is to accomplish (i.e., to contain contaminant plume, minimize infiltration and gas emission, etc.).

___The remedy as required in the 1988 ROD was implemented in all three zones as removal, evaporation & containment of contaminated ground water using wells to meet a single set of cleanup standards. A performance monitoring well network was also implemented to track the capacity of the extraction system to cleanup ground water contamination to Site standards. Unfortunately, as the hydraulic thicknesses of the aquifers decreased & the recharge from mine dewatering ceased, the pumping efficiency of the extraction systems also decreased to below 1.0 gallons per minute (gpm). Ground water extraction systems were shut down in 1999 & 2000 with agency approval because they were no longer effectively removing contaminated ground water & treating the ground water to meet cleanup standards. There is monitoring data & scientific evidence that demonstrates natural attenuation of metals & radionuclides is reducing contaminant concentrations, but not to levels that meet all of the cleanup standards for all constituents in a reasonable amount of time. In 2006 EPA required that a feasibility study (FS) be undertaken to review alternative remedial technologies, update & propose revised cleanup standards, conduct an updated baseline risk assessment, & provide a detailed cost estimate of possible remedial alternatives that could meet proposed, revised cleanup standards. The FS follows EPA guidance for a 3 part process, Parts I completed in 2008 & Parts I and II were combined and completed in 2012 after approval by EPA. Completion of Part III is pending UNC's 2012 request for a license amendment to the NRC Ground Water Protection Standards for the Site. The remedy is still considered to be protective of human health & the environment because there is no known exposure to the contaminated ground water.__________________________________

B. Adequacy of O&M

Describe issues and observations related to the implementation and scope of O&M procedures. In particular, discuss their relationship to the current and long-term protectiveness of the remedy.

____

_____ O&M measures are adequate, but they have no effect on the current & long-term protectiveness of the remedy.____

____
____
____
____
____

C. Early Indicators of Potential Remedy Problems

	Describe issues and observations such as unexpected changes in the cost or scope of O&M or a high frequency of unscheduled repairs that suggest that the protectiveness of the remedy may be compromised in the future. ____ ______The extraction systems are not operational for two zones; the Southwest Alluvium & Zone 1 so there is no O&M cost associated with these systems except for the performance monitoring. The Zone 3 extraction system is operational in the northeast part of the impacted area on an experimental basis. The Zone 3 extraction system requires constant maintenance due to extremely low pumping rates & pump fouling-failure.____ ____ ____ ____
D.	**Opportunities for Optimization**
	Describe possible opportunities for optimization in monitoring tasks or the operation of the remedy. ____ ___Pending the completion of the FS Part III, the agencies & UNC will discuss the opportunities for optimization of the performance monitoring system & the operation of the remedy to be revised. Other opportunities for optimization in monitoring tasks & operation of the remedy include annual meetings & ongoing correspondence-discussion about reports-information as they become available.____ ____ ____ ____ ____ ____ ____

2013 UNC FIVE YEAR REVIEW SITE INSPECTION MEMORANDUM

To: 2013 UNC Five Year Review Report
From: Earle Dixon, NM Environment Department (NMED)
Subject: 2013 UNC Five Year Review Site Inspection
Date: April 18, 2013

Earle Dixon (NMED) and Janet Brooks, Environmental Protection Agency (EPA) Region 6 Remedial Project Manager (RPM) were in the Gallup, NM area to attend the 2013 Uranium Contamination Stakeholders Workshop on April 16-17, 2013. Mr. Dixon & Ms. Brooks arrived at the United Nuclear Corporation (UNC) Mill Site office at approximately 9 am to meet Mr. Larry Bush, Vice President of UNC, and Mr. Roy Blickwedel, General Electric (GE) RPM. The weather was typical for the southern Colorado Plateau-Gallup area during the middle of April: partly cloudy to partly sunny, breezy, cool (mid 30s°F), with scattered snow showers at times. After signing the visitor log book, the four of us sat down at the meeting room conference table to talk about the Five Year Review Site Inspection Checklist form items that Mr. Dixon used to help lead and generate discussion among the participants. All of the Site Inspection Checklist items for documentation are fully satisfied and present in good order at the UNC office.

With regard to Access and Institutional Controls, this item generated some lengthy discussion. UNC does a good job of maintaining a fenced perimeter around the tailings disposal area with locked gates for access and no trespassing signs posted in conspicuous places. Larry Bush and the AMEC contractor staff perform sometimes daily, weekly, and monthly patrols of the facility perimeter to ensure the fencing is intact because at various times the fencing has been cut to allow livestock to graze in vegetated areas. At some times in the past, some of the UNC signs have been removed by vandalism. Institutional Controls were discussed and the participants agreed that this item is going to need attention in the ongoing efforts to prepare the site for regulatory closure and long-term monitoring.

The checklist item for Ground Water Remedy-Extraction Wells, Pumps, & Pipelines was given a lengthy discussion especially for the benefit of Ms. Brooks as she becomes more knowledgeable about UNC Site operations and history. UNC described how the operation & maintenance (O&M) is a constant challenge because of the very low groundwater extraction rate, and encrustation from carbonate, gypsum, and iron-hydroxide precipitation may cause the wells and pumps to foul. Extraction pumps fail and burn-out on a regular basis. Due to encrustation on the pump impellors, the pumps must be disassembled and the impellors cleaned on a regular basis. Despite the O&M challenges, UNC does a good job of maintaining the equipment in good order. The evaporation ponds are mostly dry except for the collection of precipitation from storm events and very minor amount of Zone 3 extraction water. The evaporator spray guns have not operated since 2000.

The discussion moved to the checklist item of Groundwater Remedy-Monitoring Wells. UNC indicated the best source of information about the status of the groundwater remedy for each of the three hydrostratigraphic zones is the annual report. The UNC Annual Report summarizes the quarterly monitoring well data and updates the historical trend charts and contour maps for water level decline and concentrations of Contaminants of Potential Concern (COPC). The Site Wide Supplemental Feasibility Study (SWSFS) work (Parts I & II) was cited as some of the major steps toward preparing the information necessary to support revision of the Record of Decision (ROD). The ProUCL statistics, proposed Background Threshold Values, Updated Baseline Human Health Risk Assessment, and the Groundwater Flow Model were highlighted as significant accomplishments in the 2008-2013 period. The recent Source Material License Amendment request that UNC submitted to the NRC in 2012 is an important next step as well. UNC is looking forward to completing a draft of the SWSFS Part III (technical analysis of remedial alternatives) in late 2013-early 2014. The issue of natural attenuation as part of the groundwater remedy was discussed, and it is considered to be a major feature of the natural buffering system. Slow movement of the plume in Zone 3 are considered to be a challenge for final regulatory compliance and site closure. The installation of groundwater model verification and sentinel wells was discussed as an important step that needs to occur in 2013 if possible because UNC is ready to move forward with well permitting, drilling, and well construction. Ideally, well drilling and construction would occur during the time of year when the weather is best (late spring-summer-early fall). UNC is waiting on a request from Navajo Nation to EPA for the installation of the wells. NMED is going to assist Navajo with the letter later this year.

After almost 2 hours of office discussion Mr. Bush led the participants on a tour of the UNC tailings pond disposal and ground water remedy performance monitoring area beginning at 11 am. The section on site photographs presents the areas that were toured. It is important to bear in mind that the tailings disposal area encompasses about 100 acres. The north, central, and south tailings cells are capped with the radon barrier and interim soil cover. The south cell contains the two evaporation ponds in the northern part of the cell. There are no active requirements for radon and air quality monitoring at the site as approved by the Nuclear Regulatory Commission (NRC) under source material license SUA-1475.

The tour started along the north end of the north cell. Crossing the Pipeline Arroyo, Mr. Bush pointed out where the natural gradient of the channel was returning to normal after they removed the culverts in 2011. The culverts caused a reduction in flow during major storm events and runoff backed up & flooded the area. UNC also reworked the Pipeline Arroyo channel from the north cell tailings dam down to the Nick Point area which resulted in better drainage during storm runoff events. From the north the end of the north cell, we proceeded to the overlook known locally as "Dilco Hill" where there is an outcrop of the lower section of the Crevasse Canyon Formation known as the Dilco Coal member. The Dilco Coal member contains visible gypsum crystals.

From Dilco Hill we went south along the eastern part of the central cell and stopped briefly to look east from the berm at the Zone 1 plume monitoring area (See Figure C-1, 2012 UNC Annual Report). From there we went along the southern margin of the central cell (photograph 5) to the northeast side of the south cell where we could see the evaporation ponds (photograph 2). We drove across the northern berm of the south cell to the basalt rock jetty and Nick Point area. The jetty area is the location for a problem caused by the natural vegetation of salt cedar and rabbit brush that causes significant ponding during storm events. The storm water runoff builds up behind the vegetation and flows out between the vegetation at a velocity high enough to move the rock boulders a few feet away from the original jetty location. UNC is going to have to consult with the NRC about what to do with the natural vegetation causing this problem. There is no headwall erosion from the toe of the dam. See photograph 9 for a view of the area where storm runoff has moved the rock jetty.

The Nick Point is an important stopping point for understanding some of the main features of the UNC Site hydrogeology (photographs 6 & 7). The Nick Point is an outcrop of the Gallup Sandstone Formation that has been incised by the Pipeline Arroyo. During the period of active mine dewatering, the Nick Point was covered in water. After the mine dewatering stopped completely in 1986, the Arroyo has returned to the natural intermittent condition. The Southwest Alluvium (SWA) has continued to drain down due to the lack of recharge water. Ground water is separated at the Nick Point, and it either flows to the south or it ponds up behind the Point. Due to the lack of mine dewatering recharge and the tailings material dewatering as well, the ground water in the SWA, Zone 1, and Zone 3 continues to drain out with very little to no natural recharge. At the Nick Point one is also able to see the arkosic nature (high feldspar content) of the Gallup Sandstone which alters to clay when contacted by tailings seepage, and helps seal the formation after it is impacted.

From the Nick Point we traveled south to the SWA 800 series of extraction-monitoring wells (photograph 10). Next we went up to the Zone 3 plume extraction and monitoring area where a significant level of effort has been expended by UNC to address the migration of tailings seepage water. Photographs 11, 12, and 13 show some of the monitoring, extraction, and injection wells that have been employed to create a hydraulic barrier to slow down the migration rate of the Zone 3 plume, and to extract seepage impacted water. A couple of the extraction wells were operating at about 1 gpm when we visited the area. We talked about the need for ground water model verification wells north of this area, the location of the Section 36 boundary, and the issue of institutional controls to prevent any possibility of exposure to contaminated ground water. We concluded the tour and returned to the UNC Mill Office at about 1230 pm.

ATTACHMENT 5

PHOTOGRAPHS

Photograph 1. View generally west across central evaporative tailings disposal pond area toward UNC Mill Site office and shop buildings.

Photograph 2. View from east side central tailings pond area west toward UNC Mill Site office road. Water in ponds is mostly from precipitation & rest is from Zone 3 extraction well system.

Photograph 3. Close-up view generally westward across UNC Mill Site central evaporative tailings disposal pond area. Tailings are covered with radon barrier & interim soil cover.

Photograph 4. View of locked gate system on road to UNC Mill Site north end/Zone 3 remediation area.

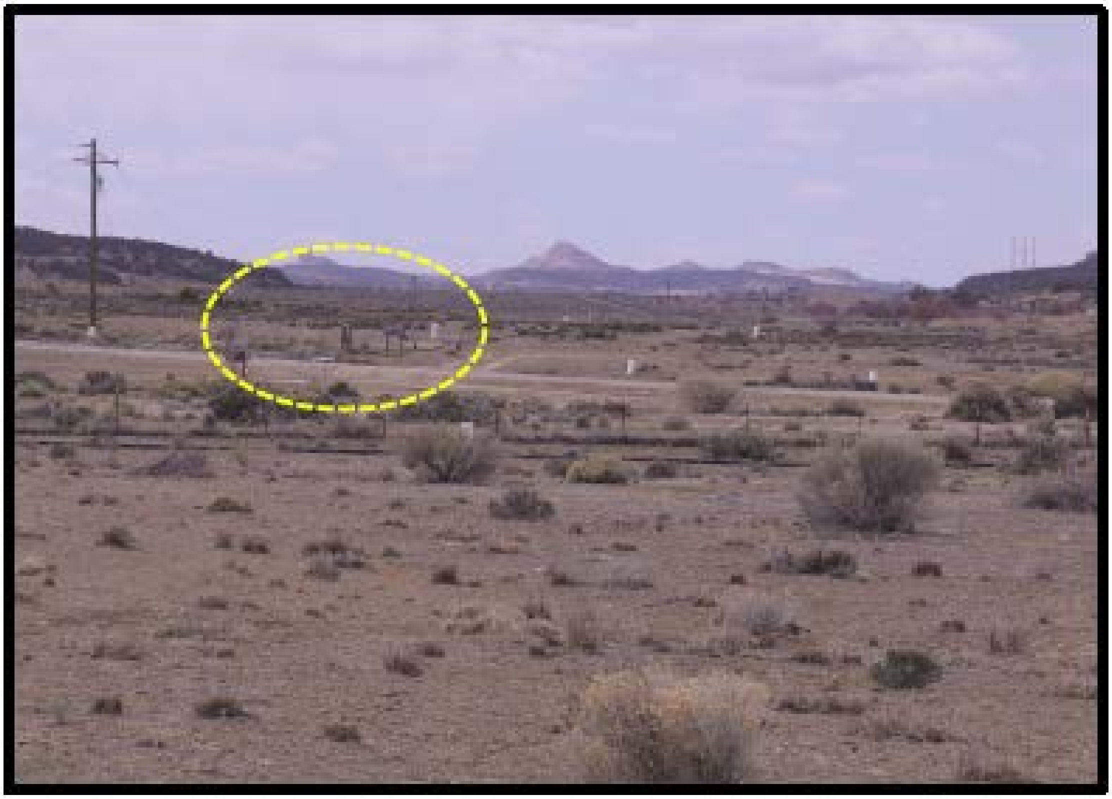
Photograph 5. View of evaporator spray guns (3 ea.) in central area of UNC Mill Site evaporative tailings pond disposal area. Evaporators have not operated since 2000.

Photograph 6. View looking south down Pipeline Arroyo channel from Nick Point at UNC Mill Site.

Photograph 9. View of rock jetty showing effects of storm event runoff caused by water build up and release through an opening in a wall of natural vegetation (circled area). Runoff moved boulders a short distance at UNC Mill Site evaporative tailings pond disposal area.

Photograph 10. View of Southwest Alluvium extraction-monitoring well No. 803 at south end of UNC Mill Site evaporative tailings pond disposal area. Well has not been used for extraction since 1999.

Photograph 13. View looking south down Zone 3 plume extraction & monitoring area at the UNC Mill Site evaporative tailings pond disposal area. Ellipse indicates extraction wells & electrical panel



ATTACHMENT 6

INTERVIEW RECORDS

United Nuclear Corporation 2013 Five-Year Review

Questions for Roy Blickwedel, General Electric Company

1. What is your overall impression of the project? (general sentiment)

    Remediation has generally been effective and it has been protective of human health and the environment.

2. What is the current status of the ground-water remediation at the Site?

    The active groundwater pumping systems in two of the three water-saturated strata that were impacted by tailings seepage migration have been discontinued. Zone 1 was discontinued in July 1999 with the approval of the Nuclear Regulatory Commission (NRC) because the decommissioning criteria were achieved. Groundwater quality in the offsite portion of Zone 1 is in compliance with the NRC groundwater protection standards. In some locations within the UNC-owned property, cobalt, nickel, and total trihalomethanes may exceed the NRC groundwater protection standards, although there is ample empirical evidence that shows the extent of seepage-impacted water is naturally diminishing in Zone 1.

    In the Southwest Alluvial system, active pumping was discontinued in 2001 with EPA and NRC approval to conduct an 18-month natural attenuation test. The report, completed in December 2002, recommended the replacement of the current remedy with a natural attenuation remedy for metals and radionuclides, and a Technical Impracticability Waiver for sulfate and TDS. The Southwest Alluvium is currently in compliance with all of the NRC groundwater protection standards, but not all of the EPA-mandated standards.

    Zone 3 pumping was discontinued in December 2000 with the approval of NRC. EPA recognized during the 1st Five-Year Review of 1998 that Zone 3 pumping was not effective, and was perhaps detrimental to the containment of seepage-impacted water in Zone 3. Approval to cease pumping was granted in December 2000, conditioned on the installation of a sentinel monitoring well and the evaluation of other remedy enhancement alternatives. Alternative remedy enhancements were pilot tested between 2003 and 2012. None have been successful in enhancing the effectiveness of the remedy for very long. However, the hydraulic fracturing test resulted in the placement of some new extraction wells that avoid the problems associated with the former pumping system. Pumping from the new Zone 3 wells continues, albeit it at a consistently declining yield. Current groundwater recovery from all Zone 3 pumping wells *combined is about 2.3 gallons per minute or about the same as a garden hose turned on low.*

3. Did the ground water remedy function as expected in the Southwest Alluvium and Zone 1? How well did the ground water remedy perform?

The groundwater pumping remedy has achieved significant desaturation of the impacted groundwater in each area. As anticipated in the June 1988 Record of Decision (ROD) and the initial Five-year Review, and as substantiated in the various technical reports for the site, groundwater pumping has reached the limits of its effectiveness. In all three groundwater target areas further groundwater pumping will have no additional, appreciable, beneficial effect on achieving cleanup goals beyond the natural processes that are occurring. The remedy has functioned as well as was expected when EPA chose it in the ROD.

As a practical matter, EPA expected that it would be necessary to re-evaluate the performance goals that were established in the ROD. EPA expected that significant desaturation of the impacted media could occur and that it would be necessary to change the performance goals that were established in the ROD. Despite the anticipated technological limitations, groundwater quality in the offsite portion of Zone 1 is in compliance with the NRC groundwater protection standards, and the Southwest Alluvium is in full compliance with the NRC groundwater protection standards.

The impacted media have a high natural capacity to neutralize the effects of tailings seepage so that in some ways the remedy performance can be considered to have been better than expected. In fact, further improvements in the groundwater quality in Zone 1 and the Southwest Alluvium will only be realized through natural geochemical processes.

4. Is the ground water remedy performing as expected in Zone 3?

The remedy functioned as well as was expected when EPA chose it in the June 1988 Record of Decision (ROD). While the groundwater pumping remedy has not attained all of the remediation goals that were established in the Record of Decision (ROD), this was anticipated in the ROD. EPA expected that significant desaturation of the impacted media could occur and that it would be necessary to change the performance goals that were established in the ROD.

UNC has expended tremendous effort and resources to enhance the effectiveness of EPA's selected remedy for Zone 3 as recommended in the 2nd Five-Year Review. While UNC's efforts have improved upon the *original remedial design, they too are reaching the limit of their effectiveness. Migration of the Zone 3 plume has been slowed, but it will only cease to migrate when certain natural hydraulic forces are balanced by the chemical reactions that are attenuating and restricting the movement of the seepage-impacted water. At this point, continued downgradient migration can no longer be altered by using hydraulic modifications (i.e. pumping) due to the dip of the geologic strata within which the groundwater moves. UNC has not identified other proven, innovative, or emerging technologies that will achieve cleanup goals in Zone 3 because of declining saturated thicknesses, the alteration of arkosic sandstone to clay, encrustation; and the resultant poor formation yields.*

5. What does the monitoring data show? During the operation of the remedial systems, were there any trends that showed contaminant levels were decreasing?

Descriptions of contaminant trends depend on the compound considered and whether one is discussing Zone 1, Zone 3, or the Southwest Alluvium, and so the annual review reports should be consulted for detailed answers to this question. In general, the trends for hazardous constituents had diminished both with distance from the tailings disposal area and through time and reached asymptotic conditions before groundwater recovery ceased in Zone 1 and the Southwest Alluvium. The concentrations since pumping was terminated remain stable, and are the result of the natural capacity of the formation to immobilize the hazardous constituents rather than the former pumping that took place.

In Zone 3, concentrations of regulated constituents have been stable for several years; the limited groundwater recovery that UNC is currently able to accomplish is sufficient to capture seepage-impacted water at the leading edge of impacts, but is not and will not ever be capable of achieving either the current NRC groundwater protection standards or the EPA's ROD standards.

Some of the EPA-mandated constituents-of-concern, such as sulfate and manganese, are controlled solely by equilibration with naturally occurring minerals in the formation that the water moves through. As a consequence, the monitoring data for these constituents are remarkably stable through time. It was NRC's conclusion in 1996 that these constituents are inappropriate for determining the effectiveness of the groundwater corrective action program.

6. From the General Electric Corporation's perspective, have any of the remedial systems for ground water reached their limit of effectiveness? If so, please explain.

First, let me explain the General Electric Company's (GE's) role on this project. In September 1997 UNC was acquired by a company that was in turn acquired by GE, and as a result UNC became a wholly-owned, indirect subsidiary of GE. GE Corporate Environmental Programs was retained through a separate administrative services agreement to assist UNC both technically and administratively with environmental issues at Church Rock.

As to GE's perspective, it is clear that the current remedy has reached the limits of effectiveness for Zone 1 and the Southwest Alluvium. Moreover, the remedial systems have achieved what was anticipated in the ROD even though the ROD standards have not been achieved. Water quality due to tailings seepage has generally remained stable or improved since the cessation of pumping operations in both of these units. As recommended in the 2nd Five-Year Review, UNC believes that EPA should complete the analysis of the natural attenuation and TI Waivers for Zone 1 and the Southwest Alluvium and make decisions with respect to their acceptability in accordance with NCP procedures.

In Zone 3, the new pumping configuration which was adopted since the last five-year review has slowed the rate at which seepage-impacted water can migrate. This has been beneficial because it allowed natural restorative processes to be more effective. Over, the past few years, UNC has adjusted the configuration by adding wells and removing them as needed to maximize hydraulic control over the seepage-impacted water. UNC also injected alkalinity into the seepage front to help neutralize the seepage-impacted water; however, it was necessary to cease the alkalinity injection because of its tendency to promote the retention of uranium in solution. Current groundwater recovery from all Zone 3 pumping wells combined is about 2.3 gallons per minute or about the same as a garden hose turned on low, and this rate is in steady decline. It will be necessary to change the remedial goals and/or to invoke other administrative controls for the CERCLA process to attain closure and for the site to be transferred to the DOE for long-term stewardship.

7. Are there any trends that show contaminant levels are increasing in the Southwest Alluvium since shut down? Please explain.

There are no water quality trends, which are attributable to the seepage of tailings-impacted water, to indicate that contaminant levels are increasing in the Southwest Alluvium. There has been some re-equilibration in the water quality attributes of some of the wells due to the system responding to the changed pumping conditions.

For example, uranium concentrations trended upwards for a couple of years in some wells following the pumping shut down. Alkalinity trended upwards in the same wells, and it is a well-understood geochemical principle and a common occurrence that uranium concentrations correlate with alkalinity. Naturally, UNC and the agencies want to know whether the concentration changes were the result of the cessation of pumping seepage-impacted groundwater or something else. In this case, the uranium concentration increase had nothing at all to do with uranium in the tailings-seepage. In fact, it could only be explained by a natural re-equilibration of background uranium in a system that responded to changed stresses because uranium in the tailings seepage is less concentrated that that of the mine groundwater dewatering.

Uranium concentrations in well GW-3 have continued to increase and are currently in the 0.3 mg/L range which is the concentration that has been shown to be the natural concentration that all Southwest Alluvium waters, including background water, are capable of approaching. This is true regardless of whether that concentration is approached from above the 0.3 mg/L value (such as the background water containing up to 2 mg/L of uranium), or whether it is approached from below (such as the seepage-impacted water that contains much less than 0.3 mg/L of uranium, but which re-mobilizes uranium in the alluvium until the 0.3 mg/L concentrations are potentially reached).

The pumping never fully captured the tailings-seepage to begin with. We know that tailings-seepage had been migrating through these particular wells for the duration of pumping; we know that uranium concentrations may be correlated with alkalinity, and we know that uranium concentrations do not correlate as well with the pumping that had taken place; and most importantly, we know that the upstream discharges of groundwater into Pipeline Canyon, which occurred from historical pumping to dewater ore-bearing formations were permitted to contain up to 2 ppm of uranium.

This example illustrates two important points. First, the question that should be asked is not whether contaminant levels increased or decreased after altering pumping conditions, but rather, whether the changes are attributable to tailings seepage; and second, whether those changes are within the range of concentrations that are naturally encountered in the background water. In the Southwest Alluvium, where buffering capacity is quite high, there are no increasing trends that can be attributed to tailings seepage and which are greater than the natural condition.

8. From the General Electric Corporation's perspective, have any of the changes in the Site operations affected the protectiveness or effectiveness of the ground water remedy? Please explain.

It is GE's perspective that the cessation of pumping has not affected protectiveness. The remediation remains protective of human health and the environment. The remedy functioned as well as was expected when EPA chose it in the June 1988 Record of Decision (ROD). EPA expected that significant desaturation of the impacted media would limit or end the ability to achieve improvement in groundwater quality through continued pumping, and that it would be necessary to change the performance goals that were established in the ROD.

GE believes that it is the attenuative capacity of the natural system, more than the pumping remedy, which has produced most of the remedial progress that has been observed in the Southwest Alluvium and in Zone 1. The stable water chemistry that has occurred post-shutdown attests to this conclusion.

As for Zone 3, UNC remains willing to recover seepage-impacted groundwater until it is no longer practicable to do so, and to put off-site administrative controls in place. The definition of "practicable" should be based upon an ability to sustainably pump seepage-impacted water in sufficient quantities to mitigate seepage-migration. It appears that the recovery system is very close to this limit. The endpoint cannot be based upon the current ROD standards; those levels quite simply can never be achieved.

9. How will conclusions from the Zone 3 In-Situ Alkalinity Stabilization Study and the Hydraulic Fracturing Pilot Test influence the preparation of the Site-Wide Supplemental Feasibility Study?

The pilot projects that were attempted by UNC represented some potentially creative enhancements to the available technology; however, there have not been other technological advances over the past 25 years that change the fundamental way that the Zone 3 remediation can be viewed. UNC has not identified other proven, innovative, or emerging technologies that will achieve cleanup goals in Zone 3 because of: the geologic structure, declining saturated thicknesses, the alteration of arkosic sandstone to clay, encrustation; and the resultant poor formation yields.

UNC has done its best to comply with EPA's requirement to perform another feasibility study; this has added six years to the project as we speak. The conclusions from the Zone 3 In-situ Alkalinity Stabilization

Study and the Hydraulic Fracturing Pilot Test have only served to strengthen UNC's firm conviction, based upon our understanding of the site geochemistry, hydrology, and about 25 years of remedial operations, that the supplemental FS will not change what was recognized in the ROD and the initial Five-year Review.

10. Do you have any comments, suggestions, or recommendations regarding the project?

EPA recognized as early as the 1988 ROD and as late as the First 5-year Review in 1998, that technical limitations would be reached with respect to meeting the goals that were established for the site. In the First 5-year review in 1998, EPA validated the technical limitations that it anticipated in the ROD using the 10 years of operational data in existence at that time. EPA recommended that UNC begin to use other available tools to fully close the site, such as Alternate Concentration Limits and Technical Impracticability Waivers. UNC embarked upon a program to develop the EPA's recommendations and for the next several years conducted appropriate investigations and reported on its progress. Several NRC license amendments were adopted to advance these recommendations.

In the Second 5-year Review in 2003, EPA changed course with the recommendation that a new Feasibility Study be undertaken in place of the course of action that it had recommended in the First 5-year Review. UNC has been complying with the requirement for the past several years. Currently, two of the three FS phases have been approved. Further FS progress is awaiting EPA's and NRC's approval of revised background-based water quality standards.

The fundamental technical limitations that EPA anticipated from the ROD and the First 5-Year Review have not changed. When the supplemental FS is issued the CERCLA process will have to be completed using the available and appropriate administrative tools. UNC understands that EPA believes that performing a second FS is the best approach to make sure that the stakeholders are fully involved.

*The supplemental FS will not change what EPA anticipated 25 years ago in the ROD. As stated in Appendix A of the ROD: "**However, operational results may demonstrate that it is technically impractical to achieve all cleanup levels in a reasonable time period, and a waiver to meeting certain contaminant-specific applicable or relevant and appropriate requirements (ARARs) may require re-evaluation as a result. Operational results may also demonstrate significant declines in pumping rates with time due to insufficient natural recharge of aquifers. The probability of significant reductions in the***

saturated thickness of aquifers at the site must be considered during performance evaluations since much of the water underlying the tailings disposal area is the result of mine water and tailings discharge, both of which no longer occur. In the event that saturated thicknesses cease to support pumping, remedial activity would be discontinued or adjusted to appropriate levels." *This is precisely what has taken place over the nearly quarter century of performance monitoring; more importantly, the remedy has always been and continues to be considered effective. The new FS will not change the fact that the original cleanup goals cannot be met, and that waivers and other administrative tools will have to be adopted before the Church Rock Mill can be transferred to the Department of Energy's Long-term Stewardship Program.*

UNC understands that USEPA may evaluate institutional controls as a potential supplement to the ROD, in addition to or in combination with the adoption of natural attenuation mechanisms, Technical Impracticability Waivers or modified cleanup standards for the Church Rock site. As EPA is aware, UNC worked with the Navajo Nation from 2001 to 2003 to develop an institutional control plan to prevent potential exposure to seepage-impacted water. Neither the proposed Tribal Resolution nor the environmental right-of-way that was developed has been formally responded to since they were first proposed more than 10 years ago. Given that it is unrealistic to consider the background groundwater as a viable source of water for human and/or animal consumption at present or in the future, UNC continues to believe administrative controls should be considered as part of the final remedy. For its part, UNC has demonstrated its willingness over the past 15 years to work cooperatively with all parties to forge an outcome that benefits local residents. This has included an offer made more than 10 years ago to provide for an alternative water source to nearby residents should they not have access to viable supplies either for stock watering or domestic consumption because of the naturally poor water quality in the region. UNC believes that these discussions should be re-invigorated.

Thank you for allowing us to share our perspective during this fourth 5-year review.

8

2013 United Nuclear Corporation (UNC) Five-Year Review Interview Questions

Date: May 13, 2013

Interviewer: Earle Dixon, Environmental Scientist, New Mexico Environment Department (GWQB)

Person or Entity Interviewed: U.S. Department of Energy, Office of Legacy Management

<u>NOTE:</u> U.S. Department of Energy (DOE) responses apply to activities associated with the groundwater operable unit at the United Nuclear Corporation (UNC) Superfund Site. Although DOE is currently involved in a design work group which is reviewing documents for a proposed repository anticipated to contain mine waste at the UNC Superfund Site, responses do not pertain to this effort.

1. What is the U.S. Department of Energy's (DOE's) role on this project?

DOE will have a future role at the Church Rock Uranium Mill Tailings Radiation Control Act (UMTRCA) Title II Site which shares its location with the UNC Superfund Site regulated by the U.S. Environmental Protection Agency (EPA). It is anticipated that DOE will become general licensee to the U.S. Nuclear Commission (NRC) for the Church Rock site. After site transfer, DOE will perform long-term surveillance and maintenance (LTS&M) activities at the Church Rock site under UMTRCA and in accordance with 10 CFR 40.28.

2. What is the DOE's overall impression of the ground water remediation effort at the Site?

Active groundwater treatment activities have removed contaminated groundwater from the aquifer, reducing the mass of contaminants in the aquifer and the volume of contaminated groundwater. Remediation efforts have generally not controlled the migration of the Zone 3 sandstone plume. DOE recognizes that active treatment is hampered by reduced saturation and low yields. A GE/UNC flow model which accompanied a license amendment to establish background threshold values at the Church Rock UMTRCA Title II Site also showed that contaminated groundwater is expected to travel at least 1,500 feet within the next 15 years, and will come within approximately 500 – 600 feet of the site boundary. DOE believes it is plausible that the groundwater plume will cross this boundary, migrating offsite, before dissipation of contamination occurs.

3. From the DOE's perspective, what effects have Site operations had on the surrounding community?

Although DOE has had limited contact with the surrounding community, our experience at other sites has shown that residents are very concerned about the quality of their drinking water and potential impacts from site operations.

4. Is the DOE aware of any community concerns regarding the Site or its operation and administration? If so, please give details.

Please see previous response.

5. Have there been routine communications or activities (e.g., site visits, inspections, reporting activities, etc.) conducted by the DOE regarding the Site? If so, please describe purpose and results.

DOE is invited by NRC and EPA to attend annual meetings and to participate in periodic teleconferences with GE/UNC, and other stakeholder agencies, to gain an understanding of groundwater activities and compliance issues in anticipation of assuming LTS&M responsibility for the Church Rock UMTRCA Title II Site. DOE periodically attends site visits with regulatory agencies including NRC, EPA and the New Mexico Environment Department. DOE is not involved with compliance activities such as site inspections, reporting activities, etc. as the Department is not yet general licensee to NRC. However, DOE recently conducted a review of an UMTRCA-related license amendment application submitted by the current licensee (GE/UNC) to NRC to establish background threshold levels.

6. Is the ground water remedy progressing in accordance with the DOE's expectations or requirements for the Site? Please explain.

DOE does not have the regulatory authority nor have we evaluated the progress of the groundwater remedy related to this project. DOE's role is to perform LTS&M at the Church Rock UMTRCA Title II Disposal Site in accordance with 10 CFR 40.28 after becoming the general licensee. The Church Rock site will need to achieve groundwater compliance prior to site transfer, and therefore active groundwater remediation will not be required to maintain compliance.

7. Is the DOE aware of opportunities to optimize the operation, maintenance, or sampling efforts at the Site?

At this time, DOE is not aware of opportunities at this Site.

8. From DOE's perspective, have any of the changes in Site operations had an affect on the protectiveness or effectiveness of the ground water remedy? Please explain.

DOE has been generally aware of the progression of GE/UNC efforts to remediate site groundwater over time, although remediation strategies have generally been ineffective in containing the Zone 3 sandstone groundwater plume. However, there appear to be no complete exposure pathways to contaminated groundwater at this time.

9. Have there been any changes in DOE standards since the time the remedial approach was delineated which may call into question the protectiveness or effectiveness of the ground water remedy?

No. Groundwater standards listed in 10 CFR 40 apply to the Church Rock UMTRCA Title II Site where DOE will perform LTS&M. Under UMTRCA, and as general licensee to NRC, DOE will be required to comply with these standards. Standards were promulgated by EPA as required by UMTRCA of 1978.

10. Does the DOE feel well informed about the Site's ground water cleanup activities and progress?

DOE commends and appreciates efforts shown to-date by site regulators to provide the Department with opportunities to become informed about the Site's groundwater cleanup activities and progress.

11. Does the DOE have any comments, suggestions, or recommendations regarding the Site's management or operation?

DOE does not have suggestions regarding the Site's management and operation at this time.

2013 United Nuclear Corporation (UNC) Five-Year Review
Interview Questions – NNEPA Superfund

Date: _____May 3, 2013_________

Interviewer: _______Earle Dixon, New Mexico Environment Department_________

Person or Entity Interviewed: __________Eugene Esplain. Navajo Nation EPA Superfund. He Started on UNC project in 2009 after Diane Malone. Eugene is the Project Manager-Contact Person, health physicist for NNEPA on the UNC Site_____

1. **What is Navajo Nation EPA Superfund's overall impression of the project? (general sentiment).**

It is complex project with a lot of changes that are happening. The changes have to occur, and the company (UNC) has to react to the changes. The project has a very slow pace (Mr. Esplain also talks about the UNC project relationship to the Northeast Church Rock-NECR Mine cleanup project). Water volume is so small in Zone 3, 2 gpm-hard to understand and get too concerned compared to the NECR project. Zone 3 has most of the focus compared to Zone 1 and the Southwest Alluvium. Seems more concern has shifted to use of the UNC Site for mine waste disposal than the ground water issue.

2. **What is the Navajo Nation role in this project?**

Make sure that all parties do what they are supposed to do. We help review documents and activities and write comments. We help people understand the activities of the project. One in particular is the issue and siting of a water supply well offered by UNC-GE. It is a challenge to explain and understand the UNC NPL groundwater issue and the NECR Mine cleanup project. The risk to groundwater exposure is low, but the risk to people from soil exposure is greater so that has been the priority. Need to address surface risk and address the complex groundwater issue later which will take more time and more studies.

3. **From the Navajo Nation EPA, what effects have site operations had on the surrounding community?**

EPA Superfund program has tried to help Navajo Nation leadership, President Shelly and his staff, understand the site issues relative to the NECR Mine cleanup process and the UNC groundwater remediation issue. Most of the community impacts have been the inconvenience of all the surface work and planning for the mine cleanup. The community needs to be given education sessions to understand the groundwater issues and give them a chance to ask questions. The sessions would be conducted on a one-on-one, family basis at their convenience. Mr. Dixon concurred with Mr. Esplain and indicated that he and Ms. Janet Brooks, the EPA UNC Project Manager head the same thing from the Red Water Pond Road Community Association when they met with them during the Uranium Contamination Stakeholder Workshop in Gallup, NM on April 16, 2013.

4. Is Navajo Nation EPA aware of any community concerns regarding the site or its operation and administration? If so, please give details.

NNEPA has become aware of community concerns through all the various public meetings primarily on the NECR Mine Site cleanup. Residents will confide in NNEPA about their concerns at meetings or in separate communications with NNEPA staff. Residents are struggling to understand the roles of the various agencies particularly the two EPA Regions, the NRC, and now the DOE has come onto the scene. There are also concerns about the state lands in the area and how they fit into the future land use plans for the area.

5. Have there been any complaints, violations, or other incidents related to the Site that required a response by Navajo Nation EPA? If so, please describe the events and the results of the responses.

No, no events come to mind. Only damaged fencing comes to mind, but UNC responds to that. UNC has mentioned fencing that was cut for livestock grazing some years ago, and had to be repaired.

Pipeline Road drainage in the UNC Mill Site area is a major concern and problem during and after storm events that causes problems for the local residents. They have voiced concerns about the drainage to NNEPA.

6. Have there been routine communications or activities (e.g., site visits, inspections, reporting activities, etc.) conducted by Navajo Nation EPA regarding the site? If so, please describe purpose and results.

The routine communication through regular meetings and tours of the NECR Mine Site provide opportunities to learn more about the UNC Mill Site. Mr. Esplain notes there are not many meetings just for the UNC groundwater issue. NNEPA would like to understand more about the remedial activities that have taken place for the Zone 3 plume especially the ground water flow model and the need for verification and sentinel wells.

7. Is the ground water remedy progressing in accordance with Navajo Nation EPA's expectations for the site? Please explain.

NNEPA understands that the groundwater remedy is very time consuming and various attempts have been made to enhance the remediation progress. Navajo understands that the mine dewatering created most of the groundwater problem along with the tailings seepage. The minerals in the groundwater were there originally so it is hard to remove all the contaminants down to levels of zero. The technology should focus on getting levels to as low as possible and stopping the flow of groundwater.

8. From Navajo Nation EPA's perspective, have any of the changes in site operations had an affect on the protectiveness or effectiveness of the ground water remedy? Please explain.

No, the site groundwater issues seem to have defaulted to a situation of Monitored Natural Attenuation or MNA for remediation of the contaminants. NNEPA wants to understand more about the subject of natural attenuation and how it applies to the contaminants at the UNC Site.

9. Does Navajo Nation EPA feel well informed about the site's activities and progress?

Only NMED provides regular and explanatory updates for the UNC groundwater issue. NNEPA feels adequately informed but would like to hear more from UNC, EPA, NRC, and eventually DOE.

10. Does Navajo Nation EPA have any comments, suggestions, or recommendations regarding the site's management or operation?

The highest priority recommendation would be that community outreach-education session-workshops have to be conducted for the community to understand the groundwater issues at the UNC Site.

NNEPA wants to learn more and receive a tour on the history of groundwater monitoring and remediation at the site especially for Zone 3 and the ground water flow model verification-sentinel wells.

NNEPA would like to learn more about the groundwater conditions going west toward Quivira and the unnamed drainage, where the hydrogeology is less well known. Mr. Esplain wants to know if there is enough groundwater in this area to support a community garden that residents have expressed support for at various public meetings.

2013 United Nuclear Corporation (UNC) Five-Year Review
Interview Questions For Local Residents

Date: __April 16, 2013____________

Interviewer: ____Earle Dixon, NMED and Janet Brooks, EPA_____________________
____

Person or Entity Interviewed: Red Water Pond Road Community Association, Members of Coyote Canyon Chapter of Navajo Nation & Larry King, local resident living downstream of UNC Mill Site____

1. What is your overall impression of the project? (general sentiment)

Most residents do not have any knowledge of the groundwater contamination issue at the UNC Mill Site and cannot provide an impression of the project. Their primary concern has focused on the Northeast Church Rock (NECR) Mine Site surface soil cleanup and they know that the proposed alternative is to dispose of the radioactive soil at the UNC Site. Residents expressed how educational sessions will be necessary for them to gain knowledge about the UNC groundwater issues before they can have an opinion and provide any feedback. The requested educational sessions will have to consider the education level of residents which is not technical enough to read and understand the UNC Annual Review Reports and the complex technical and regulatory history of the site.

2. What effects have site operations had on the surrounding community?

Residents expressed that the location of the tailings disposal ponds have the drainage of the Pipeline Arroyo system to change and storm water runoff backs up and floods during major storm events. The flooding can extend as far as Red Water Pond Road. Residents are concerned about the track out of NECR radioactive soil on vehicles during storm events that flood Red Water Pond Road. The intersection of State Highway 566 and the Pipeline Road cattle guard needs to be cleaned out and maintained on a more regular basis to provide more positive drainage and minimize flooding. Residents also voiced complaints about the telephone pole located on UNC Mill Site property that carries their internet connection is inside a locked gate that the Sacred Wind internet provider cannot access when their internet connection is having difficulties or not operating.

3. Are you aware of any communities' concerns regarding the site or its operation and administration? If so, please give details.

Residents expressed that communities along the Puerco River drainage from the UNC Mill Site and into the Navajo Nation Chapters past the New Mexico state line and into Arizona still have health concerns over the 1979 tailings spill. Larry King expressed the need for Chapter meetings along the Puerco River to discuss health concerns from the 1979 spill with local residents (chapters include Manuelito, Lupton, Sanders, Houck and Chambers). Residents note that there is lots of dried vegetation along the Puerco River, and they wonder whether it is safe or not to have plants come back-are they contaminated from the 1979 spill.

4. Are you aware of any events, incidents, or activities at the Site such as vandalism, trespassing, or emergency responses from local authorities? If so, please give details.

Residents described how street signs have been vandalized or stolen because they are loosely attached to the pole. The Kerr McGee Mine Sign was taken down. Rebecca Nakai's hogan burned down recently before local emergency responders could arrive.

5. Do you feel well informed about the Site's activities and progress?

All the residents gave a resounding, "NO" in agreement. They do not know about the UNC Mill Site groundwater issues and they want to know more, but as indicated above they want educational sessions geared to their level.

6. Do you have any comments, suggestions or recommendations regarding the Site's management or operation?

The residents expressed their concern about the liner issue related to the NECR proposed mine soil disposal at the UNC tailings disposal ponds. They wanted know why the EPA wasn't proposing to have 2 liners on top of the tailings ponds one of which is clay to prevent more contamination of groundwater. Earle Dixon and Janet Brooks tried to explain the groundwater situation relative to the liner issue for the NECR Mine soil disposal proposal. The discussion came back to the need for educational sessions with the community to give them a chance to understand and ask questions about the UNC Site groundwater contamination.

2013 United Nuclear Corporation (UNC) Five-Year Review Interview Questions

Date: _July 1, 2013

Interviewer: ___Earle Dixon, New Mexico Environmental Department_(NMED is the Support agency to the U.S. Environmental Protection Agency - Region 6)_

Person or Entity Interviewed:

___Yolande Norman, Project Manager, U.S. Nuclear

Regulatory Commission, Mail Stop T8-F5, Washington D.C. 20555-0001

1. What is the U.S. Nuclear Regulatory Commission's (NRC's) role on this project?

Between 1974 and June 1986, the UNC Church Rock Mill site was under the jurisdiction of New Mexico that derived its regulatory authority from the Atomic Energy Commission (AEC) Agreement State Program. The AEC is the precursors to the U.S. Nuclear Regulatory Commission (NRC). Regulatory authority for uranium mill and uranium recovery sites, including the UNC Church Rock Mill Site was returned to the NRC at the request of the Governor of New Mexico. In June 1986, the NRC issued a source material license – SUA-1475 to United Nuclear Corporation (UNC). The licensee (i.e. UNC) must comply with stipulated license conditions, which include groundwater quality standards for all three water bearing zones; (i) Southwest Alluvium, (ii) Zone 1, (iii) and Zone 3.

2. What is the NRC's overall impression of the ground water remediation effort at the Site?

UNC has made a valiant effort to continually characterize and perform remedial actions within the three-water bearing zones (i.e. Southwest Alluvium, Zone 1, and Zone 3) using the best available technology. Currently a small scale groundwater extraction system operates on-site. However, this and any other active groundwater remediation technology is challenged by the low rate of recharge. Groundwater remediation has effectively reduced the overall mass of constituents in each of the water-bearing zones. The project manager, Ms. Norman is of the opinion that the remediation effort is fast approaching the threshold of technical impracticability.

3. From the NRC's perspective, what effects have Site operations had on the surrounding community?

There has not been any quantitative adverse affects to the local community resulting from Site Operations. This is a sparsely populated area with a few regulated drinking water wells in the vicinity of the Site. There have been no impacts to drinking water sources off-site. Also, in accordance with their license condition,

UNC continue to provide Annual Land Use Reports, documenting land use activities and significant events within a 2 mile radius of the UNC Church Rock Mill site. In addition, UNC submit their Annual As Low as Reasonable Achievable (ALARA) Audits that describe their radiological monitoring programs and efforts to maintain exposure to radiation as far below the dose limits consistent with the purpose for its licensed activity, taking into account the wider socio-economic benefits and the benefits in relation to public health and safety.

Since the last 5-year review the significant event in the vicinity of the UNC Church Rock Mill Site has been the interim soil removal action in nearby communities by the EPA-Region9. This activity is related to the Northeast Church Rock Mine site that is under the jurisdiction of EPA Region 9.

4. Is the NRC aware of any community concerns regarding the Site or its operation and administration? If so, please give details.

The overarching concern of the community is the potential for the transfer of legacy mine waste from the Northeast Church Rock to the UNC Church Rock Mill Site. Of concern is whether the additional weight of the mine waste will cause consolidation within the tailings impoundment exacerbating groundwater conditions and whether the groundwater plume will expand.

The community has also expressed displeasure in the slow pace of the remediation efforts and their desire that the groundwater be returned to pristine conditions.

5. Have there been any complaints, violations, or other incidents related to the Site that required a response by the NRC? If so, please describe the events and results of the responses.

No violations to the license were noted during the NRC's past two site inspections conducted in 2009 and 2011.

6. Have there been routine communications or activities (e.g., site visits, inspections, reporting activities, etc.) conducted by the NRC regarding the Site? If so, please describe purpose and results.

Since the previous five-year review, the NRC Region IV inspectors performed biennial inspections in May 2009 and August 2011. These inspections were performed to determine if activities at the UNC Church Rock Mill site complies with the NRC's rules and regulations and the stipulated conditions of the NRC license. The inspectors determined that UNC/GE was conducting site activities in accordance with the NRC's regulatory and license requirements. The NRC has also conducted site visits in 2009,

2010, and 2011. The next biennial inspection of the UNC Church Rock Mill Site will occur in mid- to late-2013.

In December 2012, the NRC proposed minor administrative revisions to the existing Memorandum of Understand and these changes were accepted by the EPA in March 2013. In October 2012, the NRC began providing quarterly progress report to the EPA on the status of the UNC Church Rock Mill site remediation effort to achieve groundwater protection standards.

7. Is the ground water remedy progressing in accordance with the NRC's expectations for the Site? Please explain.

The remediation of groundwater is typically not a simple effort and the difficulties of such an effort are exemplified by the UNC Church Rock Mill site due to hydrogeologic and geochemical complexities, past industry practices, and, scant environmental and regulatory requirements in the past.

The groundwater extraction effort in Zone 3 continues to provide diminishing extraction rates resulting in reduced hydraulic control of the plume due to the elevation of the water table being controlled by the dipping bedrock surface at the extraction locations. The NW-series extraction wells located north of monitoring well NBL-1 have provided containment of the seepage impacted water in Section 36. Sodium bicarbonate injection began in well IW A during April of 2011, but injection rates progressively declined and the injection of sodium bicarbonate was terminated in June 2011. The groundwater remedial efforts have been significant in Zone 3, but progress has been slower than initially anticipated.

Groundwater data continues to be analyzed in the Southwest Alluvium to monitor the effectiveness of natural attenuation. The results of the natural attenuation testing continue to be promising and are progressing within the NRCs expectations.

Groundwater extraction was discontinued for Zone 1in 1999 due to steadily declining productivity of groundwater extraction rates over the 15 year effort that began in 1984. Historically the groundwater flow was approximately eastward due to mounding and recharge that occurred from the borrow pits and the alluvium to the west. Dewatering of Burrow Pit Number 2 and termination of mine effluent discharged into Pipeline Arroyo has reduced the groundwater mound and changed the groundwater flow direction to follow the northerly dip of the Zone 1 sandstone.

Overall, the NRC believes that the remedial effort is progressing as expected based on the stable to reducing concentrations observed in each water-bearing zone.

8. Is the NRC aware of opportunities to optimize the operation, maintenance, or sampling efforts at the Site?

Optimization is always an ongoing effort during groundwater remedial efforts and UNC/GE continues to optimize all aspects of their efforts as the corrective action progresses. The NRC is not aware of any other opportunities to optimize the corrective action efforts.

9. From NRC's perspective, have any of the changes in Site operations had an affect on the protectiveness or effectiveness of the ground water remedy? Please explain.

No changes at the Site have affected the protectiveness of the remedy.

10. Have there been any changes in NRC standards since the time the remedial approach was delineated which may call into question the protectiveness or effectiveness of the ground water remedy?

No. There have not been any changes to the NRC groundwater protection standards, but changes to the background values used for site specific standards have been modified in the past, as mentioned in the 2008 five-year review interview. In December 2008, UNC submitted a license amendment request to; apply alternate concentration limits in Zone 1 of the Lower Gallup Sandstone, reduce the sampling frequency for the entire compliance groundwater monitoring network and, designate the point-of-exposure as off-site using two point-of-compliance wells in Section 1. In April 2009, the NRC placed this amendment request in abeyance pending the completion and submittal of the Site Wide Supplemental Feasibility Study requested by the EPA-Region 6.

In April 2012, UNC submitted a license amendment request supplemented by a groundwater flow model in October/November 2012, to update some of the current site specific groundwater protection standards by applying background threshold values to three water bearing zones. This license amendment request is currently under review by the NRC. The NRC evaluates each request based on its technical merits and potential health effects and environmental impact before granting the amendment.

11. What is the status of the NRC license for the Site?

The NRC license is active, and there are a number of conditions that UNC must meet, which includes groundwater protection standards. The UNC license is in good standing and UNC continues to maintain the annual update to their financial surety.

12. Does the NRC feel well informed about the Site's ground water cleanup activities and progress?

The NRC believes that it has been well informed regarding the Site's groundwater cleanup activities and progress. The Site is inspected every two years and the NRC is kept apprise of the groundwater monitoring program via annual and semiannual reports that are prepared to encompass all sampling results, site activities, and future recommendations to optimize the ongoing corrective actions. In addition the NRC staff meets with the stakeholders including (i.e. EPA – Region 6, EPA Region 9, UNC, New Mexico Environmental Department (NMED), Department of Energy – Office of Legacy Management (DOE-LM), Navajo Nation EPA (NNEPA)] via teleconferencing on a regular basis and face-to-face on an annual basis for technical discussions to assess the status of the groundwater remediation effort.

13. Does the NRC have any comments, suggestions, or recommendations regarding the Site's management or operation?

The NRC believes that UNC has made a good faith effort to progressively conduct decommissioning activities. It is anticipated that of the three water-bearing zones, Zone 3 remediation effort will continue to remain a challenge, which could be further complicated if it is ascertained that the groundwater contaminant plume has migrated off-site beyond UNC's private property.

The complexity of fulfilling the requirements of State, Tribal, and Federal agencies to ensure that all requirements are satisfied prior to license transfer to the long-term care custodian will require continued interagency discussions among the NRC, the DOE-LM, EPA-Region 6, EPA – Region 9, NNEPA and, NMED.

On a long-term basis UNC and all the regulatory stakeholders will need to enhance its community relations with the local community and the Navajo Nation in seeking creative solutions to address final groundwater conditions after the remediation effort has been exhausted (e.g. exploring conventional and unconventional methods of institutional controls).

ATTACHMENT 7

SUMMARY OF THE THIRD (2008) UNC FIVE YEAR REVIEW ISSUES AND RECOMMENDATIONS

Summary of the Third (2008) UNC FYR Issues and Recommendations		
	Issue	**Recommendation**
1	Ground Water remedy in ROD not able to attain clean up levels due to insufficient saturation for pumping.	Complete SWSFS to: develop remedial alternatives; provide support for waiving ARARS due to technical impracticability; document the appropriateness of adopting the NRC revisions to the License ground water protection standards, and monitoring program by identifying or updating COCs, preliminary clean up levels, including background water quality estimations, and performance monitoring requirements in support of future EPA decision making. The SWSFS to also include a screening-level reassessment of risk, based on more recent toxicological information.
2	Tailings seepage in Zone 3 cannot be controlled hydraulically allowing for seepage to migrate northward toward Navajo Reservation.	In interim, prior to completion of SWSFS, continue effort to minimize advancement of the Zone 3 seepage-impacted water northward and extract contaminated ground water to the maximum extent practicable by installing and operating additional extraction wells at the leading edge of the seepage-impacted front.
3	Uranium concentrations in the Southwest Alluvium less than the clean up level of 5 mg/L, but are greater than the new MCL of 0.03 mg/L, UNC contended that uranium concentrations in background water (post-mining/pre-tailings) were greater than the 0.03 mg/L.	As part of SWSFS, determine post-mining/ pre-tailings background concentrations of uranium for comparison to the seepage-impacted uranium levels and assess whether uranium concentrations can further be reduced in the Southwest Alluvium.
4	It was unresolved whether or not extraction wells were effective at reducing uranium concentrations in the Southwest Alluvium.	Reassess the effectiveness of the Southwest Alluvium extraction wells to improve ground water quality with respect to uranium.
5	Specific COCs or clean up levels were not clearly provided in the ROD. SWSFS needs to include COCs, RAOs, and preliminary clean up levels.	As part of SWSFS, identify COCs, RAOs, and preliminary clean up levels and codify in a decision document.
6	Some contaminants are consistently below clean up levels. COCs and clean up levels need to be evaluated.	After the COCs and clean up levels are modified in EPA decision-making, the ground water monitoring program should be updated to ensure that it is consistent with the revised COCs and clean up levels, and at the appropriate well locations and aquifers.
7	NRC has revised UNC's license regarding COCs and the monitoring program. EPA has not revised the selected remedy or clean up levels in a decision document. Consistency, where appropriate, should be achieved.	Update EPA requirements in a decision document as appropriate to be consistent with NRC License requirements.
8	Agreement between EPA and NNEPA has not been achieved regarding the use of ICs as a component of remedial alternatives in the SWSFS.	A renewed effort should be made to establish ICs that will restrict the use of contaminated ground water on Navajo, Tribal Trust and Indian Allotment lands.
9	UNC has performed a TI evaluation and recommended that EPA invoke a TI waiver of the sulfate, TDS standards (as well as manganese). Data	As part of the SWSFS, include an evaluation of remedial technologies and process options to achieve the clean up levels for sulfate and TDS, or

Summary of the Third (2008) UNC FYR Issues and Recommendations		
	Issue	**Recommendation**
	supports the theory that that gypsum and anhydrite equilibrium controls sulfate and TDS concentrations and concentrations of these analytes will remain above clean up levels as long as the Southwest Alluvium and Zone 1 are saturated.	provide a basis for EPA to invoke a waiver of those standards for sulfate and TDS due to TI.
10	EPA acknowledged that any significant change to background estimations could impact the remedial action in each aquifer.	As part of the SWSFS, complete the reassessment of post-mining/pre-tailings background water quality based on ground water monitoring data.
11	The local community is not fully informed regarding the nature of the ground water contamination, the performance of the remedy, and likely future actions necessary to ensure protectiveness.	Increase effort to share information with community regarding the ground water remedy.
12	There is a lack of schedule for completing the SWSFS.	Develop a schedule for completion of the SWSFS.

ATTACHMENT 8

TABLE 15 FROM THE SITE WIDE SUPPLEMENTAL FEASIBILITY STUDY

TABLE 15

Contaminant-Specific Groundwater Cleanup Levels and Other Comparison Values
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Source	Standards Used for 3rd 5-Year Review (September 2008, Table 3-1) and ROD (September 1988)				NRC Source Materials	Potential ARARs					Standard Compared to in 2010 Annual Review		Current Health-Based Criteria (+)		
Contaminant	New Mexico WQCC Standards	Health-based	Maximum Concentration Limit (MCL)	Background Level	License Compliance Standards	NRC Appendix List*	New Mexico WQCC Standards		EPA Drinking Water MCL	EPA Drinking Water Other**	EPA	NRC	Health-Based Criterion	Source	
Sulfate				2160			2125***				2125***				SO4
Total Dissolved Solids				3170			4800***				4800***				TDS
NO3 as N				30			190***		10		190***		10	MCL	NO3
Manganese				2.6			0.2	O			2.6		0.88	RSL	Mn
Chloride	250						250	O			250				Cl2
Aluminum	5						5	I			5		37	RSL	Al
Antimony		0.014							0.006				0.006	MCL	Sb
Arsenic			0.05		0.05	0.05	0.1	HH	0.01		0.05	0.05	0.01	MCL	As
Barium	1		1			1	1	HH	2				2	MCL	Ba
Beryllium		0.017			0.05				0.004		0.017	0.05	0.004	MCL	Be
Cadmium	0.01		0.01		0.01	0.01	0.01	HH	0.005		0.01	0.01	0.005	MCL	Cd
Chromium	0.05		0.05			0.05	0.05	HH	0.1				0.1	MCL	Cr
Cobalt	0.05						0.05	I			0.05		0.011	RSL	Co
Copper	1						1	O	1.3	MCLG & TT			1.3	MCL(++)	Cu
Iron				5.5			1	O					26	RSL	Fe
Lead	0.05		0.05		0.05	0.05	0.05	HH	0.015	MCLG & TT	0.05	0.05	0.015	MCL(++)	Pb
Mercury	0.002		0.002			0.002	0.002	HH	0.002				0.002	MCL	Hg
Molybdenum	1						1	I			1		0.18	RSL	Mo
Nickel	0.2				0.05		0.2	I			0.2	0.05	0.73	RSL	Ni
Selenium			0.01		0.01	0.01	0.05	HH	0.05		0.01	0.01	0.05	MCL	Se
Silver	0.05		0.05			0.05	0.05	HH					0.18	RSL	Ag
Thallium		0.014							0.002	MCLG = 0.0005			0.002	MCL	Tl
Vanadium		0.7			0.1						0.7	0.1	0.18	RSL	V
Zinc	10						10	O					11	RSL	Zn
TTHMs****					0.08		0.1	HH	0.08	MCLG = 0.07****		0.08	0.08	MCL	TTHMs
Uranium	5				0.3		0.03	HH	0.03		5	0.3	0.03	MCL	U
Radium 226 and 228			5 pCi/l		*****	5 pCi/l	30 pCi/l	HH	5 pCi/l		5 pCi/l	*****	5 pCi/l	MCL	comb Ra
Lead-210					1 pCi/l							1 pCi/l	0.0601 pCi/L	PRG	Pb-210
Thorium-230			15 pCi/l		5 pCi/L							5 pCi/l	0.581 pCi/l	PRG	Th-230
Gross Alpha			15 pCi/l		15 pCi/l	15 pCi/l			15 pCi/l		15 pCi/l	15 pCi/l	15 pCi/l	MCL	GA

Notes:

Units = mg/L unless otherwise noted

Yellow cells = constituents not analyzed since site active remediation started in 1989, per EPA FS (August 1988) and ROD (September 1988)

* 10 CFR Appendix A to Part 40

** "Other" includes non-zero Maximum Contaminant Level Goals (MCLG) or Treatment Technology Action Levels (TT)

*** New Mexico Environment Department recommended background values (letter to EPA of January 6, 1998); EPA has not formally adopted these revisions

**** TTHMs (total trihalomethanes) include chloroform; TTHMs MCL = 0.08 mg/L; in addition, chloroform has an MCLG = 0.07 mg/L

***** Combined radium NRC Site Groundwater Protection Standards are 5.0 pCi/L for Zone 3; 5.2 pCi/L for Southwest Alluvium (background); and 9.4 pCi/L for Zone 1 (background)

(+) Sources of health-based criteria include the November 2010 EPA Regional Screening Level (RSL) Summary Table (tapwater RSLs) and August 2010 EPA Preliminary Remediation Goals for Radionuclides (PRGs) (resident tapwater PRGs). For those contaminants with federal MCLs, the MCL is shown as the health-based screening level, per January 25, 2008 letter from EPA to UNC (General Comment 5).

(++) Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

HH = Human Health Standard

I = Irrigation Standard

O = Other Standards for domestic water supply

green = "Comparison Values" column in N.A. Water Systems report (2008b): Calculation of Background Statistics with Comparison Values (also see Appendix B Tables 7, 8, and 9 in the present report)

Updated March 18, 2011 (11-6209-SC-111)

Chester Engineers

ATTACHMENT 9

TABLES 6, 7, and 9 FROM THE UNC

SITE WIDE SUPPLEMENTAL FEASIBILITY STUDY

UPDATED HUMAN HEALTH RISK ASSESSMENT

Risk and Hazard Summary by Hydrostratigraphic Unit and Exposure Pathway UNC Church Rock Mill and Tailings Site

(UNC Updated Baseline HHRA-Final, August 2012, Table 6)

Hydrostratigraphic Unit	Exposure pathway	Total Non-carcinogenic Hazard Index (Child)	Chemical Carcinogenic Risk (Child/Adult)	Radionuclide Carcinogenic Risk (Child/Adult)	Total Carcinogenic Risk (Child/Adult)
Southwest Alluvium	Ingestion	12.9	5.9E-05	1.5E-04	2.1E-04
Southwest Alluvium	Dermal	1.3	4.7E-07	N/A	4.7E-07
Southwest Alluvium	Inhalation	0.0041	2.1E-06	*2.9E-04*	2.9E-04
Southwest Alluvium	**Total**	**14.2**	**6.2E-05**	**4.4E-04**	**5.0E-04**
Zone 1	Ingestion	20.1	3.3E-05	*5.3E-05*	8.6E-05
Zone 1	Dermal	0.96	2.1E-07	N/A	2.1E-07
Zone 1	Inhalation	0.0008	4.2E-07	*1.3E-03*	1.3E-03
Zone 1	**Total**	**21.1**	**3.4E-05**	**1.4E-03**	**1.4E-03**
Zone 3	Ingestion	*229*	9.2E-03	5.3E-04	9.7E-03
Zone 3	Dermal	6.9	5.3E-05	N/A	5.3E-05
Zone 3	Inhalation	0.004	2.0E-06	1.2E-02	1.2E-02
Zone 3	**Total**	**236**	**9.3E-03**	**1.3E-02**	**2.2E-02**

Notes:

N/A = Not applicable, radionuclides were not retained as COPCs under the dermal exposure pathway.

Italics indicate that the hazard or risk shown for seepage-impacted groundwater is within background hazard or risk for hydrostratigraphic unit and exposure pathway.

TABLE 7
Designation of Retained Chemicals of Potential Concern (RCOPCs)
UNC Church Rock Mill and Tailings Site
Church Rock, New Mexico

Hydrostratigraphic Unit	COPCs Retained in "Table 10s" (1)	Non-carcinogen or Carcinogen	Risk or Hazard (From Appendix A) (2)	Retained as Risk-Based RCOPC	RCOPC Retention Rationale
Southwest Alluvium	Arsenic	Carcinogen	Risk = 5.8E-05 (Ingestion and dermal)	No	Similar to background concentrations; below MCL
Southwest Alluvium	Cobalt	Non-carcinogen	HQ = 2.14 (Child)	No	One detected result in impacted water; background concentrations higher than impacted water concentrations
Southwest Alluvium	Manganese	Non-carcinogen	HQ = 8.7 (Child)	Yes	HQ > 01
Southwest Alluvium	Uranium	Non-carcinogen	HQ = 2.7 (Child)	Yes	HQ > 01
Southwest Alluvium	Chloroform	Carcinogen	Risk = 1.7E-06 (Ingestion and dermal) Risk = 2.1E-06 (Inhalation)	Yes	Risk > 1E-06
Southwest Alluvium	Uranium isotopes	Carcinogen	U-234 Risk = 5.8E-05 U-235 Risk = 2.7E-06 U-238 Risk = 7.0E-05 Total Risk = 1.3E-04 (Ingestion)	Yes	Total Risk > 1E-06
Southwest Alluvium	Radium-226	Carcinogen	Risk = 1.9E-06 (Ingestion) Risk = 2.9E-04 (Inhalation)	No	Background concentrations higher than impacted
Southwest Alluvium	Radium-228	Carcinogen	Risk = 1.7E-05 (Ingestion)	No	Background concentrations higher than impacted
Zone 1	Cobalt	Non-carcinogen	HQ = 11.9 (Child)	Yes	HQ > 01
Zone 1	Manganese	Non-carcinogen	HQ = 6.1 (Child)	No	Background concentrations higher than impacted
Zone 1	Vanadium	Non-carcinogen	HQ = 2.6 (Child)	No	Hazard based on only one historical detection in seepage impacted water
Zone 1	Arsenic	Carcinogen	Risk = 3.3E-05 (Ingestion and dermal)	No	Similar to background concentrations; below MCL
Zone 1	Radium-226	Carcinogen	Risk = 8.8E-06 (Ingestion) Risk = 1.3E-03 (Inhalation)	No	Background concentrations higher than impacted water concentrations
Zone 1	Radium-228	Carcinogen	Risk = 4.1E-05 (Ingestion)	No	Background concentrations higher than impacted water concentrations
Zone 1	Thorium-230	Carcinogen	Risk = 1.1E-06 (Ingestion)	No	Risk = 1.1E-06, within background radiological risk
Zone 3	Aluminum	Non-carcinogen	HQ = 2.5 (Child)	Yes	HQ > 01
Zone 3	Arsenic	Non-carcinogen	HQ = 88.4 (Child)	Yes	HQ > 01
		Carcinogen	Risk 9.3E-03 (Ingestion and dermal)		Risk > 1E-06
Zone 3	Beryllium	Non-carcinogen	HQ = 1.3 (Child)	Yes	HQ > 01
Zone 3	Cadmium	Non-carcinogen	HQ = 1.1 (Child)	No	Background concentrations higher than impacted water concentrations
Zone 3	Cobalt	Non-carcinogen	HQ = 94.2 (Child)	Yes	HQ > 01
Zone 3	Manganese	Non-carcinogen	HQ = 33.8 (Child)	Yes	HQ > 01
Zone 3	Molybdenum	Non-carcinogen	HQ =9.5 (Child)	No	Background concentrations higher than impacted water concentrations
Zone 3	Nickel	Non-carcinogen	HQ = 1.6 (Child)	Yes	HQ > 01
Zone 3	Vanadium	Non-carcinogen	HQ = 2.3 (Child)	Yes	HQ > 01
Zone 3	Uranium	Non-carcinogen	HQ =0.92 (Child)	No	Background concentrations higher than impacted water concentrations
Zone 3	Chloroform	Carcinogen	Risk = 1.6E-06 (Ingestion and dermal) Risk = 2.0E-06 (Inhalation)	Yes	Risk > 1E-06
Zone 3	Uranium Isotopes	Carcinogens	U-234 Risk = 7.9E-07 U-235 Risk = 3.7E-08 U-238 Risk = 9.6E-07 (Ingestion)	No	Background concentrations higher than impacted water concentrations
Zone 3	Radium-226	Carcinogen	Risk = 8.5E-05 (Ingestion) Risk = 1.2E-02 (Inhalation)	Yes	Risk > 1E-06
Zone 3	Radium-228	Carcinogen	Risk = 3.5E-04 (Ingestion)	Yes	Risk > 1E-06
Zone 3	Lead-210	Carcinogen	Risk = 5.5E-05 (Ingestion)	Yes	Risk > 1E-06

Note:

Gray highlighted rows indicate Retained Constituents of Potential Concern (RCOPCs).

(1) COPCs shown here include only those resulting from RAGS Part D table analysis (i.e., Tables 10.1 - 10.9 in Appendix A). Includes COPCs with HQ > 0.1 (where total segregated HI > 1) or Risk > 1E-06 (where total exposure scenario risk exceeds EPA's target risk range of 1E-04 to 1E-06).

(2) All HQ values are for ingestion and dermal exposure by a child receptor (noncarc. hazard associated with inhalation pathway hazard is not significant)

TABLE 8

Summary of HHRA Screening, HHRA Results, and ARAR Comparison for COPCs

UNC Church Rock Mill and Tailings Site

Church Rock, New Mexico

															Risk-Based RCOPC?		ARAR-Based RCOPC?		
Exposure Point	CAS Number	Chemical (1)	Exposure Point Concentration (EPC) (4)	EPC Statistic	Units	Concentration Used for Screening (5)	Background Value (6)	Screening Toxicity Value (N/C) (7)	Potential ARAR/TBC Value (8)	Potential ARAR/TBC Source (8)	HHRA COPC Flag (Y/N)	Rationale for Selection or Deletion (9)	Non-Carcinogen or Carcinogen	Risk or Hazard (From Appendix A) (10)	Risk RCOPC Flag (Y/N) (11)	Rationale for Selection or Deletion	EPC Exceeds ARAR? (Y/N)	ARAR RCOPC Flag (Y/N)	Rationale for Selection or Deletion
Zone 1 Tapwater	7429-90-5	Aluminum	0.44	UCL95	mg/l	1.3	0.117	1.6 (N)	5	NMWQCC-I	N	BSL	Screened out from HHRA				No	No	EPC < ARAR
	7440-38-2	Arsenic	0.00145	UCL95	mg/l	0.003	0.00117	0.000045 (C)	0.01	MCL	Y	ASL	Carcinogen Non-carcinogen	Risk = 3.3E-05 (Ingestion and dermal) HQ = 0.31 (Child)	No	Similar to background concentrations; below MCL; HQ > 0.1, but HI (skin) < 1	No	No	EPC < ARAR (MCL); Similar to background concentrations
	7440-48-4	Cobalt	0.0557	UCL95	mg/l	0.06	0.0112	0.00047 (N)	0.05	NMWQCC-I	Y	ASL	Non-carcinogen	HQ = 11.9 (Child)	Yes	HQ > 0.1	Yes	Yes	EPC > ARAR
	7439-96-5	Manganese	1.95	UCL95	mg/l	2.96	2.519	0.032 (N)	0.2	NMWQCC-O	Y	ASL	Non-carcinogen	HQ = 6.1 (Child)	No	Background concentrations higher than impacted	Yes	No	Background concentrations higher than impacted
	7440-02-0	Nickel	**0.0533**	Mean	mg/l	0.06	0.0602	0.030 (N)	0.2	NMWQCC-I	Y	ASL	Non-carcinogen	HQ = 0.18 (Child)	No	Similar to background concentrations; few detects	No	No	EPC < ARAR; Similar to background concentrations
	7782-49-2	Selenium	**0.001**	Max	mg/l	0.001	0.00107	0.0078 (N)	0.05	MCL	N	BSL	Screened out from HHRA				No	No	Maximum detected concentration < ARAR
	7440-62-2	Vanadium	**0.2**	Max	mg/l	0.2	ND	0.0078 (N)	0.1	NRC GPS	Y	ASL	Non-carcinogen	HQ = 2.6	No	Hazard based on only one detection in seepage-impacted water dataset	Yes	No	Hazard based on only one detection in seepage-impacted water dataset
	7440-61-1	Uranium	0.00174	UCL95	mg/l	0.0022	0.0255	0.0047 (N)	0.03	MCL	N	BSL	Screened out from HHRA				No	No	EPC < ARAR; Background concentrations higher than impacted
	13966-29-5	Uranium-234 (2)	5.94E-01	NA	pCi/L	NA	NA	NA (C)	NA	NA	Y	DET	Carcinogen	Risk = 7.9E-07	No	Total Uranium Isotopes Risk = 1.8E-06; Background concentrations higher than impacted	NA	NA	Total uranium EPC < ARAR; Background concentrations higher than impacted
	15117-96-1	Uranium-235 (2)	2.71E-02	NA	pCi/L	NA	NA	NA (C)	NA	NA	Y	DET	Carcinogen	Risk = 3.7E-08			NA	NA	
	7440-61-1	Uranium-238 (2)	5.80E-01	NA	pCi/L	NA	NA	NA (C)	NA	NA	Y	DET	Carcinogen	Risk = 9.6E-07			NA	NA	
	67-66-3	Chloroform	**0.00068**	Mean	mg/l	0.00076	NBC	0.00019 (C)	0.08	MCL (TTHM)	Y	ASL	Carcinogen Non-carcinogen	Risk = 3.4E-07 (Ingestion and dermal) Risk = 2.8E-08 (Inhalation) HQ = 0.005	No	Risk < 1E-06 and HQ < 0.1	No	No	EPC < ARAR
	13982-63-3	Radium-226 (3)	1.213	UCL95	pCi/L	1.8	1.314	NA (C)	5	MCL (combined radium)	Y	DET	Carcinogen	Risk = 8.8E-06 (Ingestion); Risk = 1.3E-03 (Inhalation)	No	Background concentrations higher than impacted water concentrations	No	No	Background concentrations higher than impacted water concentrations
	15262-20-1	Radium-228 (3)	2.087	UCL95	pCi/L	4	2.946	NA (C)	5	MCL (combined radium)	Y	DET	Carcinogen	Risk = 4.1E-05 (Ingestion)	No	Background concentrations higher than impacted water concentrations	No	No	Background concentrations higher than impacted water concentrations
	14269-63-7	Thorium-230	**0.65**	Mean	pCi/L	0.7	0.403	NA (C)	5	NRC GPS	Y	DET	Carcinogen	Risk = 1.1E-06 (Ingestion)	No	Risk near 1.0E-06, within background radiological risk	No	No	EPC < ARAR
	16887-00-6	Cl	214.3	UCL95	mg/L	NA	39.03	NA	250	NMWQCC-O	N	GGP	Non-carcinogen	NA	No	General chemistry parameter. No applicable toxicity value	No	No	EPC < ARAR
	18785-72-3	SO4	4049	UCL95	mg/L	NA	2773	NA	2125	NM BKGD	N	GGP	Non-carcinogen	NA	No	General chemistry parameter. No applicable toxicity value	Yes	Yes	EPC > ARAR
	14797-55-8	NO3_as_N	152	UCL95	mg/L	NA	1.754	NA	190	NM BKGD	N	GGP	Non-carcinogen	NA	No	General chemistry parameter. Toxicity values limited to infant (0-3 mo) effects, MCL based on toxicity to infants.	No	No	EPC < ARAR
	N/A	Lab_TDS	6843	UCL95	mg/L	NA	4319	NA	4800	NM BKGD	N	GGP	Non-carcinogen	NA	No	General chemistry parameter. No applicable toxicity value	Yes	Yes	EPC > ARAR
	7440-14-4	Rad_totl	2.8	UCL95	pCi/L	NA	3.841	NA	5	MCL	N	GGP	Individual isotopes are carcinogens	NA	No	Radium isotopes evaluated individually	No	No	EPC < ARAR; Background concentrations higher than impacted
	12587-46-1	Gross_Alpha	2.319	UCL95	pCi/L	NA	2.361	NA	15	MCL (gross alpha)	N	GGP	Individual alpha-emitters are carcinogens	NA	No	Gross alpha is screening parameter, no applicable toxicity value	No	No	EPC < ARAR; Background concentrations similar to impacted

ATTACHMENT 10

TABLES 33 and 40, AND APPENDIX G FROM THE UNC SITE WIDE SUPPLEMENTAL FEASIBILITY STUDY PART II REMEDIAL ALTERNATIVES EVALUATION

Identification and Applicability of General Response Actions for Ground Water Remediation (from SWSFS Part II, April 2011, Table 33)

General Response Actions	Description	Associated Groundwater Remedial Technologies	Applicability
No Further Action	No further actions taken at the site to remediate impacted target area(s) (excluding long-term surveillance monitoring by DOE under UMTRCA Title II).	None.	Retained for consideration. Will not meet goals in Zone 3.
Hydraulic Containment with Extraction and Evaporation	Pumping control of impacted are with constituent removal and evaporation.	Groundwater extraction and evaporation. Directional/horizontal wells. Vertical wells.	Retained for consideration. See footnote 1. See Section 4.1.4.1 and pages 49-51.
Enhanced Extraction	Rapid dewatering to reduce volume of impacted water.	Relatively large number of vertical wells.	Retained for consideration. May be useful for groundwater containment and rapid mass removal. If total pumpage volume exceeds capacity of evaporation ponds, discharge to Pipeline Canyon after treatment may be required (see Table 41 for summary). See footnote 1. See Section 4.1.4.2 and page 51.
Physical Barriers	Physical or hydraulic barriers to prevent migration of seepage-impacted water.	Vertical engineered physical barriers. Hydraulic barriers or "fences" from vertical injection-well arrays.	Zone 3 and Zone 1 are too deep for physical vertical barriers but retained for consideration in Southwest Alluvium (SWA). Hydraulic barriers retained for consideration. May be useful for containment. See footnote 1. See Section 4.1.3.1 and pages 41-43; Section 4.1.4.3 and pages 52-59.
Permeable Reactive Barriers (PRBs)	Contaminated water is channeled between impervious vertical walls to naturally flow through a permeable reactive barrier where constituents are passively treated in situ.	Overlaps with treatment GRA. Typically emplaced by trenching (excavate-and-fill). Reactive medium sometimes can be emplaced by jetting or hydraulic fracturing.	Retained for consideration in SWA. See Section 4.1.3.2 and pages 43-46.
Passive Treatment Wells	Non-pumped well arrays are filled with reactive media through with the contaminated water flows with constituents passively treated in situ.	Overlaps with treatment GRA. Specialized non-pumped well construction fosters through-flow of contaminated water. Reactive media in wells can be easily replaced.	Retained for consideration in SWA and Zone 3. See Section 4.1.3.3 and page 46.
Hydraulic Flushing with Extraction and Evaporation	Water injection matched with controlled extraction and evaporation.	Amended injection water for in-situ constituent stabilization plus displacement and extraction of seepage-impacted water. Injection water potentially from deep wells in Dakota Formation or Westwater Canyon Formation. Injection water solely for displacement and extraction of seepage-impacted water.	Retained for consideration in SWA. Injected water will geochemically equilibrate to exceed ROD cleanup levels for sulfate, TDS, and nitrate. See Section 4.1.4.6 and pages 59-60.
Treatment	Methods to reduce the mobility, toxicity, or volume of impacted water.	Alkalinity amendments to injection water for in-situ stabilization and flushing. Reverse osmosis (RO) treatment of injection water for flushing and/or hydraulic barrier. All injection and flushing envisioned as combined with extraction and evaporation.	Overlaps with flushing and PRB GRAs. RO cost too high to meet demand. Retained for consideration. May be useful for containment or groundwater restoration. See Section 4.1.4.7 and pages 60-61; Appendix F.
Bioremediation	The remedial technology and process option of stimulating the indigenous microbial population to effect desired changes in contaminant chemistry, such as a reduction in mobility.	Amended injection water, vertical injection wells, groundwater monitoring.	Screened out for all three hydrostratigraphic units due to potential significant limitations in its long-term effectiveness. See Section 4.1.3.4 and page 47.
Institutional Controls	Legal or governmental controls taken to prevent contact with seepage-impacted water.	Action and use restrictions. Offsite groundwater monitoring.	Retained for consideration. Will not meet goals. Can be used as mechanism to prevent contact with water and establish environmental rights-of-way. See Section 4.1.4.8 and page 60.

Note 1: ROD cleanup levels will not be met in any of the three hydrostratigraphic units for sulfate, total dissolved solids, manganese, radium, or nitrate; nickel (Zone 3); or uranium (SWA, if EPA adopts the MCL as an ARAR).

Operable Unit Site Wide Remedy with Combined Remedial Alternatives
Shading Indicates Components Included in Alternative (from SWSFS Part II, April, 2011, Table 40)

COMBINED REMEDIAL ALTERNATIVES	COMPONENTS OF COMBINED REMEDIAL ALTERNATIVES																		
	SOUTHWEST ALLUVIUM (SWA)						ZONE 3						ZONE 1						
	No Further Action	ICs	Containment	Extraction	Passive Treatment Wells	Hydraulic Barrier	No Further Action	ICs	Containment	Extraction	Passive Treatment Wells	Hydraulic Barrier	No Further Action	ICs	Containment	Extraction	Passive Treatment Wells	Hydraulic Barrier	Evaporation
No Further Action	■												■						
Institutional Controls (ICs) Onsite and Offsite		■						■						■					
1. In SWA and Zone 3, Hydraulic Containment and Extraction Onsite			■	■					■	■									■
2. • In SWA and Zone 3, Hydraulic Containment and Extraction Onsite; • In SWA and Zone 1, ICs Offsite		■	■	■					■	■				■					■
3. • In Zone 3, Hydraulic Barrier Containment (including alkalinity amendment) and Extraction Onsite Plus Passive Treatment Wells Plus ICs in Section 36; • In SWA and Zone 1, ICs Offsite		■						■	■	■	■	■		■					■

Note: EPA views ICs as potentially useful if the Navajo Nation concurs. Otherwise, EPA has indicated it can proceed with remedy modification absent ICs (as discussed at the multi-agency technical meeting held on May 5, 2005, at the Church Rock site).

Remedial Alternative Preliminary Cost Estimate Summary (from SWSFS Part II, April 2011, Appendix G

Hydrostratigraphic Unit and Alternative	Remedial Alternative Description	Capital Cost	Annual O&M Cost	Comments
SWA - Alternative 1	No Further Action (except for Long-Term Stewardship by DOE)	$0	$0	Assume no Capital or O&M costs required.
SWA - Alternative 2	Enhanced Extraction	$1,580,857	$1,393,054	Assumes installation of 60 wells and basic wastewater treatment (precip./floc./coag.). Includes cost to design/build 300 gpm WWTP capacity for chemical precipitation/ coagulation/flocculation.
SWA - Alternative 3	Hydraulic Containment Using Vertical Pumping Wells	$160,724	$86,046	Assumes pumping from four new wells and four existing wells. Estimate does not include cost to pre-treat injection water, if necessary; unable to quantify costs until ARARs are established.
SWA - Alternative 4	Passive Treatment Wells	$640,000	$54,840	Assumes 30 new passive treatment wells. Assumes media changed in 20% of wells each year. Does not include any additional groundwater quality monitoring associated with the treatment.
SWA - Alternative 5	Vertical Physical Barrier	$2,284,224	$86,046	Jet-grouted vertical barrier installed from bedrock surface to top of saturated zone (i.e., does not extend to ground surface). Barrier approximately 1100 ft long and 50,000 sq. ft @ $30 per vertical sq ft. (1997 dollars) (L. Pearlman, March 1999, indicates a range of $15 to $30 per vertical sq ft). Includes quarterly groundwater monitoring, but no additional water level monitoring labor or equipment or evaluate barrier effectiveness. Assumes no inspection or maintenance of barrier requred.
SWA - Alternative 6	Hydraulic Barrier from Injection Wells	$255,724	$100,046	Assume 8 new wells to be used (4 injection at 5 gpm, 4 extraction at 5 gpm). Estimate does not include installation of a new injection water source well from deeper aquifer (e.g., Westwater Canyon) or cost of additional distribution line, if current mill well capacity is insufficient or unavailable ($100-200K). Estimate does not include cost to pre-treat injection water, if necessary; unable to quantify costs until ARARs are established.
SWA - Alternative 7 (+)	Permeable Reactive Barriers (+)	$3,255,121	$322,265	Funnel and gate style permeable reactive barrier. Approximately 1,030 ft long and 78,800 sq. ft with 200-ft long x 5-ft wide gate. Iron filings used for reactive media gate and sheet piling for funnel. O&M costs included in estimate are (1) media replacement at approximately five year interval (shown @ 20% replacement cost per year), (2) groundwater monitoring for remedy effectiveness.
SWA - Alternative 8	Hydraulic Flushing	$200,724	$104,898	Assume 10 wells to be used (6 existing, 4 new) 5 injection at 5 gpm, 5 extraction at 5 gpm. Estimate does not include installation of a new injection water source well from deeper aquifer (e.g., Westwater Canyon) or cost of additional distribution line, if current mill well capacity is insufficient or unavailable ($100-200K). Estimate does not include cost to pre-treat injection water, if necessary; unable to quantify costs until ARARs are established.
Zone 1 - Alternative 1	No Further Action (Except for Long-Term Stewardship by DOE)	$0	$0	Assume no Capital or O&M costs required.
Zone 1 - Alternative 2	Institutional Controls	$100,000	$20,000	Groundwater modeling/consulting and legal services to establish IC Zone and conditions. Includes $20 O&M to oversee and enforce the IC, but no additional monitoring, reporting, or inspection requirements.
Zone 1 - Alternative 3	Hydraulic Containment with Extraction and Evaporation	$253,319	$55,216	Assumes installation and pumping of 10 wells at 1.5 gpm with discharge to evaporation ponds.
Zone 1 - Alternative 4	Enhanced Extraction	$761,616	$115,161	Assumes installation of 35 wells and basic wastewater treatment (precip./floc./coag.). Does not include design/build WWTP.
Zone 3 - Alternative 1	No Further Action (Except for Long-Term Stewardship by DOE)	$0	$0	Assume no Capital or O&M costs required.
Zone 3 - Alternative 2	Institutional Controls (ICs) for Section 36 if Needed	$100,000	$20,000	Groundwater modeling/consulting and legal services to establish IC Zone and conditions. Includes $20 O&M to oversee and enforce the IC, but no additional monitoring, reporting, or inspection requirements.
Zone 3 - Alternative 3	Passive Treatment Wells	$630,000	$52,600	Assumes 20 new wells. Assumes media changed in 20% of wells each year. Does not include any additional groundwater quality monitoring associated with the treatment.
Zone 3 - Alternative 4	Hydraulic Containment with Extraction and Evaporation	$0	$53,869	This is the current remedy in Zone 3. No additional capital costs. Does not include cost of pending injection of alkalinity-adjusted water.
Zone 3 - Alternative 5	Enhanced Extraction	$2,031,803	$834,561	Assumes installation of 80 wells and basic wastewater treatment (precip./floc./coag.). Includes estimated cost to design/build 100 gpm WWTP capacity for chemical precipitation/ coagulation/flocculation.
Zone 3 - Alternative 6	Hydraulic Barrier from Injection Wells for Containment.	$90,420	$54,017	Assume 6 wells to be used (3 injection at 2 gpm, 3 extraction at 2 gpm). Estimated cost does not include connection to injection water source or cost of pumping water from deeper aquifer (e.g., Westwater Canyon) or cost of distribution line from existing water source, which are already installed. Estimate does not include cost to pre-treat injection water, if necessary.

Notes:
SWA = Southwest Alluvium.
(+) PRB costs are highly site-specific; the estimate presented here is poorly constrained.
Shading indicates that the remedial alternative has been screened out.
For groundwater pumping options, sludge disposal costs (~$0.5/1000 gal treated) are not included.