environmental
properties management, LLC

CIMARRON FACILITY DECOMMISSIONING PLAN
Revision 1

Prepared by

Environmental Properties Management LLC

With Consultants

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October 2018

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Prepared for

CIMARRON ENVIRONMENTAL RESPONSE TRUST

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Term/Phrase/Name
%	percent
µg	micrograms
µg/L	micrograms per liter
µR/hr	microroentgen/hour
ALARA	As Low As Reasonably Achievable
amsl	above mean sea level
BA1	Burial Area #1
BA2	Burial Area #2
BA3	Burial Area #3
BA4	Burial Area #4
bgs	below ground surface
BMP	Best Management Practice
Bq/g	becquerel per gram
Bq/L	becquerel per liter
BTP	Branch Technical Position
CERT	Cimarron Environmental Response Trust
cfs	cubic feet per second
cm	centimeter
cm/s	centimeters per second
cm^2	square centimeter
COC	contaminant of concern
DAC	Derived Air Concentration
DAP-1	North Stockpile
DAP-2	East Stockpile
DCE	decommissioning cost estimate
DCGL	Derived Concentration Goal Level
DCL	derived concentration limit
DEQ	Oklahoma Department of Environmental Quality
DOT	United States Department of Transportation
dpm	disintegrations per minute
EPA	United States Environmental Protection Agency
EPC	engineering, procurement, and construction
EPM	Environmental Project Management LLC
$Fe(OH)_3$	ferric hydroxide
FSSR	Final Status Survey Report
ft	foot/feet
ft^2	square foot/square feet
ft^2/d	square feet per day
ft^3	cubic foot/cubic feet
GE	Groundwater Extraction
GETR	Groundwater Extraction Trench
gpm	gallons per minute
GWI	Groundwater Injection
HDPE	high-density polyethylene
ICP-MS	inductively coupled plasma – mass spectroscopy
ICRP	International Commission on Radiological Protection
in/yr	inches per year

Acronym/Abbreviation	Term/Phrase/Name
in^2	square inch
K_d	distribution coefficient
kg	kilogram
KMNC	Kerr-McGee Nuclear Corporation
lb	pound
LLRW	low-level radioactive waste
m	meter
m^2	square meter
m^3	cubic meters
MBBR	Moving Bed Biofilm Reactor
MCL	Maximum Contaminant Level
MDA	minimum detectable activity
mEq	milliequivalent
mg/L	milligrams per liter
mL/g	milliliters per gram
MNA	monitored natural attenuation
MOFF	Mixed Oxide Fuel Fabrication
mrem/yr	millirem per year
Nextep	Nextep Environmental, Inc.
NOAA	National Oceanic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
OGS	Oklahoma Geological Survey ()
OPDES	Oklahoma Pollution Discharge Elimination System
ORAU	Oak Ridge Associated Universities
ORISE	Oak Ridge Institute for Science and Education
OWRB	Oklahoma Water Resources Board
PBA	Process Building Area
pC/kg	picoCuries per kilogram
pCi/g	picoCuries per gram
pCi/L	picoCuries per liter
PHMSA	Pipeline and Hazardous Materials Safety Administration
Plan	Final Decommissioning Plan
PM	Project Manager
POV	personally owned vehicles
PVC	polyvinyl chloride
QAC	Quality Assurance Coordinator
QAPP	Quality Assurance Program Plan
RAI	Request for Additional Information
RP	radiation protection
RPP	Radiation Protection Program
RSO	Radiation Safety Officer
Settlement Agreement	*Plan of Reorganization and a Consent Decree and Environmental Settlement Agreement*
SFC	Sequoyah Fuels Corporation
Site	Cimarron site
SNM	Special Nuclear Material
SWPPP	Stormwater Pollution Prevention Plan
Tc-99	technetium-99
TCLP	Toxicity Characteristic Leaching Procedure
TEDE	total effective dose equivalent

Acronym/Abbreviation	Term/Phrase/Name
Tronox	Tronox Worldwide LLC
Trust	Cimarron Environmental Response Trust
U_3O_8	uranium octaoxide
UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride
UIC	Underground Injection Control
UIX	Uranium Ion Exchange
UO_2	uranium dioxide
UP	Uranium Pond
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WAA	Western Alluvial Area
WATF	Western Area Treatment Facility
wt. %	weight percent
WU	Western Upland

EXECUTIVE SUMMARY

Environmental Properties Management LLC (EPM), Trustee for the Cimarron Environmental Response Trust (the Trust), submits this Decommissioning Plan (the Plan) for the Cimarron site (the Site), located at 100 N. Highway 74, Guthrie, OK.

In the 1960s and early 1970s, Kerr-McGee Nuclear Corporation (KMNC) purchased nearly 800 acres of property located at the intersection of Highways 74 and 33, approximately seven miles south of Crescent, OK, as shown in Figure 1-1. KMNC manufactured nuclear fuel under two Nuclear Regulatory Commission (NRC) licenses. Uranium fuel was produced under NRC Special Nuclear Material (SNM) License SNM-928, and mixed oxide fuel was produced under NRC license SNM-1174. Waste was buried in three locations, and wastewater containing licensed material was stored in impoundments and discharged to the Cimarron River, in accordance with the regulatory requirements of that time.

Four parcels containing a total of nearly 290 acres of property have been divested since the license was transferred to the Trust. The Site now consists of approximately 330 acres of rolling hills and 170 acres of floodplain (Figure 1-1). Grassland and temperate forest covers nearly all the property, and two ponds collect surface water from upland areas.

Decommissioning of materials and equipment, existing buildings and structures, and surface and subsurface soils is complete. The Site was divided into 16 "Subareas" as shown in Figure 1-2, designated Subareas A through O (there were two uranium waste ponds, both designated Subarea O), to facilitate the decommissioning and final survey process for buildings and surface and subsurface soil. Final Status Survey Reports have been submitted for all these media for all 16 Subareas. All but three of the Subareas have been released from the NRC license.

Licensed material exceeds decommissioning criteria for unrestricted release in groundwater in several portions of the Site, described in detail in Section 3 of this Plan. The intent of the Plan is to reduce the concentration of uranium in groundwater to achieve unrestricted release of the Site and license termination. The unrestricted release criterion for uranium in groundwater (the NRC Criterion), stipulated in License Condition 27(c), is 180 picoCuries per liter (pCi/L) total uranium. This activity concentration was derived by converting the toxicological risk-based criterion of 110 micrograms per liter (μg/L) at a U-235 enrichment of 2.7%. Uranium presents a greater toxicological risk than a radiological risk, so this NRC Criterion may be lower than a derived concentration goal level (DCGL) based on a 25 millirem per year (mrem/yr) annual dose limit would be.

Groundwater in several portions of the Site also contains two non-radiological contaminants of concern (COCs): nitrate and fluoride. United States Environmental Protection Agency (EPA) has established Maximum Contaminant Levels (MCLs) for drinking water. The MCLs are 30 µg/L for uranium, 10 milligrams per liter (mg/L) for nitrate, and 4 mg/L for fluoride. The Oklahoma Department of Environmental Quality (DEQ) has established 30 µg/L for uranium and 4 mg/L for nitrate as remediation goals site-wide.

Because nitrate is present at in shallow groundwater at concentrations above its MCL due at least in part to the use of agricultural fertilizer upgradient from the Site, the DEQ has approved a "mean plus two standard deviations" value of 22.9 mg/L for background nitrate in groundwater, based on analysis of samples from monitor wells located upgradient of any licensed activities. The State-approved remediation criterion for nitrate is therefore 22.9 mg/L. A small amount of property surrounding the former process buildings has been divested and is being used as a manufacturing facility. The State Criterion for nitrate in groundwater in this area is 52 mg/L. State-approved remediation goals for uranium, nitrate, and fluoride will be referred to in this Plan as the "State Criterion (or Criteria)".

The primary objective of this Plan is to reduce the activity of uranium in groundwater to less than the NRC Criterion to obtain NRC's release of the Site for unrestricted use and termination of the NRC license. The secondary objective is to remove as great a mass of all COCs as is reasonably achievable. The extent to which the concentrations of COCs can be reduced is a function of available funding. Post-remediation monitoring will be performed to demonstrate compliance with the criteria applicable to the above stated objectives.

After issuance of a license amendment by NRC and approval of this Plan by DEQ, decommissioning activities will begin with the development of specifications and requests for bids from qualified vendors. Contracts will be awarded and executed, and construction will begin. Upon completion of groundwater remediation, a minimum of three years of post-remediation groundwater monitoring will be conducted, and final status surveys will be performed as needed. After demonstrating that groundwater complies with the NRC Criterion, demobilization will be performed over a period of approximately one year following post-remediation monitoring.

This Decommissioning Plan is submitted as a License Amendment Request.

* * * * *

1.0 FACILITY OPERATING HISTORY

In the 1960s and early 1970s, Kerr-McGee Nuclear Corporation (KMNC) purchased nearly 800 acres of property located at the intersection of Highways 74 and 33, approximately seven miles south of Crescent, OK, as shown in Figure 1-1. KMNC manufactured nuclear fuel under two Nuclear Regulatory Commission (NRC) licenses. Uranium fuel was produced under NRC Special Nuclear Material License SNM-928, and mixed oxide fuel was produced under NRC license SNM-1174. Waste was buried in three locations, and wastewater containing licensed material was stored in impoundments and discharged to the Cimarron River, all in accordance with the regulatory requirements of that time.

The Site now consists of approximately 330 acres of rolling hills and 170 acres of floodplain north of the intersection of Highways 74 and 33, located approximately seven miles south of Crescent, Oklahoma (Figure 1-1) in Logan County. The current street address of the facility is 100 North Highway 74, Guthrie, Oklahoma 73044. Grassland and temperate forest covers nearly all the property, and two ponds collect surface water from upland areas. Several miles of gravel roads, a gravel parking area, and one office building remain on Trust Property.

Decommissioning of materials and equipment, buildings and structures, and surface and subsurface soils is complete. The Site was divided into 16 "Subareas" as shown in Figure 1-2, designated Subareas A through O (two Subareas, both of which contained uranium waste ponds, were designated Subarea O) to facilitate the decommissioning and final survey process for buildings and surface and subsurface soil. Subareas A through E were considered unaffected areas and were designated "Phase I" areas. Subareas F through I contained both unaffected and affected areas and were designated "Phase II" areas. Subareas K through O contained affected areas and were designated "Phase III" areas. Subareas I and K included the former processing buildings; final status surveys for these areas included surveys of the buildings in addition to surface and/or subsurface soil. Only Subareas F, G, and N remain under the NRC license.

The word "area" is used in this document to describe the areas given alphabetic designations, remediation areas, and areas associated with a feature, facility, etc. To minimize confusion, when referring to the Subareas for which final status surveys were performed and for which final status survey plans and reports were prepared, the term "Subarea" will be used. When referring to specific remediation areas, the term "Area" will be used. All other generic references to areas will simply be referred to as "areas".

1.1 LICENSE NUMBER / STATUS / AUTHORIZED ACTIVITIES

The Trust proposes to complete the decommissioning of the Site in accordance with License SNM-928, (currently Amendment 21). The license authorizes the possession of:

- ≤ 1,200 grams of U-235 in any compound containing uranium enriched to ≤ 5 weight percent (wt. %) in U-235
- ≤ 10 grams of U-235 in any compound containing uranium enriched to > 5 wt. % in U-235
- ≤ 2,000 kilograms (kg) of natural and depleted uranium source material
- ≤ 6,000 kg of thorium source material

Licensed material can be in any chemical or physical form. The radioactive material at the Site consists only of environmental media (i.e., soil and groundwater) impacted by licensed material from past burials or releases of licensed material to the environment. There is no current inventory of licensed material at the Site; licensed material will enter the inventory as it is extracted from environmental media and concentrated in treatment system media (i.e., ion exchange resin). Excluding uranium in groundwater, licensed material does not exceed criteria for unrestricted release stipulated in License Conditions 27(b) and 27(c)anywhere on the Site.

KMNC submitted an application for renewal of License SNM-928 on March 29, 1982. Sections of the application for license renewal addressing the processing of nuclear materials were deleted "for the standby period". License SNM-928 was renewed on March 31, 1983. Since the license was last renewed in 1983, 21 license amendments have been issued. A brief description of each follows.

- Amendment 1 was issued October 24, 1985. It transferred SNM-928 from KMNC to Sequoyah Fuels Corporation (SFC), and added letters dated March 28, 1984, September 28, 1984, and October 8, 1984 to License Condition 10, which address planned decommissioning activities.
- Amendment 2 was issued December 20, 1985. It added an August 6, 1985 letter to License Condition 10.
- Amendment 3 was issued April 16, 1986. It authorized the possession of up to 6,000 kg of thorium, which authorized SFC to package and dispose of thorium-impacted material being removed from a site near Cushing, Oklahoma, which was owned by Kerr-McGee Corporation (SFC's parent corporation), under License SNM-928.
- Amendment 4 was issued April 16, 1986. It increased the authorized quantity of U-235 enriched to ≤ 5 wt. % to 6,000 g, and added letters dated August 6, 1985, November 19, 1985, and March 3, 1986 to License Condition 10.
- Amendment 5 was issued May 4, 1987. It added a letter dated February 19, 1987 to License Condition 10 and extended the deadline to complete decommissioning to December 31, 1988.

- Amendment 6 was issued October 26, 1988. It changed the licensee from SFC to Cimarron Corporation and added a letter dated October 14, 1988 to License Condition 10.
- Amendment 7 was issued December 23, 1989. It added a letter dated November 17, 1988 to License Condition 10 and extended the deadline to complete decommissioning to June 30, 1990.
- Amendment 8 was issued January 5, 1990. It added a letter dated November 2, 1989 to License Condition 10 and added License Condition 21, dealing primarily with control of access to the Site.
- Amendment 9 was issued December 28, 1992. It added letters dated September 11, 1991 and June 24, 1992 to License Condition 10, extended the deadline for decommissioning to June 30, 1995, and added License Condition 22, which authorized the backfill of the excavated sanitary lagoons and several former burial trenches in the eastern portion of the Site.
- Amendment 10 was issued November 4, 1994. It decreased the authorized quantity of U-235 enriched to ≤ 5 wt. % to 1,200 g, deleted License Condition 17 (prohibiting backfill of the excavated sanitary lagoons) and added License Condition 23 (authorizing burial of specified licensed material in an on-site disposal cell). It also included numerous significant changes related to decommissioning.
- Amendment 11 was issued July 26, 1995. It added License Condition 24, designating Karen Morgan as the Radiation Safety Officer (RSO).
- Amendment 12 was issued March 7, 1996. It corrected the name of the licensee, since Amendment 11 did not identify Cimarron Corporation as the licensee.
- Amendment 13 was issued April 13, 1996. It added License Condition 25, which released Phase I Subareas (which included Subareas A through E) from the license.
- Amendment 14 was issued July 7, 1997. It made numerous revisions to License Condition 10. It also deleted License Conditions 11, 12, 13, 14, 15, 16, 20, & 21. All of these license conditions contained radiation safety requirements which were as of that license amendment addressed in Annex A, the Radiation Protection Program (RPP). It also added License Condition 26, requiring compliance with Annex A.
- Amendment 15 was issued July 29, 1999. It revised License Condition 10 to cite the Site Decommissioning Plan. It also added License Condition 27, which specified decommissioning criteria for unrestricted release, and incorporated a provision for changing the decommissioning plan and/or RPP with ALARA Committee approval. It also revised License Condition 26 to include updates to Annex A.

- Amendment 16 was issued April 17, 2000. It added License Condition 28, which released Subareas J and O from the license.
- Amendment 17 was issued April 9, 2001. It added License Condition 29, which released Subareas H, I, L, and M from the license.
- Amendment 18 was issued May 28, 2002. It added License Condition 30, which released Subarea K from the license.
- Amendment 19 was issued October 3, 2005. It deleted License Condition 22, which authorized the backfill of the sanitary lagoons. It also revised License Conditions 23 (retaining only remaining requirements related to the on-site disposal cell) and 27(e) (addressing the process for approving changes to the decommissioning plan and/or RPP).
- Amendment 20 was issued June 12, 2009. It deleted License Condition 24, which designated the Site RSO by name, and revised License Condition 27(e) (addressing the process for approving changes to the decommissioning plan and/or RPP).
- Amendment 21 was issued February 14, 2011. This amendment transferred the license from Cimarron Corporation to the Cimarron Environmental Response Trust (CERT).

1.2 LICENSE HISTORY

The Cimarron facility was formerly operated by KMNC, a wholly owned subsidiary of Kerr-McGee Corporation. The Cimarron facility operated under two special nuclear material (SNM) licenses. License SNM-928 was issued for the production of uranium fuel, and License SNM-1174 was issued for the production of mixed oxide fuel. The principal operation under License SNM-928 involved the fabrication of enriched uranium reactor fuel pellets, and eventually fuel rods. A third license, License 35-12636-02, was issued for the possession of sealed sources (all cesium-137) for instrument calibration.

1.2.1 Mixed Oxide Fuel Production

Mixed oxide fuel was produced in the Mixed Oxide Fuel Fabrication (MOFF) facility from 1970 through 1975. Liquid uranyl nitrate and plutonium nitrate solutions were blended, co-precipitated, calcined, milled, pressed into pellets, and assembled in fuel pins. Due to the fact that the MOFF facility was decommissioned and released for unrestricted use in 1993, a more detailed description of the manufacturing process is not provided herein. Additional information concerning the mixed oxide processing is presented in *Report No. 6, Decontamination and Decommissioning of the Kerr-McGee Cimarron Plutonium Fuel Plant* (Cimarron Corporation, December 1988).

1.2.2 Uranium Fuel Production

Enriched uranium fuel was produced at the Uranium Plant from 1966 through 1975. Process facilities included a main production building; several one-story ancillary buildings, five process-related collection ponds, two original sanitary lagoons, one new sanitary lagoon, a waste incinerator, several uncovered storage areas, and three burial grounds. The main production building was divided into six major areas: ceramic uranium dioxide (UO_2), pellet, scrap recycle and recovery, waste treatment, fabrication and the high enriched area. In addition, space was provided for auxiliary services such as administrative and laboratory services, maintenance, and warehousing. Figure 1-3 shows the location of the relevant features of the facility, including the former buildings, roads, burial sites, and impoundments.

The low enriched fuel fabrication process is described as follows:

- Uranium hexafluoride (UF_6) gas was received and stored on the Site for processing.
- The UF_6 was heated; the gaseous UF_6 was then passed through an ammonia solution, producing solid ammonium diuranate.
- Ammonium diuranate was calcined to produce UO_2 powder.
- UO powder was ground to break up agglomerates, and then blended and pressed into pellets.
- The pellets were converted into ceramic-grade UO_2 in reduction furnaces.
- After sintering, the pellets were ground to a straight-sided right circular cylinder.
- The UO_2 removed by grinding was sent to the scrap purification system.

Highly enriched uranium processing was performed also at the Site within the main process building. This fuel fabrication process is described as follows:

- UF_6 was vaporized by heating cylinders with steam, reacted with a chemical to form solid uranium tetrafluoride (UF_4).
- The UF_4 was dried and placed in small muffle furnaces for conversion to UO_2 or uranium octaoxide (U_3O_8) metal oxides.
- Subsequent grinding and blending completed the oxide process.
- Uranium metal was made by blending UF_4 powder with calcium metal granules and heating.
- The uranium separated and was placed in an acid solution to remove the calcium and oxide slag.

- The metal and oxides were then packaged for shipment to fuel fabricators.

Additional operations at the facility included a solvent extraction process to recover uranium from the processing of scrap and from material that did not meet contract specifications.

1.2.3 Technitium-99 Impacted Feedstock

Groundwater samples obtained in the late 1970s yielded elevated results for gross beta activity at concentrations several times the results for gross alpha activity. Chemically processed uranium-238 has two short-lived beta-emitting daughters and one long-lived alpha emitting daughter. The beta activity should therefore be less than twice the alpha activity. Because this trend was persistent at several locations, additional investigation was conducted, and it was determined that the excess beta activity was due to the presence of technetium-99 (Tc-99), a fission product, in the groundwater.

Discussions were conducted with the Department of Energy, and it was determined that the Tc-99 was received by the Cimarron site as the result of the cleaning of cylinders at the Paducah facility. The Tc-99 was received at the time wastewater was being stored in Uranium Ponds #1 and #2, and seepage from those impoundments contained Tc-99.

1.2.4 Effluents

In general, the plant was designed to be slightly negatively pressurized at all times with plant air primarily discharging through roof vents. Exhaust systems for process equipment and operating areas provided effective control of airborne contaminants generated during processing. Special blowers, absolute filters, and exhaust ducts were utilized in areas of high airborne contamination potential. The main plant for uranium processing had 22 individual exhaust stacks which were routinely monitored for releases of radioactivity. The solvent extraction operation had a single exhaust stack which likewise was continuously sampled and periodically analyzed for radioactivity in the gaseous effluent. The contaminated waste incinerator had efficient stack gas cleaning equipment for controlling air emissions. In addition to the process buildings, there were other areas which were affected either directly or indirectly by operations. These areas included the sanitary lagoons, the waste settling ponds, the on-site disposal areas, some drain lines, and the incinerator.

In converting UF_6 gas to a solid fuel, contaminated liquids were generated which required processing prior to discharge to impoundments. The liquid wastes produced via uranium processing were passed through an ion exchange system to recover the uranium. The treated

effluent was monitored prior to being discharged to the Cimarron River from 1966 to 1971. From 1971 to 1975, the treated effluent was pumped to wastewater evaporation ponds. Contaminated sludge settled to the bottom of the ponds as the water evaporated.

Sanitary water and laundry water from the Uranium Plant operations were discharged to the East and West Sanitary Lagoons.

Radioactively contaminated solid wastes generated by Uranium Plant activities were buried at a designated on-site radioactive waste disposal area (Burial Area #1) from 1966 to 1970.

1.2.5 Termination of Operations

In a letter dated September 2, 1976, KMNC notified NRC that the plant was being placed on standby. In January 1977, KMNC submitted a description of proposed standby activities, which consisted of decontamination and cleanup activities, and requested a license renewal. NRC renewed License SNM-928 on May 3, 1977. Between 1977 and 1981, five license amendments were issued, all related to possession limits for natural and depleted uranium and authorized quantities of U-235 at different enrichments.

KMNC submitted application for another renewal of License SNM-928 on March 29, 1982. Sections of the application for license renewal which addressed the processing of nuclear materials were deleted "for the standby period". License SNM-928 was renewed on March 31, 1983. A description of the license amendments issued since this last renewal are described in further detail in Section 1.1 above.

1.3 PREVIOUS DECOMMISSIONING ACTIVITIES

This section addresses the decommissioning of buildings, impoundments, and pipelines. Buildings decommissioned under License SNM-928 include Uranium Building #1, Uranium Tank Storage Building #2, Solvent Extraction Building #3, Uranium Warehouse Building #4, the UF_6 Receiving Room, and the Emergency Response Building. Figure 1-4 shows the locations of these buildings, as well as the layout of Uranium Building #1. Impoundments included the Plutonium Waste Pond, Plutonium Emergency Pond, Uranium Emergency Pond, Uranium Waste Pond #1, Uranium Waste Pond #2, the East and West Sanitary Lagoons, and the "New" Sanitary Lagoon, shown in Figure 1-3.

1.3.1 Decommissioning Criteria

Decommissioning criteria are stipulated in License Conditions 23 and 27. For soil and soil-like (volumetrically contaminated) material, License Condition 27 lists unrestricted release criteria of

10 picoCuries per gram (pCi/g) for natural uranium, 30 pCi/g for enriched uranium, and 35 pCi/g for depleted uranium. License Condition 27 also states, "Soil and soil-like material with concentration exceeding the 1981 Branch Technical Position (BTP) Option 1 limits, but less than the Option 2 limits may be disposed in the onsite disposal cell in accordance with License Condition 23." License Condition 23 states, "The licensee is authorized to bury up to 14,000 cubic meters (m^3) (500,000 cubic feet [ft^3]) of soil contaminated with low-enriched uranium, in the 1981 BTP Option 2 concentration range, in the location described in the licensee's October 9, 1989, submittal to the NRC. The BTP Option 2 concentration range is up to 100 pCi/g for soluble uranium and up to 250 pCi/g for insoluble uranium."

For surfaces of buildings and equipment, License Condition 27 references the NRC's August 1987 *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of License for Byproduct, Source or Special Nuclear Material* which includes the following specific values:

- 5,000 disintegrations per minute (dpm) alpha/100 square centimeters (cm^2) (15.5 square inches [in^2]), averaged over 1 square meter (m^2) (10.8 square feet [ft^2]);
- 5,000 dpm beta-gamma/100 cm^2 (15.5 in^2), averaged over 1 m^2 (10.8 ft^2);
- 15,000 dpm alpha/100 cm^2 (15.5 in^2), maximum over 1 m^2 (10.8 ft^2);
- 15,000 dpm beta-gamma/100 cm^2 (15.5 in^2), maximum over 1 m^2 (10.8 ft^2);
- 1,000 dpm alpha/100 cm^2 (15.5 in^2), removable;
- 1,000 dpm beta-gamma/100 cm^2 (15.5 in^2), removable

1.3.2 Decommissioning of Former Buildings

Uranium Building #1

Uranium Building #1 was a one-story sheet metal building which contained the offices, laboratory, and change rooms, plus the majority of the equipment utilized for uranium fuel processing. Decontamination and release of equipment and building surfaces were based on the release criteria now stipulated in License Condition 27(c), measuring both direct and removable alpha contamination. Process equipment was removed from the processing areas, surveyed, and either decontaminated or shipped off Site to a licensed low-level radioactive waste (LLRW) disposal facility.

In 1977, the licensee initiated a procedure for characterizing and decontaminating Uranium Building #1 walls, floors, and ceiling surfaces. During initial characterization, all surfaces were surveyed with a portable gas proportional alpha detector. All areas yielding direct contamination measurements greater than 4,000 dpm/100 cm^2 alpha were marked. All floor surfaces and the bottom two meters (m) of each wall were completely surveyed. All hot spots greater than or equal to 15,000 dpm/100 cm^2 direct and 1,000 dpm/100 cm^2 smearable contamination were decontaminated. This general procedure was utilized to characterize and remediate all the rooms in Uranium Building #1.

Ceiling tiles were removed, vacuumed and surveyed. Ceiling tiles exceeding 2,000 dpm/100 cm^2 direct alpha or 500 dpm/100 cm^2 smearable alpha were disposed of at a licensed LLRW disposal facility. The ceiling, ceiling beams, rafters, conduit, piping and duct work were all surveyed. The entire attic area was vacuumed and cleaned. A second survey of the attic was conducted. Any areas identified as greater than 5,000 dpm/100 cm^2 alpha were acid washed and re-surveyed. Areas which could not be cleaned to less than 5,000 dpm/100 cm^2 alpha were resurveyed to ensure that they were less than 15,000 dpm/100 cm^2 alpha maximum and less than 5,000 dpm/100 cm^2 alpha average.

A roof grid was set up for the different sections of the 55,000 ft^2 roof; direct and removable contamination surveys were taken at grid intersects. Exterior wall panels were removed, surveyed for direct and removable contamination, and decontaminated if necessary. If wall panels were damaged or could not be decontaminated, replacement panels or panel sections from the Solvent Extraction Building were used to replace the exterior wall panels.

Concrete footings were decontaminated and surveyed, and new foot plates were installed prior to replacement of individual wall panels. The concrete slab was surveyed, decontaminated as required, and most of the slab was removed. Releasable and decontaminated slabs of concrete removed from Uranium Building #1 were placed in the spillway of the ponds in Subarea J, and in Subareas F and G.

Contaminated soil under the concrete was removed. Soil containing licensed material in the BTP Option 2 concentration range was stockpiled east of Uranium Building #1 for future placement in the on-site BTP Option 2 Disposal Cell. Soil containing licensed material exceeding the BTP Option 2 concentration range was shipped off-site to a licensed LLRW disposal facility. Floor drains and other drain lines were removed.

Additional details related to the decommissioning of Uranium Building #1 can be found in *Final Status Survey Report for Subarea "K"* (Nextep Environmental, Inc. [Nextep], February 2000). Decommissioning of Uranium Building #1, including the removal of contaminated soil underlying the building and drain lines extending beneath stockpiled soils, was completed in 1997. Uranium Building #1 was located in Subarea K, which was released for unrestricted use in Amendment 18, Condition 30, issued May 28, 2002.

Uranium Tank Storage Building #2

This steel building was located just south of Uranium Building #1. Building #2 was used to house 44 tanks that were 10 inches in diameter and 20 feet (ft) tall. The tanks were used to store uranium nitrate scrap solutions of less than 5% enrichment. This solution was held for subsequent reclamation by processing in the Solvent Extraction Building. The tanks were separated by concrete isolation barriers.

The concrete barriers and floor, as well as soil under and surrounding the building, were contaminated due to tank overflows, pipe leaks and pump leakage. The piping, tanks, and pumps were removed and were either decontaminated, surveyed and released, or shipped off the Site to a licensed LLRW disposal facility. The building was surveyed, dismantled, and/or disposed of as required based upon alpha survey results. The concrete divider in Building #2 was decontaminated by wet blasting and vacu-blasting. The concrete floor, footings and divider then was surveyed for both alpha and beta/gamma. The concrete floor, footings, and divider were released for unrestricted use and hauled to on-site drainage areas as rip-rap for erosion control.

Contaminated soils from beneath Building #2 were removed. Approximately 19,500 ft^3 of soil exceeding the BTP Option 2 concentration range were removed and shipped off Site for disposal at a licensed LLRW facility. The Building #2 area was initially backfilled with soil containing uranium in the BTP Option 2 concentration range up to four ft below grade. This soil was removed in 1994 and stockpiled east of Uranium Building #1 for future placement in the on-site BTP Option 2 Disposal Cell.

Additional details related to the decommissioning of Uranium Tank Storage Building #2 can be found in *Final Status Survey Report for Subarea "K"* (Nextep Environmental, February 2000). Decommissioning of Uranium Tank Storage Building #2 was completed in 1994.

Uranium Tank Storage Building #2 was located in Subarea K, which was released for unrestricted use in Amendment 18, Condition 30, issued May 28, 2002.

Solvent Extraction Building #3

This metal building was dismantled in 1986. Some of the building siding was shipped off Site as radioactive waste; some was decontaminated and used as replacement siding for Uranium Building #1. Equipment from this building was either decontaminated for unrestricted release or shipped off Site to a licensed LLRW disposal facility. The concrete flooring from this building was surveyed for alpha only, decontaminated as necessary, released, and used for on-site erosion control. Contaminated soil in this area was excavated and segregated. Soil exceeding the BTP Option 2 concentration range were removed and shipped off Site for disposal at a licensed LLRW facility. Soil containing uranium within the BTP Option 2 concentration range was stockpiled east of Uranium Building #1 for future placement in the on-site BTP Option 2 Disposal Cell.

Additional details related to the decommissioning of the Solvent Extraction Building can be found in *Final Status Survey Report for Subarea "K"* (Nextep Environmental, February 2000). Decommissioning of the Solvent Extraction Building was completed in 1986. The Solvent Extraction Building was located in Subarea K, which was released for unrestricted use in Amendment 18, Condition 30, issued May 28, 2002.

Uranium Warehouse Building #4

The warehouse is a sheet metal building which was never used to process radioactive materials. However, fuel assemblies were inspected and assembled for a short period of time within this building. Cimarron personnel requested permission from the NRC on December 28, 1979 to decontaminate the warehouse and use the building for coal liquefaction research and development.

Final release surveys were completed on the inside and outside surface of this building in 1980. The NRC gave approval on March 28, 1980 to use the "Coal Building" for non-nuclear purposes based upon these surveys. The survey conducted in 1980 was for alpha only. Additional surveys were conducted in the Coal Building in 1993 for both alpha and beta/gamma activity (Cimarron, 1993). These surveys revealed several small areas with elevated levels of beta activity in the concrete floor, which were decontaminated to unrestricted release criteria.

A portion of Uranium Warehouse Building #4 was used for coal liquefaction research and development. Although the process equipment was drained at the conclusion of testing, residual coal tar is still present in some of the process equipment. Another portion of Uranium Warehouse Building #4 was also used for titanium dioxide research and development. Although the process equipment was drained at the conclusion of testing, residual titanium tetrachloride was present in some of the process equipment. That equipment was removed by the current owner of the property on which Uranium Warehouse Building #4 is located.

Additional details related to the decommissioning of Uranium Warehouse Building #4 can be found in *Final Status Survey Report for Subarea "I"* (Nextep Environmental, June 1999). Decommissioning of this building was completed in 1994. Uranium Warehouse Building #4 is located in Subarea I, which was released for unrestricted use in Amendment17, License Condition 29, issued April 23, 2001.

UF_6 Receiving Room

This metal building was located adjacent to the south wall of Uranium Building #1. It was within this building that the cylinders of UF_6, received from Atomic Energy Commission diffusion plants, were heated with steam to vaporize the UF_6 for processing into fuel. Decontamination and decommissioning activities were initiated for the Vaporizer Building in 1991. The inner wall was removed, surveyed, decontaminated as required, and replaced. The roof and all interior and exterior walls were surveyed for direct and smearable alpha contamination. Areas exceeding unrestricted release criteria were decontaminated to comply with these criteria. The concrete floor was surveyed, decontaminated, and released for on-site erosion control.

Soil from under this building containing uranium within the BTP Option 2 concentration range was stockpiled east of Uranium Building #1 for future placement in the on-site BTP Option 2 Disposal Cell.

Additional details related to the decommissioning of the UF_6 Receiving Room can be found in *Final Status Survey Report for Subarea "K"* (Nextep Environmental, February 2000). Decommissioning of the UF_6 Receiving Room was completed in 1991. The UF_6 Receiving Room was located in Subarea K, which was released for unrestricted use in Amendment 18, Condition 30, issued May 28, 2002.

Emergency Response Building

During operating years, this building housed medical personnel, records, and emergency decontamination showers. During decommissioning activities, this building was used to house the on-site soil counter and to store records and soil samples. No decommissioning was required for the Emergency Response Building. The Emergency Response Building is located in Subarea I, which was released for unrestricted use in Amendment17, License Condition 29, issued April 23, 2001. This building was surveyed for unrestricted release. The building is currently being used as an office building for Trust personnel and contractors.

1.3.3 Decommissioning of Former Impoundments

Plutonium Waste Pond

This hypalon-lined evaporation pond was irregular in shape. In 1976, a system was installed to decant and filter water from the Plutonium Waste Pond to Uranium Pond #2. The water was pumped from the surface through the filtration system until approximately 70,000 gallons of water remained, which were not processed because the radionuclide concentration was greater than 0.1 times the maximum permissible contamination limit.

The remaining water contained radioactive particles in colloidal suspension. Treatment of the 70,000 gallons of water in the Plutonium Waste Pond involved decanting water, treating it with ferric sulfate and sodium hydroxide to precipitate an iron hydroxide flocculent, and discharging it to the Plutonium Emergency Pond. The water from the Plutonium Emergency Pond then was decanted to Uranium Pond #2. After all water from the Plutonium Emergency Pond was transferred to Uranium Pond #2, the ferric hydroxide ($Fe(OH)_3$) sludge was transferred to the Plutonium Waste Pond and solidified with concrete. A total of 491 drums of solidified waste containing less than 1 gram of plutonium (total) were shipped off the Site for disposal at a licensed LLRW disposal facility.

The Plutonium Waste Pond liner was surveyed for alpha contamination, rolled up, and left in place prior to backfilling. The liner was later removed in 1986 when the New Sanitary Lagoon was constructed.

The Plutonium Waste Pond is located in Subarea L, which was released for unrestricted use in Amendment 17, License Condition 29, issued April 9, 2001.

Plutonium Emergency Pond

This hypalon-lined evaporation pond was irregular in shape, with a capacity of approximately 250,000 gallons. In 1976, water from the Plutonium Emergency Pond was pumped to Uranium Pond #1 with no visible sludge remaining. The Plutonium Emergency Pond was left undisturbed until it was used for treatment of water from the Plutonium Waste Pond. Waste precipitate residue was removed from the Plutonium Emergency Pond and placed in the Plutonium Waste Pond.

The Plutonium Emergency Pond liner was surveyed for alpha contamination prior to being rolled up and left in place prior to backfilling. The Plutonium Emergency Pond is located in Subarea L, which was released for unrestricted use in Amendment 17, License Condition 29, issued April 9, 2001.

Uranium Emergency Pond

This unlined evaporation pond was irregular in shape, with a capacity of approximately 180,000 gallons. In 1976, water from the Uranium Emergency Pond was pumped to Uranium Pond #1, with no visible sludge remaining. After being pumped dry and characterized, the Uranium Emergency Pond was left undisturbed (no additional remediation was performed) until written approval was received from the NRC to backfill five ponds. The Uranium Emergency Pond is located in Subarea L, which was released for unrestricted use in Amendment 17, License Condition 29, issued April 9, 2001.

Uranium Pond #1

This asphalt pitch, felt and pea-gravel-lined evaporation pond was rectangular, with a capacity of approximately 1,150,000 gallons. Uranium Pond #1 was closed by crushing the asphalt liner into the pond. The underlying clay dike material and clean soil were used to fill in the depression (a depth of approximately 4 ft). This pond was backfilled in 1978 after confirmatory sampling by NRC.

The closure of Uranium Pond #1 began with the construction and installation of a dike across the south half of the pond. This enabled Waste Pond #1 to be consolidated into a much smaller area. Excess water was decanted to Uranium Pond #2. Sludge solidification consisted of mixing the sludge with approximately 15% cement. 865 drums of solidified waste containing 3,002 grams of U-235 were shipped from Uranium Pond #1 to a licensed LLRW disposal facility.

Uranium Pond #1 is located in Subarea O, which was released for unrestricted use in Amendment 16, License Condition 28, issued April 17, 2000.

Uranium Pond #2

Uranium Pond #2 had a compacted clay bottom liner with poly rubber sidewalls anchored at the bottom and top of the dike. The pond was rectangular, with a capacity of approximately 3,000,000 gallons. Sludge removal was not required because sludge had not been generated in this pond.

Uranium Pond #2 is located in Subarea O, which was released for unrestricted use in Amendment 16, License Condition 28, issued April 17, 2000.

East and West Sanitary Lagoons

These unlined ponds were rectangular in shape, and the capacity of each pond was approximately 500,000 gallons. The East and West Sanitary Lagoons received all liquid waste from the Uranium Plant from 1966 to 1970. In 1970, liquid waste from the Uranium Plant was diverted to other ponds located on the Site. From 1970 until 1985, the MOFF Plant septic tank, the Uranium Plant septic tank, the Uranium Plant laundry, the MOFF Plant lab, the Uranium Plant lab, the Uranium Plant dock drain, and numerous floor drains in the Uranium Plant discharged into the East and West Sanitary Lagoons.

In 1986, residual water in the East and West Sanitary Lagoons was pumped to the New Sanitary Lagoon. Initial soil removal and packaging of contaminated soil from the East Sanitary Lagoon was completed in 1986. Initial soil removal and packaging of contaminated soil from the West Sanitary Lagoon was completed in 1987. Approximately 55,000 ft^3 of waste were shipped off Site to a licensed LLRW disposal facility. Final clean-up and survey work was performed on both lagoons in 1990.

The East and West Sanitary Lagoons were located in Subarea H, which was released for unrestricted use in Amendment17, License Condition 29, issued April 23, 2001.

"New" Sanitary Lagoon

The hypalon-lined New Sanitary Lagoon was installed by January 1986. The New Sanitary Lagoon was located directly above the closed Plutonium Waste Pond and a portion of the closed Plutonium Emergency Pond. This lagoon replaced the East and West Sanitary Lagoons, which were being decommissioned. A French drain was installed under the New

Sanitary Lagoon prior to construction to divert groundwater that may collect under this area. All liquids from the East and West Sanitary Lagoons were pumped to the New Sanitary Lagoon prior to the start of remediation on the East and West Sanitary Lagoons. Wastewater from the ion exchange system and Uranium Building #1 drains was also released to the New Sanitary Lagoon. The New Sanitary Lagoon was utilized from early 1986 to October 1992.

The rainwater which collected in the lagoon was land applied in accordance with Oklahoma State Department of Health requirements. The sediments were then dewatered, sampled, and analyzed for total uranium. All sediment was removed. Material containing uranium within the BTP Option 2 concentration range was stockpiled east of Uranium Building #1 for future placement in the on-site BTP Option 2 Disposal Cell.

The liner surface was then surveyed in accordance with NUREG-5849. Any liner found to exceed free release criteria was either decontaminated or disposed in a licensed LLRW disposal facility. The liner was cut into sections for removal.

After removal of the liner, surface soil was surveyed at the surface and at 1 m with a micro-R meter. A 5 m x 5 m grid area was established, and any location yielding two times background was marked. At marked locations and grid intersects, soil samples 0 to 6 inches below grade were collected for analysis. Samples were analyzed for total uranium. Areas that yielded uranium at concentrations exceeding the BTP Option 1 limit (30 pCi/g above background) were further characterized by sampling at a greater density. Soil containing uranium at concentrations exceeding the BTP Option 1 limit were packaged and shipped to a licensed LLRW disposal facility.

The "New" Sanitary Lagoon was located in Subarea L, which was released for unrestricted use in Amendment17, License Condition 29, issued April 23, 2001.

1.3.4 Decommissioning of Former Pipelines

Figure 1-5 shows the locations of pipelines beneath and near the buildings. Figure 1-6 shows the locations of pipelines and spills site wide. Nearly all the pipelines indicated as "removed" on Figure 1-5 were excavated in 1985. Soil stockpiles containing uranium within the BTP Option 2 concentration range were located east of Uranium Building #1. Only those drain lines which were beneath Uranium Building #1 and extending east of Uranium Building #1 (beneath soil stockpiles) remained until 1997, when the last drain lines beneath the soil stockpile were removed as the soil was placed in the on-site BTP Option 2 Disposal Cell.

The process for removal and survey of drain lines was similar for all pipelines. Pipelines were removed by excavation of a trench following the pipeline. The trench was surveyed and sampled at 10-meter intervals. When scan readings indicated (or soil samples yielded) uranium concentrations exceeding the BTP Option 1 limit, additional measurements and samples were obtained between 10-m locations. Soil exceeding the BTP Option 1 limit was excavated and shipped to a licensed LLRW disposal facility. More detailed information on the decommissioning of each pipeline can be found in "*Radiological Characterization Report for Cimarron Corporation's Former Nuclear Fuel Fabrication Facility*" (Chase Environmental Group, 1994). The following describes the removal of pipelines and surveys of soil related to pipelines for which there was no evidence of leakage or release of licensed material. The removal, survey, and decommissioning of pipelines and releases from those pipelines is further discussed in Section 1.4, "Spills or Releases".

Drain Line from Uranium Pond #1 to the Cimarron River

This six-inch polyvinyl chloride (PVC) pipe was installed for liquid effluent discharges from Uranium Pond #1 to the Cimarron River. Records indicate that liquid was only discharged two times from Uranium Pond #1 to the Cimarron River. The drain line was excavated and removed in 1985. Surveys of the trench yielded no areas with elevated uranium concentrations. A soil sampling program was conducted at 10-meter intervals, collecting soil samples at 6-inch intervals for the first ft, and at 1-foot intervals to 4 ft in depth. No samples exceeded BTP Option 1 limits.

Drain Line from Uranium Pond #1 to Uranium Pond #2

This 4-in PVC drain line was used for transfer of liquid from Uranium Pond #1 to Uranium Pond #2. Transferred liquid involved only slightly contaminated water. Uranium Pond #2 was used for evaporation purposes only and did not discharge. This drain line was excavated and removed in 1985. A gamma survey was conducted after the pipe was removed, with measurements taken at the bottom, at the surface, and at 1 m above the surface of the excavated area. No contaminated soil was identified in the trench.

1.3.5 Decommissioning of Soil

Decommissioning of both soil and waste was based on criteria specified in the 1981 BTP, SECY 81-576, "Disposal or On Site Storage of Residual Thorium or Uranium (Either as Natural Ores or Without Daughters Present) From Past Operations". The BTP criteria were first formally introduced into the license when the on-site burial of up to 14,000 m^3 (500,000 ft^3) of material

within the BTP Option 2 concentration range was authorized in License Condition 23 of License Amendment 10. The use of the BTP Option 1 criteria as unrestricted release criteria was formally incorporated into the license in License Condition 27 when License Amendment 15 was issued July 29, 1999.

The Site was divided into 16 "Subareas", designated Subareas A through O (Subarea O is comprised of two areas which formerly contained two uranium waste ponds). Subareas A through E were considered unaffected areas and were designated "Phase I" areas. Subareas F through I contained both unaffected and affected areas and were designated "Phase II" areas. Subareas K through O contained affected areas and were designated "Phase III" areas. A total of three final status survey plans were submitted to NRC, one addressing each "Phase" of Subareas. Subareas I and K included former processing buildings, and final status surveys for these areas included surveys of the buildings in addition to surface and/or subsurface soil.

Phase I Areas

The October 24, 1994 *Final Status Survey Plan for Unaffected Areas* was a single final status survey plan for Subareas A through E. The August 9, 1995 *Final Status Survey Report, Phase I Areas* (Chase Environmental Group, 1995) presented the results of the final status survey for all five areas. A March 1998 *Confirmatory Survey of the Phase I Unaffected Areas* (Payne, 1998) concurred with the results of the final status survey. NRC released Subareas A through E from License SNM-928 in License Amendment 13, dated April 23, 1996.

Phase II Areas

The July 25, 1995 *Final Status Survey Plan for Phase II Areas* (Chase Environmental Group, 1995) was a single final status survey plan for Subareas F through J.

Final Status Survey Report for Phase II Subarea J (Nextep Environmental, 1997) was submitted September 9, 1997. NRC released Subarea J from License SNM-928 in License Amendment 16, dated April 17, 2000.

Final Status Survey Report for Subarea H (Nextep Environmental, 1998) was submitted November 16, 1998. *Final Status Survey Report, Subarea I* (Nextep Environmental, 1999) was submitted June 29, 1999. NRC released Subareas H and I from License SNM-928 in License Amendment 17, dated April 9, 2001.

Final Status Survey Report, Subarea G (Nextep Environmental, 1999) was submitted October 21, 1999. When license SNM-928 was transferred to the Trust, the February 16, 2011 license transfer order stated, "Final status surveys and confirmatory surveys have confirmed that Subareas G and N are releasable for unrestricted use, but NRC has determined that these areas should not be released until groundwater remediation is complete."

Decommissioning and Final Survey Report for Cimarron Facility Contaminated Waste Burial Ground (Cimarron Corporation, 1991), submitted November 25, 1991, presented final status survey results for the excavated burial trenches in Subarea F prior to their backfilling, which NRC approved in License Amendment 9, dated December 28, 1992. *Final Status Survey Report for Concrete Rubble in Sub-Area F* (Chase Environmental, 1998) presented final status survey results for concrete slabs which had been removed from buildings and structures in other areas and placed in Subarea F. *Final Status Survey Report for Concrete Rubble in Sub-Area F* (Chase Environmental Group, 1998) presented final status survey results for concrete slabs which had been removed from buildings and structures in other areas and placed in Subarea F. *Final Status Survey Report, Subarea F* (Nextep, 2005) was submitted September 5, 2005, with additional information provided in the November 20, 2007 *Burial Area #1 Subsurface Soil Assessment* (Cimarron Corporation, 2007). Oak Ridge Associated Universities (ORAU) issued a letter report on the analysis of seven confirmatory subsurface soil samples on March 6, 2013; all results were less than one-third of the criteria for unrestricted release. When license SNM-928 was transferred to the Trust, the February 16, 2011 license transfer order stated, "Because groundwater exceeds license criteria in Subarea F, this area cannot be released for unrestricted use until groundwater remediation is complete."

Phase III Areas

The June 24, 1997 *Final Status Survey Plan for Phase III Areas* (Chase Environmental Group, 1997) was a single final status survey plan for Subareas K through N. Two final status survey reports were submitted for Subarea O. *Final Status Survey Report for Phase III Subarea O Uranium Waste Ponds #1 and #2 (Subsurface)* (Nextep Environmental, 1998) was submitted March 12, 1998. *Final Status Survey Report, Subarea O (Surface)* (Nextep Environmental, 1999) was submitted February 9, 1999. NRC released the two Subarea O areas from License SNM-928 in License Amendment 16, dated April 17, 2000.

Two final status survey reports were submitted for Subarea L. *Final Status Survey Report for Subarea L (Subsurface)* (Nextep Environmental, 1996) was submitted May 29, 1996. *Final Status Survey Report for Subarea L* (Nextep Environmental, 1998) was submitted July 27, 1998.

Final Status Survey Report for Subarea M (Nextep Environmental, 1998) was submitted December 31, 1998. NRC released Subareas L and M from License SNM-928 in License Amendment 17, dated April 9, 2001.

Final Status Survey Report for Subarea K (Nextep Environmental, 2000) was submitted February 15, 2000. NRC released Subarea K from License SNM-928 in License Amendment 18, dated May 28, 2002.

Final Status Survey Report for Subarea N (Nextep Environmental, 2002) was submitted January 31, 2002. NRC performed an inspection/confirmatory survey for Subarea N. An inspection report dated September 18, 2002 stated, "These confirmatory measurements were consistent with the licensee's determination that Subarea N of the Site meets the criteria established in NRC License SNM-928, License Condition 27 for unrestricted use." When license SNM-928 was transferred to the Trust, the February 16, 2011 license transfer order stated, "Final status surveys and confirmatory surveys have confirmed that Subareas G and N are releasable for unrestricted use, but NRC has determined that these areas should not be released until groundwater remediation is complete."

Summary

As a result of all the above described final status surveys, confirmatory surveys, and license amendments, surface and subsurface soil has been demonstrated to comply with unrestricted release criteria in all Subareas. All Subareas except Subareas F, G, and N have been released for unrestricted use.

1.4 SPILLS OR RELEASES

Several types of spills or releases of licensed material occurred at the Site. Some subsurface drain lines, including pipelines carrying wastewater to ponds, leaked wastewater in quantities that were too small to be detected during operations, but which yielded elevated scan or soil sample results upon excavation and removal of the pipeline. Beneath Uranium Building #1, soil was found to be contaminated by leaking drain lines or by migration of licensed material through penetrations in the concrete floor, such as locations where cracks developed or where electrical conduit penetrated the

floor. Soil removal and disposal (based on the uranium activity of the soil) was required in these cases. Figure 1-6 shows the locations of pipeline leaks, spills, and releases which were identified during their excavation and removal.

Uranium Ponds #1 and #2 were primarily evaporative ponds, but wastewater seeped through the pond liners and impacted the groundwater underlying the ponds. Movement of groundwater has resulted in migration of uranium, nitrate, and fluoride beyond the footprint of the impoundments, extending into the Western Alluvial Area. The extent of contaminant migration is addressed in Section 3.

Burial of wastes containing licensed material in trenches in the three burial areas that were used during operations resulted in the leaching of uranium and/or nitrate and fluoride into groundwater. Movement of groundwater has resulted in migration of licensed material beyond the burial trenches. The extent of contaminant migration is addressed in Section 3.

Finally, contaminated equipment was stored outside in a storage yard located east of Uranium Building #1. A water supply well (Well 1319) had been drilled in the storage yard but had never been used to produce water for production operations. The well casing was cut off at grade but had not been securely covered. Rainwater rinsed some licensed material off of contaminated equipment, which then flowed down the well. This resulted in the contamination of groundwater in the Well 1319 Area. The extent of contaminant migration is addressed in Section 3.

1.4.1 Leaking Drain Lines Causing Soil Contamination

Main Drain Line from Uranium Building #1 to Uranium Pond #1

Except for portions of this line underlying Uranium Building #1 and the soil stockpiles, this four-inch PVC line was excavated and removed in 1985. The excavated trench was surveyed, and 150 drums of soil that exceeded the BTP Option 1 limit due to a leak located south and east of Uranium Pond #1 were packaged and shipped to a licensed LLRW disposal facility.

Liquid Waste Line from Uranium Building to Emergency Ponds

This four-inch PVC line was excavated and removed in 1985. Surveys of the trench yielded several areas with elevated uranium concentrations, which were removed and shipped to a licensed LLRW disposal facility.

Drain Line from Closed Sanitary Lagoons to Cimarron River

This four-inch steel drain line was used for liquid effluent discharges from the Sanitary Lagoons to the Cimarron River. The drain line was excavated and removed in 1985. Surveys of the trench yielded several areas with elevated uranium concentrations, which were removed and shipped to a licensed LLRW disposal facility.

Uranium Building #1 Drain Lines

For those drain lines that were under Uranium Building #1, it was not possible to distinguish between soil that had been impacted by releases from drain lines and soil that had been impacted by releases through penetrations in the floor (e.g., electrical conduit, floor joints, etc.). Drain lines under the laboratory were removed in 1990. Drain lines under the Wet Ceramic area were removed in 1990 and 1991. This area was included in a 1991 confirmatory survey performed by Oak Ridge Institute for Science and Education (ORISE) prior to backfilling (Landis, 1993). Drain lines under the Scrap Area Floor were removed in 1990 and 1991. This area was included in an ORISE confirmatory review. Drain lines along the North wall of the Uranium Building were removed in 1991. Drain lines east of Uranium Building #1 were excavated and removed in 1992. In all areas beneath the processing areas of Uranium Building #1, soil underlying the concrete slab was surveyed. Soil containing uranium within the BTP Option 2 concentration range was stockpiled east of Uranium Building #1 for future placement in the on-site BTP Option 2 Disposal Cell. Soil exceeding the BTP Option 2 limit was packaged and shipped to a licensed LLRW disposal facility.

Once the stockpiled soil had been placed in the on-site BTP Option 2 Disposal Cell, the pipeline under the stockpile was excavated and removed in 1997. Material containing uranium within the BTP Option 2 concentration range was transferred to the on-site BTP Option 2 Disposal Cell.

1.4.2 Leaking Drain Lines Causing Groundwater Contamination

Leaking wastewater from drain lines resulted in the contamination of groundwater in several areas. In the Western Alluvial Area, uranium activity exceeds the NRC Criterion, and uranium, nitrate, and fluoride all exceed their State criteria. A pipeline leak near Well 1350 resulted in a nitrate concentration below its State Criterion but above its MCL. A pipeline leak near Well 1355 resulted in a nitrate concentration below its State Criterion but above its MCL. West of the southern end of the 1206 drainage way, fluoride exceeds its State Criterion in Well 1348.

1.4.3 Groundwater Contamination from Leaking Ponds

Leaking wastewater from Uranium Pond #1 has resulted in both fluoride and nitrate exceeding their State Criteria, but uranium concentrations are below the MCL. Leaking wastewater from Uranium Pond #2 has resulted in both fluoride and nitrate exceeding their State Criteria, and while uranium concentrations are below the NRC Criterion, they exceed the MCL.

1.4.4 Groundwater Contamination from Buried Waste

Burial Area #1 – Leachate from Burial Area #1 has resulted in uranium concentrations exceeding the NRC Criterion, but nitrate and fluoride concentrations are below the State Criteria. Nitrate exceeds its MCL at two locations (1315R and 02W29). Both locations yield less than 15 mg/L nitrate.

Burial Area #2 – Leachate from Burial Area #2 has resulted in uranium concentrations that formerly exceeded the NRC Criterion, but uranium concentrations dropped below the NRC Criterion in 1999 and dropped below the State Criterion in 2016. Uranium, nitrate and fluoride concentrations are both below their MCL.

Burial Area #3 – Leachate from Burial Area #3 has resulted in uranium concentrations exceeding the NRC Criterion, and nitrate concentrations exceed the State Criterion. Fluoride concentrations have been below the MCL.

1.4.5 Rainwater Causing Contamination through Well 1319

Contaminated runoff from precipitation apparently flowed down the former uncapped water supply Well 1319. The potentiometric surface in this water well appears to have been in Sandstone B, because the uranium concentration previously exceeded the NRC Criterion only in Sandstone B (described in Section 2.5). Groundwater extraction reduced the uranium concentration to less than the NRC Criterion, but uranium and nitrate concentrations continue to exceed the State Criteria. Fluoride concentrations are below the MCL.

Figure 1-6 shows the locations of the sources of spills and releases. The extent of contaminant migration in groundwater is addressed in Section 3.

1.5 PRIOR ON-SITE BURIALS

During operating years, licensed material was disposed of in burial trenches in three locations, in accordance with subsequently-superseded 10 CFR 20.302. Some of the material in these trenches, while complying with 10 CFR 20.302, exceeded unrestricted release criteria later incorporated into

License SNM-928 and was removed. Soil containing low concentrations of licensed material has been buried on Site in a fourth area, as discussed in Section 1.5.4. The locations of all four burial areas are shown on Figure 1-3.

1.5.1 Burial Area #1

This burial area, constructed in 1965, was opened in 1966 for disposal of radioactive material, including thorium-contaminated waste from the Kerr-McGee Corporation's Cushing, OK facility. Burial Area #1 (BA1) was closed and capped in 1970. Records show that 1,303 kg of depleted uranium, 148 kg of enriched uranium, and 5,555 kg of natural thorium were buried in this area. An investigation was initiated in 1984. From 1986 through 1988, the trenches were excavated. Waste exceeding the BTP Option 2 limits was shipped for disposal at a licensed LLRW disposal facility. Waste shipment records indicate that approximately 65,000 ft^3 of waste were shipped for disposal. Approximately 16,000 ft^3 of contaminated soil within the BTP Option 2 concentration range were stockpiled east of Uranium Building #1 awaiting on-site disposal.

In 1988, ORAU performed a confirmatory survey for BA1 and found eight locations requiring further remediation. An additional 14,000 ft^3 of material were removed and stockpiled east of Uranium Building #1. Confirmatory soil sampling and surveys by ORAU were completed in December 1991, with a final report issued in July 1992. BA1 was released for backfilling with clean soil in Amendment #9, License Condition 22, issued December 28, 1992.

1.5.2 Burial Area #2

Burial Area #2 (BA2) was utilized in the 1970s for the disposal of industrial solid waste generated during processing operations. Analysis of soil samples collected in May 1990 determined that licensed material was present in this buried waste. Remediation of BA2 began in 1991.

Remediation involved the location and excavation of all material exceeding BTP Option 1 and Option 2 soils from BA2. Material containing licensed material in the BTP Option 2 concentration range was stockpiled east of Uranium Building #1 for future placement in the on-site BTP Option 2 Disposal Cell. Approximately 20,000 ft^3 of material exceeding the BTP Option 2 concentration range were packaged and shipped off the Site for disposal in a licensed LLRW disposal facility. Industrial waste was also packaged and shipped off the Site for disposal in a licensed LLRW waste disposal facility. Excavations were backfilled with soils from unaffected areas, which were sampled and analyzed after placement.

NRC staff supervised a confirmatory sub-surface sampling effort for BA2on October 30, 1996. Based upon the results of this confirmatory sampling effort, the NRC staff approved the backfilling of BA2. BA2 was backfilled with clean soil and final grading was completed in January 1997. BA2 was released for unrestricted use in Amendment17, License Condition 29, issued April 9, 2001.

1.5.3 Burial Area #3

This area was intended to be utilized for the disposal of non-radioactive solid waste materials. In 1990, soil sampling and gamma surveys indicated that radioactive materials were present in the buried waste. In-depth characterization completed in 1992 led to the removal of approximately 100 ft^3 of waste exceeding the BTP Option 2 concentration range. This waste was packaged and shipped to a licensed LLRW disposal facility.

Cimarron later excavated all non-native soil from the Burial Area #3 (BA3) trenches. All industrial solid waste and non-native soils were spread in lifts approximately 6 inches thick and were surveyed with both gamma scans and collection of soil samples. Material containing licensed material in the BTP Option 2 concentration range was stockpiled east of Uranium Building #1 for future placement in the on-site BTP Option 2 Disposal Cell. Material and/or soil exceeding the BTP Option 2 concentration range were packaged and shipped off-site for disposal in a licensed LLRW disposal facility. BA3 was released for unrestricted use in Amendment 17, License Condition 29, issued April 9, 2001.

1.5.4 Burial Area #4

Burial Area #4 (BA4) is an on-site disposal cell approved by NRC and DEQ for the on-site disposal of soil containing uranium in the BTP Option 2 concentration range. The lower bound of the BTP Option 2 concentration is 30 pCi/g total uranium. The upper bound varies from 100 pCi/g total uranium for soluble uranium to 250 pCi/g total uranium for insoluble uranium. Cimarron performed tests to evaluate lung solubility as well as tests to determine environmental leachability, including the EPA-approved Extraction Procedure for Toxicity and Toxicity Characteristic Leaching Procedure (TCLP), but was unable to obtain NRC approval for any calculated solubility. Consequently, Cimarron utilized the 100 pCi/g total uranium concentration as the upper bound for the BTP Option 2 concentration range, and shipped all soil exceeding 100 pCi/g total uranium off-site to a licensed disposal facility.

Soil containing uranium at concentrations between 30 pCi/g and 100 pCi/g total uranium was placed in four flat-topped stockpiles for final characterization. The North Stockpile (DAP-1) was located north of Uranium Building #1 and measured approximately 40 m by 25 m by 2 m thick. The East Stockpile (DAP-2) was located east of Uranium Building #1 and measured approximately 80 m by 30 m by 2 m thick. Stockpiles DAP-1 and DAP-2 were generated from soil generated during decommissioning activities prior to 1994. Stockpiles DAP-3 and DAP-4 were smaller stockpiles generated from 1994 through 1996.

For these four stockpiles, soil samples were collected for on-site analysis from borings drilled on a 5-m grid and sampled at 0.5-m depth intervals. Soil that exceeded the BTP Option 2 criterion was removed and shipped for off-site for disposal at a licensed disposal facility. For Stockpiles DAP-3 and DAP-4, hot-spot averaging criteria contained in NUREG/CR-5849 was applied to the stockpile characterization data.

The disposal cell consisted of three trenches, referred to as Pits #1, #2, and #3. Pit #1 was excavated in 1994 and measured approximately 50 ft by 425 ft at its base. Placement of BTP Option 2 material was completed in February 1995. Pit #2 was excavated in 1995 and measured approximately 60 ft by 470 ft at its base. Placement of BTP Option 2 material was completed in September 1996. Pit #3 was excavated in 1997 and measured approximately 60 ft by 470 ft at its base. Placement of Option #2 material was completed in July 2000. Soil from stockpiles was placed in Pits #1 and #2. Pit #3 was filled with soil excavated in the field as decommissioning operations in various areas were completed.

One-foot lift markers were placed at 50-ft intervals along the east and west walls of each excavated trench. One-foot lifts were placed in the trench, compacted, and measured to demonstrate compliance with compaction and moisture criteria. Characterization data from Stockpiles DAP-1 through DAP-4 were used to characterize the soil placed in Pits #1 and #2. As Pit #3 was filled with soil from various areas during the completion of soil and waste decommissioning, each 1-foot lift was sampled on a 5-m grid.

A total of approximately 452,000 ft^3 (16,740 cubic yards) of BTP Option 2 soil was placed in the disposal trenches. The average concentration of uranium in the three pits varies from 35.7 to 45.0 pCi/g total uranium. The total quantity of uranium in the soil placed in BA4 is approximately 0.98 Curies.

After placement of waste, Pits #1 and #2 were covered with at least 4 ft of cover soil. Due to excess capacity, Pit #3 was covered with approximately 6 ft of cover soil. All cover soil came from areas of the Site not affected by previous operations. Several inches of topsoil were placed over the entire area, which was then seeded with a winter seed mix. Concrete cairns were placed at the corners of the disposal cell. Each cairn contains a brass marker with the words "Radioactive Disposal Area", lines indicating the boundaries of the pits, and the northing and easting coordinates of the cairn.

A notice was placed in the deed in accordance with License Condition 23(b). The deed notice states that "... notice is hereby provided that uranium-contaminated soil has been buried at the following location: [legal description of the location of Burial Area #4] ... [coordinate location of Burial Area #4] ... The total volume of uranium-contaminated soil in the containment cell is 452,186 ft^3, and the total quantity of uranium is 0.98 Curies. Markers are placed at the containment site." License Condition 23(b) states, "This notification is not to be considered a restriction on the sale or future use of the site."

License Condition 23(b) also required periodic inspection of the disposal area for subsidence, erosion, and status of the vegetative cover for at least 5 years. Inspections were performed for over five years. To date, there is no evidence of erosion, and despite two years of intense drought (2011 and 2012), the vegetative cover over the disposal cell remains dense and healthy.

* * * * *

2.0 FACILITY DESCRIPTION

2.1 SITE LOCATION AND DESCRIPTION

The Site consists of approximately 503 acres of property located in Logan County, Oklahoma (Figure 1-1). Its actual acreage varies based on the location of the Cimarron River, which forms the northern property line. Prior to 2015, the Site included property located west of Highway 74, and occupied approximately 800 acres.

Approximately 117 acres west of the highway, and approximately 24 acres containing the former processing buildings were sold in 2015. Those two areas included portions of Subareas E, H, I, J, K, and L. The southwest quarter of Section 12, at the intersection of Highways 74 and 33, representing most of unimpacted Subarea A, was sold in 2017. The property on which the CERT office is located, containing slightly less than 1 acre in Subarea I, was sold in 2018. All of these Subareas had been released from License SNM-928 prior to their sale as described in Section 1. These properties are no longer owned by the licensee, and for the purposes of this Plan are no longer considered part of the Site.

In the sale of the 24-acre property, the Trust retained the environmental liability associated with groundwater which does not require remediation under License SNM-928, but which contains concentrations of nitrate exceeding State Criteria. The concentration of nitrate in groundwater exceeds State Criteria in areas that do not require groundwater remediation for decommissioning purposes. However, plans for reducing the concentration of nitrate in these areas are included herein to eliminate the duplication of effort that would be required to develop a separate groundwater remediation plan for only those areas.

The city of Cedar Valley extends to approximately ½ mile east of the Site. Cimarron City extends to the northern bank of the Cimarron River. Crescent, Oklahoma is located approximately 6 miles north of the Site. Guthrie, Oklahoma is located approximately 9 miles east of the Site. Edmond, Oklahoma extends to approximately 11 miles southeast of the Site, and Oklahoma City extends to approximately 14 miles south of the Site. Figure 1-1 shows the location of the Site relative to these cities. Figure 2-1 presents an aerial image of the Site, as well as the topographic contours of the property.

Figure 2-2 presents a topographic map of an area extending 2 miles around the Site, showing the locations of residences and other facilities, ponds, streams, lakes, the Cimarron River, water wells, oil and gas production wells, and injection wells associated with oil and gas production. The locations of residences and other facilities were obtained from GoogleEarth®. Table 2-1 lists all water wells

located within 2 miles of the Site (per the Oklahoma Water Resources Board water well registry as of December 31, 2017). Table 2-2 lists the locations of all oil and gas production wells and injection wells associated with oil and gas production (per the Oklahoma Corporation Commission Oil and Gas Well Data System as of December 31, 2017).

The Site consists of gently rolling hills, leading northward to the floodplain of the Cimarron River. Ground elevation varies from approximately 925 ft above mean sea level (amsl) at the northeastern property line to approximately 1,015 ft amsl near the southern property line. Two surface water reservoirs are present on the Site. Unnamed ephemeral streams feed these reservoirs, which discharge to the floodplain of the Cimarron River. The only structure remaining on the licensed Site is the current office building (formerly the Emergency Response Building). Figure 1-3 presents the Site and site features.

2.2 POPULATION DISTRIBUTION

The estimated population for Logan County, Oklahoma as of July 1, 2017 was 46,748. This represents a 12% increase since 2010. Guthrie, Oklahoma, located approximately 9 miles east of the Site, had an estimated July 1, 2017 population of 11,350; this represents an 11% growth since 2010. Edmond, Oklahoma, located approximately 11 miles southeast of the Site, had an estimated July 1, 2017 population of 91,950; this represents a 13% growth since 2010. Oklahoma City, Oklahoma, located approximately 14 miles south of the Site, had an estimated July 1, 2017 population of 643,648; this represents an 11% increase since 2010. Within Logan County, Cimarron City, which extends northward from the northern bank of the Cimarron River, had a 2010 population of 150; Crescent, Oklahoma, located approximately 6 miles north of the Site, had a 2010 population of 1,411. Population data for towns with a population below 5,000 is not routinely updated by the United States Census Bureau. Population data were taken from the website www.census.gov/2010census and www.census.gov/quickfacts.

2.3 CURRENT / FUTURE LAND USE

The property owned by the CERT currently lies fallow. Portions of the Site containing grasses that are beneficial for cattle feed are periodically mowed and baled. The bales are removed from the Site for use as cattle feed. Mowing of large portions of the Site is intended to minimize the fire hazard associated with tall prairie grass as well as to maintain access to groundwater monitor wells. An office building (not continuously occupied) is maintained for periodic use by personnel when at the Site.

The area surrounding the Site is primarily used for farming and ranching. The 24-acre property near the office building and the southwest quarter of Section 12 are being developed for manufacturing and warehousing. A small commercial development with a service station/convenience store, a building housing several shops, a storage facility, a realtor's office, a storage facility, and an oil and gas production facility are located near the intersection of Highways 33 and 74. A golf course is located within one mile of the southeastern corner of the Site. Less than 100 people live within one mile of the Site. Figure 2-2 presents a topographic map of an area extending 2 miles around the Site, showing the locations of residences, other facilities, ponds, streams, lakes, the Cimarron River, and off-site water wells. Table 2-1 lists water wells located within 2 miles of the Site.

2.4 METEOROLOGY AND CLIMATOLOGY

Adams and Bergman (1995) summarized the precipitation for the Cimarron River from Freedom to Guthrie, Oklahoma. Their study showed that precipitation ranges from an average of 24 inches per year (in/yr) near Freedom, Oklahoma, in the northwest part of the Cimarron River floodplain in Oklahoma, to 32–42 in/yr at Guthrie, Oklahoma. Wet years between 1950 and 1991 were in 1973–1975, 1985–1987, and 1990–1991. The wettest months are May through September, while the winter months are generally the dry months. The period from 1973 to 1975 was 23 inches above the normal total for the three-year period (Carr and Marcher, 1977).

Precipitation data collected by the National Oceanic and Atmospheric Administration (NOAA) for Guthrie in Logan County, Oklahoma, and used to calculate the 1981 to 2010 "Climate Normals" indicates that the annual average precipitation is 38.38 inches. The minimum monthly average precipitation is 1.43 inches (January) and the maximum monthly average is 5.38 inches (June). The 1981–2010 Climate Normals are NOAA National Centers for Environmental Information's latest three-decade averages of climatological variables. NOAA's computation of Climate Normals is in accordance with the recommendation of the World Meteorological Organization, of which the United States is a member. While the WMO mandates each member nation to compute 30-year averages of meteorological quantities at least every 30 years, the WMO recommends a decadal update, in part to incorporate newer weather stations. NOAA's next update to the Climate Normals will be for the data set of 1991 through 2020. (NOAA, 2018)

2.5 GEOLOGY AND SEISMOLOGY

The following two sections describe the regional and Site-specific geology. These two sections contain information summarized from *Conceptual Site Model (Revision – 01), Cimarron Site,*

Crescent, Oklahoma (ENSR Corporation, 2006). More detailed descriptions of the geology and hydrogeology of localized areas of interest are provided in Section 2.7, "Groundwater Hydrology".

2.5.1 Regional Geology

The bedrock geology of Logan County is dominated by Permian-age clastic sedimentary rocks of the Garber-Wellington Formation as shown in Figure 2-3. These units dip to the west at 30 to 40 ft per mile. The Permian-age Garber Sandstone and underlying Wellington Formation, which comprise the Garber-Wellington Formation, include lenticular channel and sheet-flood sandstones interbedded with shales and mudstones. The combined thickness of the Garber Sandstone and the Wellington Formation is about 1,000 ft. Because the two formations are difficult to distinguish in drill core and in outcrop and have similar water bearing properties, they are often treated as a single mappable formation and grouped into a single hydrostratigrahic unit, the Garber-Wellington Aquifer (Wood and Burton, 1968).

Structurally, the Cimarron area is part of the Nemaha Uplift of Central Oklahoma. The Nemaha Uplift trends northward across Oklahoma and was formed during a period of uplift, faulting, and erosion that occurred between the Mississippian and Pennsylvanian Periods in the Oklahoma area. The Nemaha Uplift consists of north-northwest trending normal faults and anticlinal structures that influenced early Pennsylvanian-age sedimentation in the Oklahoma region. By middle Pennsylvanian time, the Nemaha Uplift was not active. During the Permian, when the Garber-Wellington Formation was deposited, Central Oklahoma was part of the eastern shelf of a shallow marine sea. The sandstones and shales of the Garber-Wellington Formation were deposited as part of a westward-advancing marine delta fed by numerous streams flowing to the west and northwest. Thus, the sands of the Garber-Wellington Formation are often sinuous and discontinuous, and exhibit the rapid facies changes typical of a deltaic channel and overbank depositional system. Sand accounts for 35% to 75% of the Garber-Wellington Formation (Carr and Marcher, 1977).

There is no evidence of subsidence, karst terrain, or landsliding within several miles of the Site. Bank erosion is present along streams and the Cimarron River. Floodplain and upland erosion rates are typically insignificant due the heavy vegetation throughout the area, although agricultural fields are subject to sediment erosion during heavy precipitation events.

There are no man-made geologic features such as mines and quarries within several miles of the Site.

2.5.2 Site Geology

The stratigraphy of the Site is dominated by the Garber-Wellington Formation. The Garber Formation is exposed along the escarpment that borders the Cimarron River. The Wellington Formation is not exposed within the project area. The deeper stratigraphic units in the area were penetrated by a proposed deep disposal well that was completed in 1969. This well is the deepest borehole known to have been drilled in the immediate vicinity of the site. The deep well is on Cimarron facility property near the uranium plant. The depth of the well is 2078 ft. The top of the unit immediately underlying the Garber, the Wellington formation, was identified at 200 ft below the ground surface. The Wellington consists of 960 ft of red shale with several thin siltstone beds. The top of the Wolfcampian age Stratford formation was found at 1160 ft. It is 870 ft thick and consists of red and gray shale with thin anhydrite beds in the upper part (Grant, 1989).

Within the Site, the Garber Formation consists primarily of sandstone layers separated by relatively continuous siltstone and mudstone layers. The sandstone units frequently have interbedded, but discontinuous, red-brown shale and mudstone lenses. Lateral facies changes are common in the sandstones and represent shifting channel locations in the Garber delta. The Garber sandstones can be divided into three basic sandstone units separated by two relatively continuous and identifiable mudstone layers, as follows:

- Sandstone A is the uppermost sandstone unit, generally red-brown to tan in color and up to 35 ft in thickness. The bottom of this sandstone unit occurs at an elevation of approximately 950–970 ft amsl. To the south, there is a zone of perched groundwater. Monitor wells installed in the perched zone exhibit a higher groundwater elevation than wells installed in the lower portion of Sandstone A. This is evident in the paired "CDW" wells. Monitoring Well 1353 is screened in a perched zone.
- Mudstone A is a red-brown to orange-brown, sometimes tan mudstone and claystone that separates Sandstones A and B. It ranges from 6 to 20 ft thick.
- Sandstone B is the second sandstone unit, underlying Mudstone A, and similar in color and sedimentary features to Sandstone A. It is found at elevations between 925 and 955 ft amsl and is up to 30 ft thick.
- Mudstone B consists of mudstone and claystone separating Sandstone B and Sandstone C. It is similar in color to Mudstone A and ranges from 6 to 14 ft thick.

- Sandstone C is the lowermost sandstone in the Garber-Wellington Formation, similar in color and sedimentary features to the overlying sandstones. This unit varies in thickness from 10 to 25 ft at the Site to at least 100 ft thick regionally.

Figure 2-4 presents a lithologic column describing these three zones, based on the boring logs for Monitor wells 1311 and 1321. The three sandstone members of the Garber Formation at the Site are similar in lithology. They are fine to very fine-grained red-brown to tan sandstones with well-sorted sub-angular to rounded grains and contain variable amounts of silt. The silt content ranges from 10% to 50% and the sandstones with high silt content are difficult to distinguish from siltstone. The sand grains are mostly quartz with minor amounts of feldspar and occasional magnetite and mica. The inter-granular porosity varies with the silt content. The sandstones are weakly cemented and often friable. Cementing agents are calcite and hematite. Locally, thin intervals can be found that are well cemented with gypsum and barite. These intervals are often conglomeratic. The sandstones exhibit planar cross-stratification with thin, silty laminae. Conglomeratic intervals are common in most of the borings and they are observed to contain clasts of mudstone and occasionally sandstone in either a sandstone or mudstone matrix. These conglomeratic zones are up to 2.5 ft thick. Vugs found in these conglomerate zones are lined with calcite, gypsum, and barite. The sandstones of the Garber Formation were deposited in a fluvial deltaic environment, probably as channel sands.

The mudstone layers that separate the sandstones in the Garber Formation at the Site are mostly fine-grained, silty to shaley beds with a red-brown to orange-brown and tan color. The mudstones occasionally exhibit desiccation cracks. The mudstones are poorly consolidated. The mudstone layers are often encapsulated by thin, bluish-gray laminae that range in thickness from 0.1 to 4.0 inches. These "reduction zones" are common in red beds; at the Site the thickness of these reduction zones is approximately proportional to the thickness of the mudstone layer. These continuous mudstone layers probably represent deltaic overbank deposits formed during flooding of the Garber delta.

A mineralogical analysis of the sandstones and mudstones of the Garber Formation was conducted by Auburn University using X-ray diffraction, grain-size determinations, and cation exchange capacity measurements. Quartz and feldspar were found to be the main clastic grains with kaolinite and montmorillonite as the clays in the fine-grained fractions. Illite, smectite, chlorite, hematite, and goethite were also among the minerals detected in the clay fractions according to United States Geological Survey (USGS). Calcite, iron oxides, and iron hydroxides

were identified as the main cementing agents. The clay fraction ranged from 6% to about 20% in the sandstones and from about 14% to 50% in the mudstones. The mudstones had a cation exchange capacity in the range of 6 to 22 milliequivalent (mEq)/100 grams. The sandstones had a cation exchange capacity generally below 6 mEq/100 grams. Exchangeable cations were generally calcium and magnesium for both the sandstones and the mudstones. Within the "reduction zones," minerals formed with metals in low oxidation states, including uranium, were identified.

The Cimarron River floodplain alluvium consists of sand and silt, developed by the erosion of the Garber Formation from the escarpment bordering the river on the south, as well as material transported to the floodplain from upstream within the river system. This alluvium formed gradually over time and contains many buried channels reflective of both transport of the alluvial materials northward toward the river from the escarpment and meandering of the main river channel. Near the present river channel, buried oxbow meanders can be expected. Near the escarpment, buried channels would be expected to be the continuation of present drainages incised into the escarpment sandstones. The alluvium is about 30 to 40 ft thick. Along the present escarpment face, there are local transition zones from the sandstones of the Garber Formation to the coarser alluvial materials. These transition zones can be clay-rich, as is the case with the transitional zone identified with borings in BA1.

At the Site, upland areas are underlain by the sandstones and mudstones of the Garber Formation, which rolling hills on either side of ephemeral streams. Two ponds created by earthen dams constructed in the1960s contain water year-round, but the ephemeral streams which supply water to the ponds are dry in the hot, dry summers, and the water level in the ponds typically lowers during the summer.

The upland areas terminate where the floodplain of the Cimarron River exists. The river has carved a floodplain nearly one-half mile wide at the Site. The erosional escarpment is evident in the Western half of the Site and rises over 30 ft above the floodplain in areas. To the east, the escarpment is present only as a shallow slope.

2.5.3 Seismology

Seismic History

In 1976, the NRC initiated several cooperative programs with state geological surveys to study areas of anomalously high seismicity east of the Rocky Mountains. The Oklahoma

Geological Survey (OGS) participated in one of these surveys. A summary report on this study is documented in an OGS Special Publication entitled *Seismicity and Tectonic Relationships of the Nemaha Uplift and Midcontinent Geophysical Anomaly* (OGS, 1983). This summary report was also published by NRC in 1983 as NUREG/CR-3117.

The Nemaha Ridge lies within one of the areas addressed in that report, having a "moderately high" seismic risk classification. The Nemaha Uplift, approximately 415 miles long, extends from Oklahoma to Nebraska. Figures 2-5 and 2-6 show the location of the Nemaha Ridge, which represents the crest of the Nemaha Uplift. OGS compiled data from over 20,000 wells to construct structure-contour maps, from which the following conclusions were drawn.

The OGS structure-contour maps reveal a complex fault pattern associated with the Nemaha Uplift. This fault pattern is dominated by several discontinuous uplifts. These features form a fault zone that extends from Oklahoma City in a northwesterly direction. Near the Kingfisher-Garfield County line, the orientation of the fault zone becomes north-northeast and extends northward through Kansas and terminates in southeastern Nebraska. The southern end of the Nemaha Ridge is believed to be the Oklahoma City Uplift and its associated faults. Another fault zone, the McClain County Fault zone, intersects the Oklahoma City Uplift in southern Oklahoma County. This fault zone, which is composed of a number of sub-parallel faults and is thought to be temporally related to the Nemaha faults, trends south-southwest and terminates against the Paul's Valley Uplift in Garvin and southern McClain Counties (OGS, 1983, p. 14-15).

In 2016, the OGS released the Open-File Report OF2-2016 *Comprehensive Fault Database and Interpretive Fault Map of Oklahoma* (Marsh and Holland, 2016), presenting an interpreted fault map compiled from oil and gas industry data and published literature. The interpreted fault map was compiled from the Oklahoma Fault Database, an ongoing database for fault information within the State of Oklahoma. Figure 2-5 includes the portion of the map within a 20-mile radius of the Facility. Figure 2-6 includes the portion of the map within a 200-mile radius of the Facility.

Table 2-3 presents a list of all recorded historical earthquakes having a magnitude of at least 3.0 within 200 miles of the Facility as of August 31, 2018, as listed in the USGS Earthquake Hazards Program database (https://earthquake.usgs.gov/earthquakes - USGS, 2018). Figure 2-7 provides evidence of the recent increase and more recent decrease in low-magnitude

seismic activity. From 1974 through 2008, 120 earthquakes with a magnitude of at least 3.0 were recorded. Of those, 10 had a magnitude between 4.0 and 4.5 (maximum magnitude). 2,929 earthquakes with a magnitude of at least 3.0 were recorded from 2009 through 2018. Of those, 92 had a magnitude between 4.0 and 5.0, and 3 earthquakes had magnitudes between 5.0 and 5.8 (maximum).

Researchers largely agree that the increase in seismic activity within this area is due to injection of wastewater from oil and gas production activities into the Arbuckle formation. The Oklahoma Corporation Commission's Oil and Gas Conservation Division initiated action to limit the injection of wastewater into the Arbuckle in September 2013. The Oklahoma Corporation Commission established a 15,000-square mile Area of Interest (inclusive of the Facility) where regular reporting of disposal volumes was required. Total injection volumes were reduced within the Area of Interest through directives to reduce injection volumes or to shut down disposal wells.

As shown on Figure 2-7, seismic activities within a 200-mile radius of the Facility have been decreasing since the high of 2015. The OGS stated in a March 2017 Statement, "The seismicity rate has declined as injection activity has declined throughout the state, due to both Oklahoma Corporation Commission directives to curtail wastewater injection rates during 2015 and 2016 and market forces. Broad reductions implemented by the Oklahoma Corporation Commission on February 24, 2017, should result in further declines in the seismicity rate and limit future widespread seismic activity like the state experienced in 2015 and 2016." (OGS, 2017)

Reported Damage to Pipelines

Beginning in 2011, increased seismic activity in Oklahoma was observed. An investigation of the potential impact of earthquakes on pipelines in Oklahoma was conducted for the time period January 1, 2011 through August 31, 2018. The Pipeline and Hazardous Materials Safety Administration (PHMSA), a division of the United States Department of Transportation (DOT) maintains records of releases of hazardous liquids including crude oil, carbon dioxide, flammable or toxic fluids, and refined petroleum products; natural gas; and liquefied natural gas. The PHMSA databases of pipeline release information is located at www.phmsa.dot/gov.

179 crude oil releases and 13 natural gas releases were reported to have occurred in Oklahoma during that time period. No liquefied natural gas releases were reported in Oklahoma. Of the 179 crude oil releases reported, all but four were due to corrosion, damage from excavation, operational failure, equipment failure or outside influences such as rifle fire or automobile accidents. Of the four releases reported due to "Natural Force Damage", one was attributed to high winds and three to temperature extremes. Of the thirteen natural gas releases only one was attributed to "Natural Force Damage" and was caused by a lightning strike.

Damage was reported to buildings approximately 30 miles from the site due to a magnitude 5.8 earthquake near Cushing, Oklahoma in September 2016.

Seismic Design Considerations

Due to the inherent ability of buried piping systems to resist lateral movements and absorb deflection, and the flexible nature of the proposed piping materials (high-density polyethylene [HDPE] and PVC), seismic activity is not expected to generate unacceptable stresses or moments within the buried piping network or at connection points above the ground surface. The buried piping network was evaluated for locations potentially susceptible to damage resulting from the following seismic conditions:

- Surface fault ruptures
- Strong ground motion/shaking
- Soil liquefaction
- Landslides
- Earthquake inducted settlement

The results of the analysis indicated satisfactory buried pipe performance for each of the seismic conditions listed above. However, conservative mitigation measures such buoyancy control, flexible connection fittings, stress loops, etc. will be incorporated into the design. Details regarding seismic analysis methods, assumptions, and results are presented in the *Preliminary Seismic Analysis of Buried HDPE Piping Report* (Burns & McDonnell, 2018). This report can be provided upon request.

Above-ground piping systems not properly designed for site seismic conditions have the potential for fluid loss through differential movement of the pipe. Above-ground piping systems were designed with supports and expansion features to allow movement that results

from seismic events. Design aspects include use of supports that restrict movement, such that piping assemblies move as a unit, not as discrete components. Expansion features include the use of hoses at locations such as connections to tanks and at the entrance to the facility. The use of hose provides for differential movement of the pipe relative to what it is connected to.

A geotechnical investigation was conducted in the area within which the Western Area Treatment facility will be constructed. Like the buried piping assessment provided above, the geotechnical report included specifications to address seismicity. Specifically, the following seismic conditions:

- Surface fault ruptures
- Strong ground motion/shaking
- Soil liquefaction
- Landslides
- Earthquake inducted settlement
- USGS one-year hazard forecast

The results of the analysis indicated relatively low likelihood of the seismic conditions listed above occurring in the vicinity of the Site. However, the potential ground motion data obtained during this evaluation were considered in the design of the treatment facility building, the nitrate treatment system foundations, and influent and effluent tank foundations. Details regarding seismic analysis methods, assumptions, and results are presented in the Terracon Consultants, Inc.'s *Geotechnical Engineering Report* included as Appendix A.

2.6 SURFACE WATER HYDROLOGY

2.6.1 Cimarron River

The Cimarron River is a perennial, gaining river over its entire course from Freedom (west of the Site) to Guthrie, Oklahoma (east of the Site). Base flow from the alluvial and terrace aquifers and from the Permian sandstone units that border the river is highest in the winter months due to the higher water tables in these aquifers, which result from decreased evapotranspiration. Base flow is lowest from late summer through early winter because water tables are at their low point during that time. Because the Cimarron River is fed mainly by base flow from groundwater aquifers, flow in the Cimarron River parallels this seasonal fluctuation in groundwater levels. River flow has not been directly measured at the Site because there are no stream gages within the Site

boundary. Adams and Bergman (1995) reported a low-water median flow rate of approximately 100 cubic feet per second (cfs) and a high-water median flow rate of 600 cfs. From 1990 to 2017, the Guthrie gage, located approximately 10 miles east of the Site, recorded from 287.1 to 3,695 cfs average annual flow rates (USGS water data website).

Flood statistics for the Cimarron River have been compiled by the USGS (Tortorelli and McCabe, 2001). Peak flow ranges from a 2-year flood with a discharge of 26,700 cfs to a 500-yr flood with a discharge of 237,000 cfs. Floods most typically occur in this area in May-June or October, largely as a function of heavy rainfall in upstream portions of the watershed. The most recent significant flood was 20 years ago in 1986. The extent of flooding for the 100-year flood includes the entire alluvial valley, but not the upland areas of the Site.

2.6.2 Other Surface Water Features

Surface water features at the Site and in the surrounding area are shown in Figure 2-8. Cottonwood Creek is located about seven miles south of the Site and flows northeast through Guthrie. Cottonwood Creek, like the Cimarron River, is a gaining stream and drains southern Logan and northern Oklahoma counties. On the north side of the Cimarron River, across from the Site, springs can be found at Indian Springs and small lakes are present at Crescent Springs. On the south side of the Cimarron River near the Site, Gar Creek to the east and Cox Creek to the west are named drainages that receive most of their flow from groundwater base flow. Most drainages within and near the Site are ephemeral in nature and flow only in response to heavy rainfall or from groundwater base flow when groundwater levels are relatively high (Grant, 1989).

Within the Site, two unnamed drainages have been dammed to form small ponds, referred to as the East and West Pond, as shown in Figure 2-8. Both ponds maintain a pool elevation of approximately 960 ft amsl. The maximum pool elevation in the East Pond is controlled by a spillway. When the East Pond pool elevation exceeds the elevation of the spillways (typically following heavy rainfall), water flows over the top of the spillway into the drainage below. The maximum pool elevation in the West Pond is controlled by two 30-inch corrugated steel culverts. The pool elevation of both ponds is above the groundwater elevation in Sandstone B, and Sandstone A does not extend beneath the ponds. Both ponds represent recharge sources for groundwater in Sandstone B. The pond evaporation rate in this part of central Oklahoma is approximately 60 in/yr (Grant, 1989).

2.7 GROUNDWATER HYDROLOGY

Groundwater in the Permian-age Garber Formation is found in the Garber Sandstones and the underlying Wellington Formation in the Site area. Shallow groundwater, defined by Carr and Marcher (1977) as groundwater at depths of 200 ft or less, is generally fresh and mostly unconfined. Groundwater deeper than 200 ft can be artesian to semi-artesian. The base of fresh groundwater at the Site is at approximately 950 ft amsl and the thickness of the fresh water zones has been estimated at 150 ft (Carr and Marcher, 1977). Data from the Site shows that groundwater in Sandstone C, which is generally more saline than groundwater in Sandstones A and B, is usually at an elevation around 900 to 920 ft amsl. Thus, at the Site, the bottom of fresh water is somewhat lower than estimated by Carr and Marcher (1977) for this part of the Garber Formation and, conversely, the thickness of the fresh water zone is somewhat greater. Following Carr and Marcher (1977), the groundwater in Sandstone C at the Site, therefore, represents the top of the saline groundwater zone in the Garber Formation.

Recharge to shallow groundwater in the Permian-age Garber Formation near the Site has been estimated at 190 acre-feet per square mile, or about 10% of annual precipitation (Carr and Marcher, 1977). Adams and Bergman (1995) estimate a similar recharge of 8% of annual precipitation. A regional groundwater high is located south of the Site between the Cimarron River and Cottonwood Creek (Carr and Marcher, 1977). The maximum groundwater elevation on this high is around 1,050 ft amsl. Groundwater flows north toward the Cimarron River from this location.

The regional northward gradient from the groundwater high to the Cimarron River in the shallow sandstone unit is approximately 0.0021 ft/ft. The gradient to the south to Cottonwood Creek is 0.0067 ft/ft. This groundwater high and the uplands at the Site are within a major recharge area for the Garber Formation.

This suggests that vertical groundwater flow in the area of recharge between Cottonwood Creek and the Cimarron River is downward. At the Cimarron River, regional groundwater flow in the fresh water zone of the Garber Formation is vertically upward to allow for discharge to the river, which acts as a groundwater drain in this part of central Oklahoma (Carr and Marcher, 1977). The nature of vertical groundwater flow in the saline water zone of the Garber Formation at the Cimarron River is uncertain.

In summary, the Site is underlain by the Garber-Wellington Aquifer of Central Oklahoma. At the site, the Garber Formation can be divided into three separate water-bearing zones that parallel the

geological division of the formation into Sandstones A, B, and C. The uppermost water-bearing zone in the Garber Formation is generally unconfined, although it can be locally semi-confined by mudstone and shale units. The two lower units in Sandstones B and C are confined to semi-confined, depending on the thickness and continuity of the overlying mudstone unit.

Groundwater flow in the uppermost water-bearing unit is local in nature and flows from topographic highs, which also act as recharge areas, to topographic low areas such as the drainages. In the western portions of upland areas, groundwater in Sandstone A discharges through groundwater seeps into the escarpment that borders the Cimarron River floodplain. In the northeastern portion of the upland area (BA1), groundwater in Sandstone B flows eastward to the drainage, and northward to the alluvial and transition zone sediments. In the deeper bedrock units, groundwater flow is regionally controlled, with flow predominantly to the north towards the Cimarron River, with a component of upward flow as it ultimately discharges to the River.

The Site is within a recharge area for the upper fresh water zone of the Garber-Wellington Formation. Thus, vertical hydraulic gradients are generally downward, except at major discharge areas such as the Cimarron River. However, the low permeability of the mudstone units results in flow predominantly horizontal in the water-bearing units, with a minor component of flow vertically across units. The Cimarron River is a gaining river and thus receives groundwater from its floodplain alluvium.

2.7.1 Saturated Zones

Groundwater occurs in both consolidated (Garber-Wellington Formation) and unconsolidated Quaternary (colluvium, terrace, and alluvium) deposits at the Site. Geologically, the Garber Formation Sandstones at the Site have been divided into Sandstones A, B, and C. The Garber and Wellington Formations have been grouped into the Garber-Wellington Formation by Carr and Marcher (1977). At the Site, the Garber-Wellington Formation can be further divided into water-bearing units because the mudstone layers that separate the three main sandstone units of the Garber Formation at the site act as semi-confining units. In the upper 200 ft at the Site, there are thus four main water-bearing units as follows:

- Sandstone A
- Sandstone B
- Sandstone C
- Cimarron River Alluvium and Terrace Deposits

2.7.2 Monitor wells

There are 239 monitor wells at the Site, including those located on the 24-acre property for which the Trust retains responsibility for groundwater remediation. Tables 2-4 through 2-9 provide a listing of all monitor wells present at the site, with selected installation and location information for each well.

2.7.3 Physical Parameters

Each of the water-bearing units at the Site has its own specific flow patterns and hydraulic properties.

For Sandstone A, slug tests completed by J.L. Grant and Associates (Grant, 1989) yielded a geometric mean hydraulic conductivity of 1.03×10^{-3} centimeters per second (cm/s) with a range from 2.41×10^{-4} cm/s to 5.7×10^{-3} cm/s. The geometric mean for transmissivity was 33.4 square feet/day (ft^2/d) with a range from 10.3 ft^2/d to 108 ft^2/d. For Sandstone C, the geometric mean hydraulic conductivity was 7.85×10^{-5} cm/s.

Aquifer tests in BA1 included slug tests on many of the monitor wells and two pumping tests. For Sandstone B, hydraulic conductivity estimates ranged from 9.97×10^{-4} cm/s to 2.39×10^{-5} cm/s. For the alluvial sediments of the Cimarron River floodplain, hydraulic conductivity estimates varied from values in the 10^{-2} cm/s to 10^{-3} cm/s range for the coarser sediments (sandy alluvium) to values in the range of 10^{-3} to 10^{-5} cm/s for sediments high in clays and silts (transitional zone). Because the alluvial sediments have higher clay and silt content near the escarpment where Sandstone B is exposed, the slug tests in the alluvial sediments gave lower hydraulic conductivities nearer the escarpment.

In 2014, pneumatic slug tests were performed in select monitor wells in the western portion of the floodplain alluvium. A pumping test was conducted at GE-WA-01. Hydraulic conductivity values were calculated to range from 10^{-1} cm/s to 10^{-4} cm/s.

2.7.4 Groundwater Flow Directions and Velocities

The general groundwater flow direction at the Site is northward from the groundwater high south of the Site toward the Cimarron River. Within the Site, groundwater flow directions vary locally depending on depth within the Garber Formation.

Figures 2-9, 2-10, and 2-11 present potentiometric surface maps for the Site.

In those areas where Sandstone A is the uppermost water-bearing unit, the hydraulic gradient in Sandstone A mimics the local overlying topography. Groundwater in Sandstone A flows from the topographically higher areas to adjacent drainages and reflects local recharge from precipitation events. That is, the hydraulic gradients in Sandstone A are northwards towards the escarpment, with components of flow to the east and/or west towards the drainages in the vicinity. This same pattern is observed in water levels in Sandstone B where it is the uppermost water-bearing unit (in BA1).

Flow in deeper Sandstones B and C is more regionally influenced. Generally, flow in Sandstones B and C is north to northwest toward the Cimarron River. Flow in the alluvium is generally northward toward the Cimarron River because the river is a gaining stream from Freedom to Guthrie.

Locally, groundwater flow directions are impacted by local geologic features. Based on the interpretation of subsurface data, a partially hydraulically connected series of sandy lenses in transition zone silts and clays in BA1 may provide a preferential pathway for groundwater flow. The presence of mudstones between sandstone units minimizes flow between the units. Similarly, intermittent layers of silts and clays in the sandy alluvial materials may influence groundwater flow.

In addition to the horizontal groundwater flow, vertical components of hydraulic gradient depend on localized groundwater recharge-discharge relationships. In the uplands and generally to the south, the vertical component of the gradient may be downward, as this is an area of groundwater recharge. In the alluvium and near the Cimarron River, vertical gradients are upward, reflecting groundwater discharge to the River.

Because groundwater flow varies locally across the Site, a discussion of groundwater flow for specific areas of interest is presented in this section.

Burial Area #1

Groundwater in the vicinity of BA1 (Figure 2-9) originates as precipitation that infiltrates into the shallow groundwater unit recharge zone in the area of the former disposal trenches and Sandstone B. Groundwater also enters Sandstone B from upgradient, driven by a relatively steep hydraulic gradient (0.10 ft/ft).

Groundwater in Sandstone B flows across a buried escarpment (the interface between Sandstone B and the floodplain alluvium) into a former drainage channel filled primarily with silts and clays (a transition zone). Groundwater appears to preferentially flow through the transition zone material via a series of sandy lenses, discharging into the more permeable sands of the floodplain alluvium. Once groundwater enters the Transition Zone of the floodplain alluvium, the hydraulic gradient decreases to around 0.023 ft/ft and flow is refracted to a more northwesterly direction. The decrease in hydraulic gradient is due in part to the much higher overall hydraulic conductivity in the floodplain alluvium compared to Sandstone B and lower permeability material in the Transition Zone (10^{-1} cm/s to 10^{-4} cm/s versus 10^{-4} cm/s to 10^{-5} cm/s in Sandstone B).

Once groundwater passes through the Transition Zone, it enters the sandy alluvial material where the hydraulic gradient is very flat (0.0007 ft/ft). The decrease in gradient is caused by the higher permeability of the sandy alluvium. Groundwater flow in the alluvium is northward, with discharge ultimately to the Cimarron River. In the alluvium, there is expected to be upward flow from the underlying bedrock as groundwater in the bedrock is discharging to the River.

The elevation of Reservoir #2 is above the groundwater in BA1. Any potential hydrologic effect that the reservoir has on groundwater is reflected in the measured groundwater levels. It is unlikely that fluctuations in the level of the reservoir would affect groundwater flow.

Groundwater velocities in BA1 can be estimated based on measured hydraulic gradients and estimated hydraulic conductivities. Average linear groundwater velocities were calculated using the hydraulic properties presented above and assuming porosity for the sandstone of 5%, 20% for the Transition Zone, and 33% for the alluvium. The calculated velocities are 0.6 ft/day for Sandstone B, 0.03 ft/day for the Transition Zone, and 0.3 ft/day for the alluvium.

Western Upland

Groundwater in the Western Upland and the Western Alluvium (Figures 2-10 and 2-11) also originates as precipitation that infiltrates into the shallow groundwater unit recharge zones and flows into Sandstone A. Figure 2-10, which presents the potentiometric surface for Sandstone A, does not utilize groundwater elevation data from Monitor Well 1353, which is screened in a perched groundwater zone that is not present at lower elevations.

In the Western Upland, the 1206 Drainage (west of Monitor wells 1400, 1354, 1352, etc.) and a smaller drainage to the northeast (east of Monitor Wells 1397, 1340, and 1396) act as local drains for groundwater in Sandstone A. Groundwater flows toward the 1206 Drainage from both the east and west. The thick vegetation and groundwater seeps within the drainage attest to groundwater base flow discharging from Sandstone A into this drainage, becoming surface water in the drainage channel.

Groundwater gradients steepen along the cliff faces of the 1206 Drainage. Along the bedrock escarpment, groundwater flows north to northwest toward the floodplain in Sandstone A and discharges in numerous small seeps. Groundwater gradients in Sandstone A vary significantly due to the presence of the drainages, but average approximately 0.01 ft/ft toward the drainage to the northwest and about 0.02 ft/ft toward the north.

To the west of the 1206 Drainage, groundwater flows northeastward towards the drainage, and more northerly toward the alluvial floodplain at greater distances from the drainage. At the western edge of the Western Upland (well south of the escarpment), groundwater flow immediately east of Highway 74 appears to be to the west. However, that westward flow is significantly influenced by the groundwater elevation in Monitor Wells 1327B and 1329, older monitor wells which are screened in a deeper zone than the newer monitor wells installed in Sandstone A (e.g., 1374 and 1376).

Groundwater elevations in Sandstone A (excluding the perched zone in the southern part of the Site) range from approximately 973 ft amsl in Monitor Well 1325, to approximately 960 ft amsl near the escarpment (Monitor Well 1336A).

The presence of mudstone units between sandstone units (i.e., Sandstones A, B, and C) restricts vertical movement of groundwater in preference to horizontal flow. Vertical hydraulic conductivities across units are expected to be significantly smaller than horizontal conductivities within water-bearing units.

This is demonstrated by the presence of the Sandstone A seeps within the 1206 Drainage and along the bedrock escarpment, representing horizontal flow within Sandstone A unit. Seepage from Sandstone A into the drainage way does not infiltrate into Sandstone B, but discharges into the 1206 Drainage, in which it flows as surface water to transition zone material between the upland sandstone and mudstone and the floodplain alluvium.

Groundwater velocity in the Western Upland water-bearing units can be estimated based on measured hydraulic gradients and estimated hydraulic conductivities. Average linear groundwater velocity was calculated using the hydraulic properties presented above and assuming porosity for the sandstone of 5%. The calculated groundwater velocity is 1.2 ft/day for Sandstone A.

Groundwater in Sandstones B and C is present approximately 30 ft below the groundwater in Sandstone A. The deeper groundwater flows northwest toward the Cimarron River. In Sandstone B, the groundwater gradient is toward the north-northwest at about 0.023 ft/ft. In Sandstone C, the gradient is also toward the north at about 0.013 ft/ft (Grant, 1989). Groundwater flow in Sandstones B and C is below the base of the escarpment in the Western Upland, thus Sandstones B and C do not discharge to seeps located along the escarpment. These two water-bearing units are not intercepted by the 1206 Drainage.

Western Alluvial Area

The water table in the Western Alluvial Area (Figure 2-11) is found in the alluvial floodplain of the Cimarron River. Groundwater flow in the Western Alluvial Area is generally northward toward the Cimarron River, as shown in the groundwater contour map in Figure 2-11. The hydraulic gradient is approximately 0.002 ft/ft. This gradient is significantly lower than those associated with the adjacent uplands, due to the increased permeability of the alluvial materials.

As in the BA1 area, there is expected to be upward flow from the underlying bedrock into the alluvial material as groundwater in the bedrock is discharging to the Cimarron River.

Average linear groundwater velocity was calculated using the hydraulic properties presented above and assuming a porosity for the alluvium of 33%. The calculated groundwater velocity is 0.9 ft/day for the alluvium in the Western Alluvial Area. The groundwater flow velocity generated by the groundwater flow model is approximately 1.5 ft/day.

2.7.5 Unsaturated Zone

Unsaturated zones (vadose zones) exist within the uppermost soils in the upland, transitional, and alluvial material at the Site. No vadose zone monitoring has been performed at the Site.

2.7.6 Groundwater Models

Groundwater flow models for the Western Alluvial Area and BA1 were initially developed by ENSR Corporation, and submitted to NRC in *Groundwater Flow Modeling Report*, (ENSR 2006). Those flow models were revised in 2013 and again in 2016, based on information obtained from additional COC delineation and aquifer testing performed in 2013 and additional groundwater assessment performed in 2014. The groundwater flow models incorporate area-specific lithologic and hydraulic detail to describe groundwater gradients and flows and assist in determining the locations and probable production of groundwater from groundwater extraction technologies such as groundwater recovery wells and groundwater extraction trenches.

Burial Area #1

The model domain for BA1 is shown on Figure 2-12. There are twelve layers in the model. This complex model layering system setup was initially described in the *2006 Groundwater Flow Modeling Report* (ENSR, 2006b). Flow into the model domain is from recharge both from upgradient and from precipitation, and general head boundaries and flow out of the model is to the Cimarron River. Figure 2-12 also shows the simulated potentiometric surface based on static groundwater elevations (i.e., not influenced by extraction or injection).

Western Alluvial Area

The model domain for the Western Alluvial Area (WAA) is shown on Figure 2-13. The original model domain was expanded eastward to address remedial alternatives in the entire area of the nitrate plume as defined by the 10-mg/L isoconcentration contour; it therefore covers a larger area than the 2006 groundwater model. The WAA model domain includes two layers: Layer 1 represents the alluvium and Layer 2 represents the underlying bedrock. Flow into the model domain is from recharge and general head boundaries and groundwater flow out of the model is to the river. Figure 2-13 also shows the simulated potentiometric surface based on static groundwater elevations (i.e., not influenced by extraction or injection).

Western Upland

The Western Upland (WU), which includes BA2, BA3, the Process Building Area, the former lagoons, Uranium Pond #1 (UP1), and Uranium Pond #2 (UP2), is underlain primarily by Sandstone A. Sandstone B is exposed near the base of the 1206 Drainage. Near BA3 and the former Sanitary Lagoons, the upper part of Sandstone A is composed mostly of siltstone and shale, rather than sandstone (*Conceptual Site Model*, ENSR, 2006).

As in BA1, groundwater in the WU also originates as precipitation that infiltrates into the shallow groundwater unit recharge zones and flows into Sandstone A. In the Western Upland, the 1206 Drainage acts as a local drain for groundwater in Sandstone A. Groundwater flows toward this drainage from both the east and west, including BA3 and the former Sanitary Lagoons. Groundwater gradients steepen along the cliff faces of the drainage. Along the escarpment bordering the Cimarron River floodplain alluvium just north of the former Uranium Pond #1, groundwater flows north to northwest toward the floodplain in Sandstone A and discharges in a myriad of small seeps that are difficult to locate (*Conceptual Site Model*, ENSR, 2006).

2.7.7 Distribution Coefficients

The primary mechanisms controlling transport in groundwater at the Site are advection (within groundwater flow) and dispersion (spreading during transport). Numerical groundwater flow models demonstrate that the groundwater flow directions generally mirror the contaminant plumes moving away from the source areas.

An important aspect of the site hydrogeology is the mobility of the contaminants in various strata under influence of groundwater flow. The distribution coefficient, also known as the partition coefficient, K_d, is used to describe the decrease in concentration of contaminant in solution through interaction with the geologic material in a soil/rock-groundwater system. The K_d is defined as the ratio of concentration of a species sorbed, divided by its concentration in solution under steady-state conditions. It is an empirical parameter and its use in a given situation implies that soil/rock-groundwater system under study is in equilibrium.

The primary chemicals of concern at the site are uranium, nitrate, and fluoride. The K_d values can vary across the site depending upon the geochemistry and soil type, which potentially results in a range values.

Uranium K_d Literature Values

K_d values for uranium have been shown to vary with pH, total dissolved carbonate, and dissolved calcium due to geochemical processes (Zachara et al. 2007 and EPA, 1999). Groundwater data (2011-05-06 Comprehensive Water Data tables) from the Site indicate average pH for all measurements is 7.2. K_d values reported by EPA (1999) range between 63 to 630,000 milliliters per gram (mL/g) for a pH of 7. *Understanding Variation in Partition*

Coefficient, K_d (EPA, 1999) also noted that the K_d for clays is much larger than the K_d for sands.

Site-Specific K_d Values for Uranium

Previously reports used K_d values averaging 3 mL/g (*3/31/2004 Travel time estimate*). Using samples of soil and groundwater from the site, column tests were conducted by Hazen Research, Inc. (Johnson and Kenney, 2006). K_d values were calculated and reported in *Conceptual Site Model (Revision – 01)* (ENSR, 2006).

Alluvial sand yielded a K_d of 0.5 mL/g, silt yielded a K_d of 2.0 ml/g, and clay yielded a K_d of 3.4 ml/g. All tests were conducted with groundwater from BA1, and it is acknowledged that the minor variations in groundwater geochemistry may impact K_d values. Consequently, more conservative values than those reported were agreed upon for use in retardation calculations.

Because none of the borings completed in the Transition Zones yielded all clay, but consisted of a mixture of clay, silt, and fine sand, the use of a uranium K_d value of 3.4 ml/g for all Transition Zone material was deemed overly conservative. Similarly, borings drilled in Sandstones A and B contained a high degree of silt. Based on these observations, it was decided that a K_d lower than that which had been reported for clay should be used for Sandstones A and B. A conservative value of 3.0 was selected for Sandstones A and B and Transition Zone materials.

Clean sand yielded a uranium K_d of 0.5 during the Hazen tests. However, although borings in the floodplain do contain intervals of very "clean" sand, there is sufficient silt and/or clay to justify the use of a higher K_d value than had been reported for clean sand. A K_d of 2.0 was applied to alluvial areas.

More detailed information on the derivation of the site-specific values for K_d was provided in a letter dated July 5, 2016.

Nitrate K_d Literature Values

Nitrate is highly mobile and has little potential for sorption to soil therefore K_d values for nitrate are expected to be very low. Krupka et al (2004) recommend for groundwater scenarios a K_d of 0 L/kg for nitrate with a possible range from 0 mL/g to 0.0006 mL/g.

Therefore, nitrate is expected to be very mobile in groundwater. For retardation calculations, a very conservative value of 0.6 mL/g was used in retardation calculations.

Fluoride K_d Literature Values

A literature search for fluoride K_d values produced limited published information. Fluoride is usually transported through the water cycle complexed with aluminum. The K_d values were estimated between 16 mL/g to 1166 mL/g (Daniels and Das, 2007) suggesting fluoride transport in groundwater is very retarded under certain geochemical conditions. However, since fluoride concentrations only slightly exceed the MCL, it was decided that retardation calculations to estimate the time required for remediation would not need to be performed.

2.8 NATURAL RESOURCES

2.8.1 Natural Resources at or Near the Site

The mineral and water resources of Logan County are important to the overall development and progress of the county. Petroleum production is by far the most important mineral-related commercial activity. In 1993, petroleum production in Logan County amounted to about 1.1 million barrels of crude oil (valued at nearly $18.7 million) and about 12 billion ft^3 of natural gas (valued at $22.6 million). Due to these production levels, Logan County ranked near the middle of the petroleum producing counties in Oklahoma (NRCS, 2006). Significant exploration and production activities have been performed in Logan County since early 2014.

Sand and gravel have been produced from a number of sites in the alluvial and terrace deposits of the county. Some of the sandstone and siltstone beds may locally be suitable for use as building and fill material.

Agriculture has a key role in the utilization of natural resources in the vicinity of the site. The native vegetation consists of mid and tall rangeland grasses. The main agricultural enterprises are cattle and wheat production. Cattle are grazed mainly on native grasses and some improved pasture and on the side slopes. Wheat and grain sorghum are grown on the summits and gently sloping side slopes. Wheat, grain sorghum, and alfalfa are grown on the wide flood plains.

2.8.2 Water Usability

Abundant quantities of good-quality ground water occur in Quaternary alluvial and terrace deposits as well as in the extremely important Garber-Wellington aquifer that underlies much of the southern part of the county. The Garber-Wellington aquifer covers permeable sandstone

layers of both the entire Garber Sandstone section and the upper part of the underlying Wellington Formation. The saturated thickness of this aquifer ranges from about 500 to 700 ft.

Water wells in the Garber-Wellington aquifer commonly yield 25 to 100 gallons per minutes (gpm) of fresh water that contains only 200 to 500 mg/L of dissolved solids, although at the site TDS groundwater typically yields 400 – 2,000 mg/L dissolved solids. The aquifer is recharged by precipitation and runoff that percolates down through the soil into the porous and permeable sandstones of the Garber Sandstone and the Wellington Formation. Groundwater then percolates slowly downward and/or laterally dips down (westward) within the sandstone layers. Groundwater is salty in the lower part of the Wellington Formation and farther west where the Garber Sandstone extends beneath Kingfisher County. Where the Garber Sandstone and the Wellington Formation crop out, ground water generally is found in any permeable sandstone bed at or below the ground-water surface. Farther west, where the relatively impermeable Hennessey Group overlies the Garber Sandstone, wells still must be drilled down into the water-bearing sands of the Garber-Wellington aquifer. Upon encountering a fresh-water sand, the water will be forced up the borehole several hundred ft under artesian pressure to the potentiometric surface, approximately 100 to 200 ft below the land surface. Since the Garber Sandstone and the Wellington Formation contain more shale to the north, the yield of the aquifer decreases northward across the county. Fresh water still occurs in the sands (the same as it does farther south), but the sands are less abundant, and the yields typically are 5 to 40 gpm. Water wells in alluvial and terrace deposits locally yield 25 to 50 gpm, while wells in the prolific Cimarron River terrace aquifer in the west-central part of the county yield 150 to 700 gpm. The water quality in most of these aquifers includes 300 to 1,000 mg/L of dissolved solids, although at the Cimarron site, groundwater in the alluvial material often exceeds 1,500 mg/L.

2.8.3 Economical Evaluation of Natural Resources

As defined in U.S. Geological Survey Circular 831, resources in the vicinity of the Site are inferred to be viable based on known historical oil and gas production. Inferred reserves are currently economic for oil and gas.

2.8.4 Mineral, Fuel, and Hydrocarbon Resources

Mineral, fuel, and hydrocarbon resource extraction near and surrounding the site affect the licensee's dose estimates. The only potential exposure pathway would occur if exploration and production activities occurred in proximity to the remediation areas. Sundance Energy (current operator within the vicinity of the site) has established locations and drilled wells to extract oil

from Sections 11 and 12 in T16N-R4W, and Section 7 in T16N-R3W. If another operator would want to drill in Sections 1 or 2 in T16N-R4W, it is likely that the interested party would potentially drill on high ground north of the Cimarron River rather than in the floodplain. The pipeline constructed across Section 12 carries production water for disposal and presents negligible naturally occurring radioactivity material risk. The risk impact to dose estimates is therefore very small.

* * * * *

3.0 RADIOLOGICAL STATUS OF FACILITY

3.1 CONTAMINATED STRUCTURES

All formerly contaminated structures at the Site have been decommissioned and released for unrestricted use. Buildings that were formerly associated with licensed activities included:

- Uranium Building #1
- Uranium Tank Storage Building #2
- Solvent Extraction Building #3
- Uranium Warehouse Building #4
- UF_6 Receiving Room
- Emergency Response Building (now the Site Office)

A description of the decommissioning of these buildings is provided in Section 1.3.1, "Decommissioning of Former Buildings". All these buildings are or were located in Subareas I and K. Subarea I was released for unrestricted use in License Amendment 17, issued April 9, 2001. Subarea K was released for unrestricted use in License Amendment 18, issued May 28, 2002.

The Site Office (with adjacent storage containers) has been used to support continuing license activities, including:

- Storage of radiological instruments and check sources (exempt quantities only)
- Storage of sampling equipment and supplies
- Storage, packaging, and shipping of samples
- Conducting groundwater treatability tests
- Storage of potentially contaminated material prior to shipment to a licensed disposal facility

Sampling activities and groundwater treatability testing conducted in the Site Office had the potential to contaminate the building and equipment. Both routine and post-activity radiological surveys were conducted in the Site Office; no detectable contamination was present after completion of sampling activities and groundwater treatability testing. This demonstrates that contamination does not exceed criteria for unrestricted release. Routine surveys are routinely performed in the Site Office and storage areas to verify absence of contamination.

3.2 CONTAMINATED SYSTEMS AND EQUIPMENT

A trash incinerator, located south of Burial Ground #3, was used to incinerate non-radioactive waste materials released from restricted areas during site operations. Uranium was present in ash at concentrations above background because incineration increased the concentration of licensed material in waste that had been acceptably released for unrestricted use. Ash exceeding restricted release criteria was drummed and shipped to a licensed disposal facility. Soil samples collected from the area beneath the incinerator yielded uranium concentrations below the unrestricted release criteria. This area was included in the Final Status Survey Report for Subarea M. Subarea M was released for unrestricted use in License Condition 29 of Amendment 17 (issued April 2001).

All other radiologically contaminated systems and equipment associated with the former processing buildings were decontaminated and removed during the decommissioning of the buildings. Equipment that could not be practically surveyed for release was shipped for disposal at a licensed disposal facility.

The radiological status of systems and equipment that becomes contaminated during groundwater decommissioning activities is addressed in Section 8, "Planned Decommissioning Activities".

3.3 SURFACE AND SUBSURFACE SOIL CONTAMINATION

The licensee has completed decommissioning and final status surveys for all soil and buildings currently present on the Site. Surface soil (including soil to three ft in depth where soil contamination was detected in the top six inches) in all sixteen Subareas of the Site has been demonstrated to comply with criteria for unrestricted release stipulated in License Condition 27(c) (30 pCi/g total uranium).

Where pipelines were removed, the excavated trenches were surveyed, and wherever contamination was identified below the pipeline, soil was removed until subsurface soil complied with the 30 pCi/g total uranium criterion.

In all three Burial Areas, the former burial trenches were excavated, scanned, and sampled. Soil containing less than 30 pCi/g total uranium was returned to the trenches. Soil exceeding 30 pCi/g was removed.

NRC's 1981 *Branch Technical Position on Disposal or On Site Storage of Residual Thorium and Uranium from Past Operations* (USNRC, October 1981) established criteria for uranium in soil. This BTP established four options for disposal or on-site storage. The first option (Option 1) is

unrestricted use, and the Option 1 criteria were incorporated into License Condition 27(c) as unrestricted release criteria. The second option (Option 2) is on-site storage, with a minimum of four ft of "clean" cover (the cover could be Option 1 soil). The activity limit for Option 2 varies based on the solubility of the uranium in the soil. Although the licensee demonstrated that the uranium in the soil had a very low solubility, the limit for totally soluble uranium (100 pCi/g total uranium) was utilized as the limit for on-site disposal of uranium. The third and fourth options in the BTP require off-site disposal of higher activity licensed material; Option 3 pertains only to natural uranium, so all material exceeding the Option 2 limit was considered Option 4 material.

All excavated soil (and other buried material) which exceeded the Option 2 criterion (100 pCi/g total uranium) was packaged and shipped to off-site licensed disposal facilities. All excavated material which contained 30 to 100 pCi/g total uranium was placed in the on-site disposal trenches, now designated as BA4. Both surface and subsurface soil now comply with license criteria for unrestricted release Site-wide.

3.4 SURFACE WATER

All former impoundments which received or may have received licensed material at the Site have been decommissioned and released for unrestricted use. Impoundments that were or may have received licensed material included:

- Plutonium Waste Pond
- Plutonium Emergency Pond
- Uranium Emergency Pond
- Uranium Pond #1
- Uranium Pond #2
- East Sanitary Lagoon
- West Sanitary Lagoon
- "New" Sanitary Lagoon

A description of the decommissioning of these impoundments is provided in Section 1.3.2, "Decommissioning of Former Impoundments". These impoundments were in Subareas H, L, and O. Both impoundment areas identified as Subarea O were released for unrestricted use in License Amendment 16, issued April 17, 2000. Subareas H and L were released for unrestricted use in License Amendment 17, issued April 9, 2001.

The two freshwater ponds (reservoirs) on the Site are located in Subarea B. Subarea B was released for unrestricted use in License Amendment 13, issued April 13, 1996.

The Cimarron River is located along the northern boundary of the Site. Annual environmental monitoring continues to demonstrate that the Cimarron River is not impacted by any of the COCs associated with the Site.

3.5 GROUNDWATER

Groundwater is the only environmental medium for which decommissioning is required to obtain unrestricted release of the Site. This section lists the groundwater assessments that have been performed for the Site and presents the current extent of impact for all COCs in groundwater at the Site.

The NRC Criterion for the Site is 180 picoCuries per liter (pCi/L) total uranium, derived from a risk-based concentration, and stipulated in License Condition 27(c).

Groundwater in several areas of the Site contains two non-radiological COCs: nitrate and fluoride. For uranium and fluoride, the criteria to achieve an unrestricted release from the DEQ are the EPA MCLs for drinking water. The MCLs are 30 µg/L for uranium and 4 mg/L for fluoride. Because nitrate is present at concentrations above the MCL due at least in part to the use of fertilizer, DEQ has designated a value of 22.9 mg/L as the State Criterion, based on analysis of samples from monitor wells located upgradient of processing or disposal activities. The State Criterion for nitrate in the process building area is 52 mg/L.

3.5.1 Submittals Addressing Groundwater Assessment

Numerous groundwater assessment efforts have been performed at the Site. The following is a list of reports on groundwater assessment activities.

- April 17, 2002, *Former Burial Area #1 Groundwater Assessment Work Plan*, Cimarron Corporation
- September 24, 2002, *Tc-99 Site Impact Evaluation and Proposed Groundwater Assessment Work Plan*, Chase Environmental Group
- December 12, 2002, *Well 1319 Area Groundwater Assessment Work Plan*, Cimarron Corporation
- January 29, 2003, *Burial Area #1 Ground Assessment Report*, Cimarron Corporation

- December 30, 2003, *Draft Tc-99 Groundwater Assessment Report*, Chase Environmental Group
- December 30, 2003, *Assessment Report for Well 1319 Area,* Cimarron Corporation
- August 10, 2005, *Site-Wide Groundwater Assessment Review,* Cimarron Corporation
- November 5, 2005, *Refined Conceptual Site Model,* ENSR International
- October 19, 2006, *Conceptual Site Model (Revision- 01),* ENSR International
- October 23, 2006, *Groundwater Flow Modeling Report,* ENSR International
- March 3, 2013, *Pneumatic Slug Testing Memorandum,* Burns & McDonnell
- March 15, 2013, *Hydrogeological Pilot Test Report,* Burns & McDonnell
- January 6, 2014, *Groundwater Flow Modeling Report,* Burns & McDonnell
- July 22, 2014, *Hydrogeological Testing Memorandum,* Burns & McDonnell
- May 8, 2015, *Report on 2014 Design Investigation,* Burns & McDonnell
- July 5, 2016, *Distribution Coefficient Determination for the Cimarron Site,* EPM
- January 25, 2017, *Groundwater Flow Model Update,* Burns & McDonnell
- May 19, 2017, *Vertical Distribution of Uranium in Groundwater*, Burns & McDonnell
- August 22, 2017, *Determination of Conservative U-235 Enrichment Levels for Groundwater at Cimarron Site*, Enercon Services
- March 28, 2018, *1206 Drainage Sediment Assessment and Remedial Alternative Evaluation*, Burns & McDonnell
- March 28, 2018, *Groundwater Data Evaluation*, Burns & McDonnell
- April 12, 2018, *Determination of Maximum Conservative U-235 Enrichment Levels for Groundwater at Cimarron Site*, Enercon Services
- April 6, 2018, *Environmental Sequence Stratigraphy (ESS) and Porosity Analysis, Burial Area 1*, Burns & McDonnell

3.5.2 Submittals Addressing Groundwater Remediation

Numerous approaches to groundwater remediation efforts have been considered, and several proposed at different time, to address COCs in groundwater at the Site. The following is a list of submittals addressing groundwater remediation.

- October 22, 2003, *Draft Work Plan – In Situ Bioremediation Treatment of Uranium in Groundwater in Burial Area #1*, ARCADIS
- January 24, 2005, letter proposing a Well 1319 Area post-decommissioning groundwater monitoring plan

- December 11, 2006, license amendment request which included *Site Decommissioning Plan, Groundwater Decommissioning Amendment*, ARCADIS. Rejected by NRC w/a request for additional information (RAI) March 27, 2007.
- August 31, 2007, letter requesting that NRC provide closure on Well 1319 Area groundwater remediation
- June 2, 2008, *Groundwater Decommissioning Plan*, ARCADIS
- March 26, 2009, license amendment request included *Groundwater Decommissioning Plan*, ARCADIS
- June 30, 2011, *Evaluation of Potential Alternative Groundwater Remediation Technologies,* Environmental Properties Management LLC
- March 19, 2014, *Treatability Study Report*, Clean Harbors
- October 30, 2015, *Groundwater Treatability Tests*, Kurion, Inc.
- June 1, 2018, *Pilot Test Report,* Burns & McDonnell

3.5.3 Current Extent of COCs in Groundwater

The 2015 *Cimarron Facility Decommissioning Plan* presented data from the 2015 groundwater assessment sampling event. In some areas, COC concentrations appeared to be anomalously low in 2015, whereas in other areas, COC concentrations appeared to be consistent with or slightly higher than previous data. NRC requested that groundwater data be evaluated for evidence of seasonal variability, as well as to determine if changes in COC concentrations were related to changes in groundwater elevation.

Quarterly collection of groundwater samples from 44 monitor wells was begun in the first quarter of 2016. Samples were collected from wells screened in all three sandstone units, in transition zone material in the WAA and BA1, and in alluvial material in the WAA and BA1. Data from 2011 through the Fourth Quarter of 2016 were evaluated, and the evaluation results were presented in *2016 Groundwater Evaluation* (Burns & McDonnell, 2017). The evaluation concluded that there is no relationship between either season or groundwater elevation and COC concentrations. This evaluation was updated in *2017 Groundwater Evaluation* (Burns & McDonnell, 2018), yielding the same conclusion.

It is necessary to minimize the potential for individual data points to exercise undue influence on the estimated concentrations of COCs to treatment trains. Consequently, the decision was made to determine the concentration of each COC at each location at the 95% upper confidence level, based on data obtained from 2011 through the second quarter of 2017. For locations for which

the 95% upper confidence level was greater than the maximum concentration, the maximum concentration was used. For locations for which less than 4 data points were available, the average concentration was used.

Figures 3-1 through 3-4 present isoconcentration contours (isopleths) for each COC, based on the results of these calculated concentrations. Figure 3-1 presents an isopleth map for nitrate in the WA. Figure 3-2 presents an isopleth map for fluoride in the Western portion of the Site. Figure 3-3 presents an isopleth map for uranium in the Western portion of the Site. Figure 3-4 presents an isopleth map for uranium in BA1.

The values used to calculate uranium enrichment must be as accurate as reasonably achievable to estimate the mass of U-235 that may accumulate in ion exchange resin vessels during groundwater treatment. Isotopic analysis performed prior to 2016 consisted of alpha spectroscopic analysis of isotopic activity. At the relatively low uranium concentrations that exist throughout much of the area requiring remediation, the uncertainty associated with the calculated enrichment is high. In estimating enrichment values for uranium, the "mean plus 2-sigma" enrichment value for all data obtained at each location was calculated. Due to the high uncertainty associated with isotopic ***activity*** analysis, this calculation method resulted in an over-estimation of enrichment values for the groundwater treatment system influent streams.

In December 2016, groundwater samples were collected from multiple locations to obtain a data set spanning the variability of uranium enrichment and concentration that occurs across the Site. Samples were analyzed for isotopic activity by alpha spectroscopy and for isotopic mass concentration by inductively coupled plasma – mass spectroscopy (ICP-MS). The data was evaluated to determine which method would provide the most accurate isotopic results at low uranium concentrations. The result of this evaluation was reported in a technical memorandum entitled, "*Analysis of Analytical Method for Uranium Enrichment Determination*" (Enercon Services, 2017). The evaluation conclusively demonstrated that ICP-MS analysis produces isotopic results with far less uncertainty at low concentrations.

Groundwater samples were then collected from 197 monitor wells for isotopic analysis by ICP-MS during the Second Quarter of 2017. Groundwater samples were collected from all monitor wells located in areas where groundwater will be extracted for treatment, as well as areas from which groundwater will be driven to extraction components by the injection of treated water. Samples were analyzed for mass concentration of the U-235 and U-238 isotopes only, because

the mass of U-234 at the low enrichment levels encountered at the Site is negligible (less than 0.05% of the total uranium mass),

U-235 enrichment values were calculated by dividing the U-235 mass concentration by the sum of the U-235 and U-238 mass concentrations. Figure 3-5 presents iso-enrichment contours for the western areas. Contours are drawn for U-235 enrichment values of 1, 2, 3, and 4%. Figure 3-5 clearly shows that the enrichment varies in relation to the source from which the uranium came. Higher enrichment values are observed along the trace of the pipeline which formerly discharged water from the original impoundments to the Cimarron River. Lower enrichment values are associated with leachate from the uranium waste ponds. Enrichment values in groundwater associated with BA3 are typically between those associated with the pipeline or the uranium waste ponds.

Enrichment values for groundwater samples collected from monitor wells in BA1 are posted on Figure 3-6. Because the maximum enrichment in BA1 is less than 2%, the only isopleth in BA1 is the 1% enrichment contour.

The ability of groundwater extraction to recover uranium-impacted groundwater, and for uranium treatment (ion exchange) systems to remove uranium from the recovered groundwater, is unaffected by U-235 enrichment levels. The U-235 enrichment also has no impact on the adsorption capacity of ion exchange resin. Variability in uranium enrichment levels does however impact the accumulation of U-235 on ion exchange resin, relative to the license possession limit for U-235. In the western areas, this variability is substantially moderated when groundwater extracted from locations containing higher-enriched uranium is combined with groundwater extracted from locations containing lower-enriched uranium prior to treatment.

In BA1, there is little variability in enrichment, with U-235 enrichment varying from natural (0.7%) enrichment to approximately 1.9% enrichment. Even this slight variability is moderated due to the same mixing of groundwater from multiple locations prior to treatment.

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4.0 UNRESTRICTED RELEASE CRITERIA

Decommissioning Plan guidance contained in Appendix D of NUREG-1757 is based on the need to utilize a dose model to develop derived concentration goal levels (DCGLs) that will yield a site that is releasable for unrestricted use. However, unrestricted release criteria for building surfaces and equipment, surface and subsurface soil, and groundwater were established in accordance with the Site Decommissioning Management Program. NRC stated in a November 10, 2005 letter that the criteria established under the Site Decommissioning Management Program would be carried forward under the License Termination Plan and are specified in License Condition 27. Consequently, dose modeling was not performed to develop unrestricted release criteria. This section describes the criteria that are stipulated in License Condition 27.

4.1 UNRESTRICTED RELEASE CRITERIA FOR FACILITIES AND EQUIPMENT

License Condition 27(c) lists the unrestricted release criteria for facilities and equipment. This condition cites the August 1987 *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of License for Byproduct, Source or Special Nuclear Material*. License Condition 27(c) states, "Buildings, equipment, and outdoor areas shall be surveyed in accordance with NUREG/CR-5849, 'Manual for Conducting Radiological Surveys in Support of License Termination.'" The criteria are:

- 5,000 dpm alpha/100 cm^2 (15.5 in^2), averaged over 1 m^2 (10.8 ft^2)
- 5,000 dpm beta-gamma/100 cm^2 (15.5 in^2), averaged over 1 m^2 (10.8 ft^2)
- 15,000 dpm alpha/100 cm^2 (15.5 in^2), maximum over 1 m^2 (10.8 ft^2)
- 15,000 dpm beta-gamma/100 cm^2 (15.5 in^2), maximum over 1 m^2 (10.8 ft^2)
- 1,000 dpm alpha/100 cm^2 (15.5 in^2), removable
- 1,000 dpm beta-gamma/100 cm^2 (15.5 in^2), removable

The exposure rate for surfaces of buildings and equipment is 1.3 picoCuries per kilogram (pC/kg) (5 microroentgen/hour [µR/hr]) above background at 1 m (3.3 ft.)

4.2 UNRESTRICTED RELEASE CRITERIA FOR SURFACE SOIL

License Condition 27(c) also lists the unrestricted release criteria for soils and soil-like material. This license condition states, "The licensee shall use … the October 23, 1981, BTP 'Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations' for soils or soil-like material." It also

states, "... outdoor areas shall be surveyed in accordance with NUREG/CR-5849, 'Manual for Conducting Radiological Surveys in Support of License Termination'. Soils and soil-like materials with elevated activities exceeding the unrestricted use criteria shall be investigated to determine compliance with the averaging criteria in NUREG/CR-5849. These criteria address averaging concentrations over any 100 m^2 (1070 ft^2) area and use the (100/A)1/2 elevated area method." Unrestricted release criteria for soils and soil-like material are:

- Natural uranium 0.37 becquerel per gram (Bq/g) (10 pCi/g) total uranium
- Enriched uranium 1.1 Bq/g (30 pCi/g) total uranium
- Depleted uranium 1.3 Bq/g (35 pCi/g) total uranium
- Natural thorium 0.37 Bq/g (10 pCi/g) total thorium
- 2.6 pCi/kg (10 µR/hr) average above background at 1 m (3.3 ft.)
- 5.2 pCi/kg (20 µR/hr) maximum above background at 1 m (3.3 ft.)

License Condition 23 lists post-closure monitoring and notification requirements for the onsite disposal cell. The onsite disposal cell has been closed and all post-closure monitoring and notification is complete. No additional material exceeding the BTP Option 1 (unrestricted release) criteria will be placed in the onsite disposal cell. All soil and soil-like material exceeding the unrestricted release criteria will be removed and shipped off-site to a licensed low-level radioactive waste disposal site.

4.3 UNRESTRICTED RELEASE CRITERIA FOR GROUNDWATER

The only radioactive COCs in groundwater are uranium and technetium-99. Uranium is present both as natural uranium and as licensed uranium in groundwater. In addition, nitrate and fluoride are the two non-radioactive contaminants for which groundwater remediation is required to obtain unrestricted release from DEQ.

4.3.1 Uranium

License Condition 27(b) cites the unrestricted release criterion for uranium in groundwater. The NRC Criterion is based on a site-specific risk assessment rather than a dose model; and the risk of toxicity from ingestion of purified uranium is greater than the its radiological dose risk. A 1998 risk assessment established a risk-based limit of 0.11 mg/L for uranium in groundwater (Schornick, 1998). That 0.11 mg/L is approximately equivalent to an activity of 180 pCi/L, assuming an average enrichment of approximately 2.7%, so 180 pCi/L total uranium was established as the unrestricted release criterion for groundwater at the Site.

The U-235 enrichment is not constant for all licensed uranium in groundwater at the site. The U-235 enrichment of uranium in groundwater varies based on the source of the uranium. Data indicates that the U-235 enrichment associated with licensed material originating from BA3 and the pipeline that ran from the sanitary lagoons and emergency ponds is approximately 2.9%. The U-235 enrichment associated with licensed material originating from BA1 and Uranium Waste Ponds #1 and #2 averages 1.3%. The mass concentration that is equivalent to 180 pCi/L at 2.9% enrichment is 119 µg/L total uranium, and the mass concentration that is equivalent to 180 pCi/L at 1.3% enrichment is 201 µg/L total uranium.

To obtain unrestricted release from DEQ, uranium concentrations must comply with the MCL issued in the primary drinking water standards promulgated by the EPA. The MCL for uranium is 30 µg/L.

4.3.2 Technitium-99

Unrestricted release criteria for Tc-99 are not stipulated in License SNM-928. The EPA has promulgated a primary drinking water standard of 4 millirem per year (mrem/yr) for beta photon emitters. NRC developed a concentration limit for Tc-99, based on the 4 mrem/yr dose limit, using the 1982 International Commission on Radiological Protection (ICRP) Publication 30, *Limits for Intakes of Radionuclides by Workers*. The NRC concentration limit for Tc-99 is 3,790 pCi/L. Tc-99 will not be accumulated in the groundwater remediation process, so Tc-99 will not technically be "possessed". Consequently, the license does not specifically authorize possession of Tc-99. However, NRC requires that post-remediation groundwater monitoring demonstrate that Tc-99 concentrations in groundwater are less than 3,790 pCi/L to obtain unrestricted release from NRC.

EPA developed a concentration limit for Tc-99 based on the EPA MCL of 4 mrem/yr using the 1959 ICRP Publication 2, *Permissible Dose for Internal Radiation*. The EPA concentration limit for Tc-99 is 900 pCi/L. Tc-99 concentrations in groundwater must be below 900 pCi/L to obtain unrestricted release from DEQ.

4.3.3 Nitrate

DEQ formalized the remediation goals for groundwater in a letter dated August 4, 2015. The concentration of nitrate in groundwater in the Process Building Area must be remediated to less than 52 mg/L. This is a risk-based concentration for a trespasser or an agricultural worker, which

was deemed appropriate for a commercial operator obtaining drinking water from a public water supply.

The concentration of nitrate in groundwater in all other areas must be reduced to less than the State Criterion of 22.9 mg/L. This represents the maximum nitrate concentration, at a 95% level of confidence, in groundwater collected from monitor wells located upgradient of impacted areas.

4.3.4 Fluoride

The State Criterion for fluoride in groundwater site-wide is the MCL of 4 mg/L.

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