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Abbreviations and Acronyms

Term	Definition
ADU	Ammonium Diuranate
AMSL	Above Mean Sea Level
AOC	Administrative Order on Consent
ASTM	American Society for Testing and Materials
ATH	Ambient Temperature Headspace
BaCl	Barium Chloride
BH	Bore Hole
BGL	Below Ground Level
CAP	Corrective Action Plan
CFR	Code of Federal Regulations
COE	U.S. Army Corps of Engineers
DP	Decommissioning Plan
DUF_4	Depleted Uranium Tetrafluoride
DUF_6	Depleted Uranium Hexafluoride
EPA	U.S. Environmental Protection Agency
FEI	Facility Environmental Investigation
GMIM	Groundwater Monitoring Interim Measures
JTU	Jackson Turbidity Unit
KMC	Kerr McGee Corporation
MCL	Maximum Contaminant Level
MPB	Main Process Building
MSL	Mean Sea Level
MW	Monitor Well
NPDES	National Pollution Discharge Elimination System
NRC	Nuclear Regulatory Commission
ODEQ	Oklahoma Department of Environmental Quality
OSDH	Oklahoma State Department of Health
OWRB	Oklahoma Water Resources Board
OVM	Organic Vapor Meter
PQL	Practical Quantitation Limit
RCC	Resource Conservation Corporation
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SCP	Site Characterization Plan
SCR	Site Characterization Report
SCS	Soil Conservation Service
SFC	Sequoyah Fuels Corporation
SFC-N	SFC Ammonium Nitrate Fertilizer Solution
SFIC	Sequoyah Fuels International Corporation
SX	Solvent Extraction
UF_4	Uranium Tetrafluoride
UF_6	Uranium Hexafluoride
USCS	Unified Soils Classification System
USDA	United States Department of Agriculture

Abbreviations and Acronyms (Cont.)

Term	Definition
USF&W	United States Fish & Wildlife Service
WPC	Werner Phleiter Corporation

1.0 Introduction

1.1 Background

In 1970, Sequoyah Fuels Corporation (SFC) began operations of a uranium conversion industrial facility located north of Interstate Highway I-40 and west of Oklahoma State Highway 10 about 2.5 miles southeast of Gore, Oklahoma. The Facility location is shown on Figure 1. In 1987, SFC began operations of a facility for the reduction of depleted uranium hexafluoride (DUF_6) to depleted uranium tetrafluoride (DUF_4) at the Facility. SFC formally discontinued all production operations in July, 1993. On February 16, 1993, and July 7, 1993, pursuant to 10 CFR 40.42, SFC notified the NRC of its intent to terminate licensed production activities at the Facility and requested termination of license SUB-1010. Also on February 16, 1993, SFC submitted a preliminary plan for completion of decommissioning (PPCD) of the Facility.

On August 3, 1993, SFC and the Environmental Protection Agency (EPA), Region 6 office in Dallas, Texas, signed a Resource Conservation and Recovery Act (RCRA) Section 3008 (h) Administrative Order on Consent (AOC). The AOC requires SFC, among other things, to perform a RCRA Facility Investigation (RFI) consistent with the Corrective Action Plan (CAP), incorporated in the AOC. The RFI has been conducted according to the approved RFI Workplan, and a draft report was submitted to EPA on December 26, 1995. The draft RFI Report addresses the characterization of the Facility with respect to most non-radiological constituents, and has been provided to the NRC for information.

SFC submitted a draft SCP to NRC in January, 1994. NRC staff performed a review of the draft SCP and transmitted its comments to SFC by letter dated November 3, 1994. By letter dated February 5, 1995, the NRC withdrew their request for SFC to revise the draft SCP allowing SFC to proceed with site characterization activities provided SFC consider NRC comments during the characterization activities and during the preparation of the Site Characterization Report (SCR).

1.2 Purpose, Scope and Objectives of Site Characterization Activities

The purpose of this Site Characterization is to determine the extent and concentration of releases of licensed materials at the Facility and to gather data to support the Decommissioning Plan (DP). The objectives of SFC's site characterization are consistent with those stated by the NRC in its draft branch technical position regarding site characterization. In summary, the main objectives of SFC's site characterization effort are:

- To quantify the physical and chemical characteristics of contamination and the extent of contaminant distribution including the rate(s) of migration.
- To quantify environmental parameters that significantly affect potential human exposure from existing and potential future contamination under the final stabilization or use condition.

- To support evaluation of alternative decommissioning actions and detailed planning of the preferred approach for decommissioning and remediation.

The characterization activities were conducted to obtain the information needed to complete the characterization of source(s) of contamination, determine the degree and extent of contamination where releases have occurred in the environment, and complete the environmental setting characterization in order to support decommissioning planning.

Throughout the course of operation of the Facility, many reports have been developed that describe the environmental conditions at the Facility. The more significant of these are listed in the bibliography section of this report and summarized in Section 2.2.4. As applicable, information from these reports was used and/or referenced in this report.

This report incorporates applicable information from previous studies with that found in the recent characterization activities to properly characterize the Facility. The environmental setting including regional location, boundaries, physical features (e.g., topography, geology, climate, ...), and historical use of the Facility with respect to production and waste handling is described herein. Information on the nature and extent of contamination, and the potential receptors are also included or incorporated by reference.

1.3 Criteria and Guidelines

Site characterization activities were conducted in accordance with the EPA approved RFI Workplan, the draft SCP, and the comments on the draft SCP provided to SFC by the NRC. The draft NUREG/CR-5849 was consulted regarding general aspects of site characterization activities in accordance with the Action Plan to Ensure Timely Cleanup of Site Decommissioning Management Plan Sites. Additionally, the guidance in the draft Branch Technical Position on Site Characterization for Decommissioning was considered.

1.4 Report Organization

The remaining sections of this Site Characterization Report address major areas outlined in the BTP as follows:

Section	Description
2.0	General Description of the Facility
3.0	Physical Characteristics of the Facility
4.0	Extent and Concentration of Contamination
5.0	Dose Assessment

Section 2.0, General Description of the Facility, describes the location of the Facility and provides a general history of the Facility that is applicable to this report.

Section 3.0, Physical Characteristics of the Facility, describes the environmental setting at the Facility. Information pertaining to surface features, climatology and meteorology, geology, hydrogeology and surface water hydrology is included.

Section 4.0, Extent and Concentration of Contamination, presents the source and environmental media characterization. This section includes a discussion of the background conditions, source characteristics, and the extent of surface water and sediment, soil, groundwater, wetlands, and structures and equipment contamination.

Section 5.0, Dose Assessment, addresses the potential exposure pathways, receptors and radiation dose.

2.0 General Description of the Facility

2.1 Facility Location and Description

The Facility is located in Sequoyah County in mid-eastern Oklahoma at 95° 5' west longitude and 35° 30' north latitude, about 150 miles east of Oklahoma City, Oklahoma, 40 miles west of Fort Smith, Arkansas, 25 miles southeast of Muskogee, Oklahoma, and 2.5 miles southeast of Gore, Oklahoma. Figure 1 shows the general location of the Facility. The term "Site" is synonymous with the term "Facility". The Facility is located in Section 21 of Township 12 North, Range 21 East, and consists of approximately 600 acres bounded on the north by private property, on the east by State Highway 10, on the south by Interstate 40 (I-40) and on the west by U.S. Government-owned land managed by the U.S. Army Corps of Engineers (COE) which is adjacent to the Illinois and Arkansas River tributaries of the Robert S. Kerr Reservoir. Access to the Facility is via State Highway 10, adjacent to the east Facility fence. The Facility is on gently rolling terrain at an approximate elevation 570 feet M.S.L. Figure 2 shows the topography of the Facility and surrounding area.

SFC conducted uranium processing operations on an 85-acre portion of the Facility which is commonly referred to as the Process Area. In addition to the Process Area, SFC has managed storm water and byproduct materials on additional portions of its Facility. The Process Area and the additional management areas are collectively referred to here and in other documents as the "Industrial Area". The Industrial Area encompasses approximately 200 contiguous acres of the Facility and is depicted in Figure 3.

Prior to ceasing production operations, SFC conducted the majority of processing activities in the Process Area. A general Facility layout is included as Figure 4. The conversion of uranium ore concentrates into uranium hexafluoride (UF6) was conducted in the Main Process Building (MPB), the Miscellaneous Digestion Building, and the Solvent Extraction (SX) Building. The reduction of depleted uranium hexafluoride (DUF6) to depleted uranium tetrafluoride (DUF4) was conducted in the DUF4 Building. Feed material for the UF6 Conversion Plant was stored on the yellowcake storage pad southwest of the MPB. Feed material for the DUF6 reduction process was stored on a pad south and west of that facility. UF6 cylinders are stored on the cylinder storage pad north of the MPB, and DUF4 product was stored on the storage pad west of and inside of the DUF4 Building. Liquid byproduct processing was conducted primarily in the clarifiers west of the yellowcake storage pad.

Solid waste processing (sorting and compacting clean and radioactively contaminated trash) prior to discontinuing production operations at the Facility was conducted primarily in the Solid Waste Building northwest of the MPB. Radioactively contaminated trash was subsequently managed as low level radioactive waste. Analytical work to support process control and developmental activities was conducted in the Process Laboratory, which was located in the MPB. Analysis of environmental samples was performed at the Environmental Laboratory located approximately one mile east of the Facility and at off-site laboratory facilities. SFC staffed and operated the Environmental Laboratory from 1990 until it was sold in September 1995.

Certain materials are still stored at the Facility pending suitable arrangements for disposition. Depleted UF4 product is currently stored inside the DUF4 Building. Liquid byproduct materials and raffinate sludge remain in the clarifiers located west of the yellowcake storage pad. Solid waste processing associated with the decommissioning process continues to be conducted primarily in the Solid Waste Building northwest of the MPB. Packaged low level radioactive waste is currently stored in the MPB.

2.2 Facility History

2.2.1 Historic Significance

The National Register of Historic Places (Federal Register 48(41): 8626-8679, March 1, 1983, and prior annual listings) lists a number of historic places in Sequoyah County and in nearby Haskell and Muskogee Counties. The Tamaha Jail and Ferry Landing in Haskell County are within about 10 miles of the Facility. The historic places in Sequoyah County are Sequoyah's Cabin, about 25 miles east of the Facility; Dwight Mission, about 17 miles northeast of the Facility; and Parris Mound in Sallisaw, about 17 miles east-southeast of the Facility. The National Registry of Natural Landmarks has no listings for Haskell, Muskogee, or Sequoyah counties (Federal Register 48 (41): 8682-8704, March 1, 1983).

The State of Oklahoma Historical Society lists Talonteeskee, the western capital of the Cherokee Nation which was located in the area from 1829 to 1839, as a location of interest. Dwight Mission was established in the area in 1821, and served the Cherokees until after the Civil War. A stagecoach way station, initially located on the Facility, served stagecoaches running between Fort Smith, Arkansas and Fort Gibson, Oklahoma. The way station has been moved to a location on U.S. Route 64, near State Route 10, where it is preserved as a public attraction.

2.2.2 NRC License History

License SUB-1010, Docket No. 40-8027 was originally issued to Kerr McGee Corporation on October 14, 1969, for storage only of uranium ore concentrate. The license was amended on February 20, 1970, authorizing Kerr McGee Corporation to operate a Uranium Hexafluoride (UF6) Conversion Plant. The license was amended on February 25, 1987, to authorize operation of the UF6 Reduction Plant (DUF4 Building). The license was last renewed on September 20, 1985, and would have expired on September 30, 1990. The license has remained in effect, pursuant to 10 CFR 40.43, based on timely submittal of a renewal application dated August 29, 1990, and revised September 30, 1992. On February 16, 1993, and July 7, 1993, pursuant to 10 CFR 40.42, SFC notified the NRC of its intent to terminate licensed activities at the Facility and requested termination of License SUB-1010. The license remains in effect pursuant to 10 CFR 40.42 (c) until Site decommissioning is completed and the NRC approves termination of the license.

2.2.3 Other Licenses and Permits

SFC currently maintains the following additional environmental-related licenses and permits:

a. U. S. Environmental Protection Agency, National Pollutant Discharge Elimination System Permit No. OK0000191.

b. Oklahoma Department of Environmental Quality, Air Quality Permits No. 78-012-0 (UF6 Conversion Plant) and No. 86-015-0 (UF6 Reduction Plant).

c. Oklahoma Department of Environmental Quality, Waste Disposal Permit No. WD-75-074.

2.2.4 Environmental Studies/Events

Several reports have been published containing information about the environmental conditions that exist at the Facility. While not all of the reports were specifically directed toward site characterization for remediation, they all contain information that is pertinent to this effort. The relevant reports are listed here:

a. Berger, J. D. 1986. Environmental Survey at the Sequoyah Fuels Corporation Site, Gore, Oklahoma.

b. Nuclear Regulatory Commission. 1986. Assessment of the public health impact from the accidental release of UF6 at the Sequoyah Fuels Corporation Facility at Gore, Oklahoma. NUREG-1189, Vol. 1.

c. Tucker, B. B. 1988. Sequoyah Fuels Corporation fertilizer development program, 1973-1986. Publication No. A-88-5. Oklahoma State University.

d. Sequoyah Fuels Corporation. July 31, 1991. Sequoyah Fuels Corporation Facility Environmental Investigation Findings Report, Volumes I-V,

e. Sequoyah Fuels Corporation. May 21, 1992. Addendum Facility Environmental Investigation Findings Report.

f. Applicant's Environmental Report, Revision 1. License Renewal Application Docket No. 40-8027, January 10, 1992.

g. Sequoyah Fuels Corporation. February 23, 1994. Preliminary Report, Description of Current Conditions and Investigations.

h. Sequoyah Fuels Corporation. January 30, 1995. 1994 Annual Groundwater Report.

i. Sequoyah Fuels Corporation. December 2, 1997. Final Radiological Status Report for Unit 50B.

j. Roberts/Schornick & Associates, Inc. April 4, 1995. Class I Injection Well Data Evaluation Report, Sequoyah Fuels Corporation, Gore, Oklahoma.

k. Tucker, B.B. October 10, 1995. Ammonium Nitrate Fertilizer Program Evaluation, RCRA Facility Investigation, 1995 Update Report.

These documents are summarized below.

Environmental Survey

At the request of the NRC's Division of Fuel Cycle and Material Safety, the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU) performed an independent survey of effluents and environmental media at the Facility during the period of July 15 - 24, 1985. This survey included sampling of stack discharges and air, water, soil, sediment and vegetation from the vicinity of the Facility. This report presents the procedures and results of that survey.

1986 UF6 Release

In an NRC report concerning the health effects of the 1986 UF6 release (NUREG-1189), some consideration was given to environmental effects. The report concludes that uranium concentrations added to offsite soil as a result of the incident are insignificant compared to background.

Effects of chemicals released during the 1986 incident were also small. Although no acute effects on foraging animals from increased fluoride in vegetation were observed, the NRC predicted that such an affect could have occurred. However, since fluoride had not accumulated in plants from the soil to any great extent, there would be no chronic effects.

Fertilizer Program

A byproduct of the uranium hexafluoride processing at the Facility was a dilute aqueous solution of ammonium nitrate. After treatment to reduce radionuclide concentrations, this solution was applied as a fertilizer primarily to grasslands owned by SFC's parent company, Sequoyah Fuels International Corporation (SFIC).

The fertilizer program has been extensively monitored and reported in several studies carried out over a 19-year period (See Tucker Report, 1988, and 1995 Update Report). Over the course of these studies, data was obtained for loading rates and accumulation of trace elements and radionuclides from study plots, monitoring wells, and ponds. Soil samples were collected from each plot at least twice per year, forage samples were collected from each forage harvest (average 3 per year), and tissue samples were collected from cattle raised on the forage in 1979 for trace element and radionuclide analysis, histopathology, and toxicology.

The fertilizer solution (SFC-N) used in the program had lower concentrations of trace elements than commercially available nitrogen fertilizer, with the exception of copper, nickel and molybdenum. The contributions of trace elements from SFC-N to the soil and forage were small in relation to inputs from other necessary fertilizers and soil amendments.

The Tucker Report concluded that cattle raised on forage treated with SFC-N showed greater weight gain than control animals and no difference in toxic response, histopathology, or trace metal content than control animals. No increases in concentration of trace metals or radionuclides over background soils, surface waters, or groundwaters could be attributed to the use of SFC-N.

In the 1995 Update Report, Tucker concluded that loading of trace metals on fertilized properties constituted only a small fraction of EPA allowable loading rates for land application of sewage sludge. Further, he concluded that neither groundwater nor surface waters nor forage have been adversely impacted by SFC-N applications.

Facility Environmental Investigation and Addendum

One of the most comprehensive environmental investigations performed to date, the Facility Environmental Investigation (FEI), was implemented by SFC in the Fall of 1990 and concluded in the summer of 1991. The FEI was designed to identify and investigate locations at the Facility where past or present[1] operations could have resulted in the release of licensed[2] and other chemical material to the environment. The FEI focused on uranium, fluoride, nitrates, and arsenic, although some investigation of radium, thorium and organics was performed also.

SFC conducted additional investigations in 1991. The results were published as an addendum to the FEI (Addendum) in May 1992. The Addendum summarized the additional investigations and assessed the information in relationship to the findings of the original FEI.

NRC License Renewal Data

Information related to the characterization of the Facility was compiled in response to questions from the NRC related to the NRC's Environmental Assessment of the Facility in 1992 which was being performed in connection with the License Renewal Application submitted by SFC. SFC compiled a substantial amount of information regarding the hydrogeology, geology, meteorology, climatology, and demography of the Facility all of which was provided to the NRC as responses to these questions. SFC later withdrew its License Renewal Application and the Environmental Assessment was never completed by the NRC.

Preliminary Report: Description of Current Conditions and Investigations

This report provides existing background information pertinent to the Facility. Regional location, boundaries, physical features (e.g., topography, geology, climate, ...), and historical use of the Facility with respect to production and waste handling are summarized. Existing information on the nature and extent of contamination is also included. As applicable, information from the FEI and Addendum is summarized and/or referenced in this report.

In response to questions in relation to the NRC's environmental assessment of the Facility in 1992, SFC obtained and analyzed a substantial amount of information regarding the hydrogeology, geology, meteorology, climatology, demography,

1. "Present" refers to the time period during which the FEI was implemented.
2. "Licensed material" refers to radiological material which SFC is authorized to possess under Source Material License SUB-1010, Docket No. 40-8027 issued by the Nuclear Regulatory Commission under the Atomic Energy Act.

and operation of the Facility. As applicable, this information is also summarized in this report.

Annual Groundwater Report

SFC has conducted groundwater monitoring in accordance with the guidance of the Groundwater Monitoring Interim Measures (GMIM) Workplan. Data gathered by the GMIM program includes routine monitoring results (NRC commitment) from all FEI-era wells and a special monitoring program conducted on select wells. The special monitoring program includes selected well locations for analyses of certain metals and volatile and semi-volatile organic compounds.

Class I Injection Well

On April 4, 1995, Roberts/Schornick & Associates, Inc. published an evaluation of the deep injection well at the Facility in a report entitled "Class I Injection Well Data Evaluation Report, Sequoyah Fuels Corporation, Gore, Oklahoma." The report identified and evaluated all available documentation related to installation, testing and closure of the well. The report concluded that there is little possibility that the injection well acts as a conduit for vertical movement of near surface groundwater into deeper horizons, or that deeper groundwater was displaced to higher horizons by the tests that were conducted on this well.

3.0 Physical Characteristics of the Facility

3.1 Surface Features

The Facility is situated on gently rolling to level land with several steep slopes to the northwest and wooded lands to the north and south. Elevations on or near the Facility range from 460 feet AMSL for the normal pool elevation of the Robert S. Kerr Reservoir to 700 feet on top of a hill approximately one mile southeast of the Facility. Slopes over most of the upland areas of the Facility are less than 7%. Steeper slopes in creek ravines and on hillsides average roughly 28%. Approximately 600 acres are occupied by the Facility. Most of the pasture land (i.e. approximately 200 acres) surrounding the 200 acre Industrial Area is used for forage production or cattle grazing.

3.2 Climatology and Meteorology

Sequoyah County has a warm, temperate, continental climate. Storms bring ample precipitation when moisture-laden air from the Gulf of Mexico meets cooler, drier air from the western and northern regions. The most variable weather occurs in the spring, when local storms can be severe and bring large amounts of precipitation. The mean annual temperature is 61.5° F. The monthly average ranges from 40° F in January to 82° F in July. The average daily range in temperature is 24° F. The lowest temperature on record was -19° F in January, 1930, and the highest was 115° F in August, 1936. The mean annual precipitation ranges from 42.9 inches in the town of Sallisaw, to approximately 44.1 inches in the northeastern part of Sequoyah County. The seasonal distribution of rainfall is fairly even, with 31% in Spring, 26% in summer, 23% in fall and 20% in winter. The average amount of snowfall from November through April is about 5.2 inches. Lake evaporation averages about 47.5 inches annually. Of this, 72% occurs from May through October. Based on the precipitation and lake evaporation values, there is a net annual evaporation rate of about four inches in the SFC area.

The most severe storms occur in the spring, although thunderstorms are also frequent during the summer months. Strong winds, heavy precipitation, and intense lightning may be associated with these storms. Severe hailstorms are rare and only five damaging hailstorms were recorded in a 42-year period in Sequoyah County. Tornadoes touch down in Sequoyah County on the average of once every six years. During a 92-year period, 25 tornadoes were recorded in the county, with roughly 80% of them occurring from April through June. The probability of any particular point in Sequoyah county being hit by a tornado is 1.66×10^{-3} (the equivalent of once every 600 years).

The nearest Sequoyah County weather station is in the town of Sallisaw, Oklahoma. There is no national weather station in the immediate vicinity. Meteorological data may be obtained from the national weather station at Tulsa, Oklahoma, about 70 miles northwest and at Fort Smith, Arkansas, about 40 miles east. Fort Smith, Arkansas is the closest data station having similar topographic and climatological characteristics as the Facility.

Five-year composite STAR data sets were generated from data collected at Tulsa, Oklahoma, from January 1986 through December 1990 and from Fort Smith, Arkansas, from January 1984 through December 1988. The five-year STAR data for Tulsa and Fort Smith are shown in Attachment I. The Tulsa data shows a predominant north-south wind flow pattern. The wind blows generally from the south approximately 50 percent of the time. Northerly winds are observed nearly 27 percent of the time. The Fort Smith data shows a predominant east-west wind pattern. The wind blows from the east more than 47 percent of the time and from the west approximately 23 percent of the time.

The 90-degree difference in surface wind flow patterns appear to be due primarily to the topography of the region. Tulsa is located in a relatively flat region between the Arkansas and Verdigris Rivers. Both rivers flow in a general north to south direction in the vicinity of Tulsa. The nearest terrain feature to the Tulsa airport, which is 650 feet above mean sea level (msl), is a hill located approximately 6.5 miles to the northwest and rising approximately 885 feet above msl and is aligned in a north-south direction. Consequently, the surface winds are generally north and south.

Fort Smith is located at the base of the Ozark Mountains region along the Arkansas River. There are a number of mountains, hills and ridges in the vicinity of Fort Smith. These terrain features are all aligned in a general east-west pattern. Several long ridge-shaped features are located several miles south of the airport with a maximum elevation of approximately 885 feet above msl. Therefore, the surface winds are generally east and west. The Arkansas River also influences the region. In the vicinity of Fort Smith, the river flows in a meandering west-to-east direction.

The Sequoyah Facility is located near the confluence of the Illinois and Arkansas Rivers at the southwestern edge of the Ozark Mountains region. The Arkansas River flows in a northwest to southeast direction in this region. The wind direction at the Facility is primarily from the southeast. However, during the winter, cold fronts may bring winds from the north or northwest.

Based on the terrain influences, the meteorological data from Fort Smith is the most appropriate for use in modeling the Sequoyah Fuels Facility. In addition, Fort Smith is closer to the Facility than is Tulsa.

Finally, a review of the STAR data sets shows that the Fort Smith data has a higher percentage of stable atmospheric conditions than the Tulsa data. Stable atmospheric conditions usually result in higher modeled concentration, and therefore, provide a more conservative estimate of impacts of airborne emissions from the Facility.

3.3 Geology

Geological interpretation of the Facility area has been well documented over the past 25 years in numerous documents and reports. The geological information acquired from over 300 monitoring wells and over 500 boreholes has provided an extensive amount of site specific technical data which has been reviewed and evaluated. This geological information along with a limited amount of additional information is summarized to complete the geological interpretation for this report.

3.3.1 Regional Geology

The Facility is located on the southwest flank of a large structural feature known as the Ozark Uplift, a major tectonic feature extending from east-central Missouri to northwest Arkansas and northeast Oklahoma. The Arkoma Basin lies immediately to the south and southeast, while the Ouachita Mountains are about 50 miles south of the Facility. The geology in the region consists of Quaternary-age alluvial and terrace deposits along and adjacent to the major rivers in the region. Bedrock formations present in the region consist of Pennsylvanian, Mississippian, Devonian, Silurian, and Ordovician-aged shale, limestone, siltstone, and sandstone formations. The geological formations regionally dip to the southwest (approximately S 45° W) at one to four degrees toward the Arkoma Basin. The terrace deposits at the Facility are underlain by about 390 feet of the Pennsylvanian-age Atoka Formation. The Atoka Formation is underlain by the Pennsylvanian-age Wapanoka Limestone Formation. A detailed description of the deep geology of the area is presented in the Class I Injection Well Report. A geological map of the area and a regional stratigraphic column is presented on Figure 5.

The Atoka bedrock formation generally dips to the south-southwest. Jointing and fracturing are present in this bedrock formation to varying degrees but do not appear to be a prominent feature in these rocks. The silty and sandy shales are much less conspicuously jointed than the purer clay shale, and the observable joints are wavy, irregular, and short. Most of the sandstone beds also lack prominent jointing; where observed, they are short and irregular.

The Carlile School Fault (approximately 1 mile east of MPB) is the nearest structural feature in the immediate area and is located near the Carlile School in the NW 1/4 of Section 22, T12N and R21E as shown on Figure 6. The plane of the fault is not exposed, but its presence is revealed by a low ridge, 200 ft. wide by 20 ft. high, that is a drainage divide between unnamed tributaries of the Salt Branch Creek. The fault ridge is truncated at its northeastern and southwestern ends, and is breached in its central portion by streams that flow west across the fault zone. The fault ridge has a rounded crest with margins that slope less than 8 degrees. Folds and fractures in the Carlile fault zone reflect dip slip drag folding. The Carlile fault zone appears to be an erosional ridge, not a tectonic ridge since no fault scarps are present at the surface. The Carlile School Fault is less than one mile long and has no surface evidence that it connects with any other faults. There is no evidence of any recent movement (<35,000 years) and the fault is not a seismically capable fault. This fault zone probably represents a fault which developed in early Pennsylvanian time (about 320 million years ago). This region, and this fault, has been structurally stable since that time. The Carlile School Fault lies hydraulically upgradient (i.e. groundwater flow direction) and up-dip of geological strata present beneath the Industrial Area.

The Facility lies in a quiet seismic region of the United States. Although distant earthquakes may produce shocks strong enough to be felt in this area, the region is considered to be one of minor seismic risk. The most recent documented subsurface movement to have occurred within the region occurred along the Meers Fault system an estimated 2,000 years ago. This system is located in south central Oklahoma. Other tectonic movements have occurred along the El Reno-Nemaha Ridge, which extends from central Oklahoma through Kansas and into Nebraska. The most recent significant regional tectonic movement occurred in the New Madrid area of Missouri. The probability of significant damage at the Facility from earthquakes is remote.

Minerals in the area consist of coal, limestone/sandstone, sand/gravel from the Arkansas River floodplain, clay and shale. The nearest coal production in the area was approximately nine (9) miles west of the Facility. Several other coal mining operations are presently operating approximately 25 miles southwest of the Facility. There are no known oil or gas fields in the immediate area.

3.3.2 Facility Geology

Facility Soils

According to the USDA Soil Conservation Service (SCS), most of the process area is located over soils of the Pickwick Series. Other soils at the Facility include soils of the Hector Series, Linker Series, Lonoke Series, Robinsonville Series, Rosebloom Series, Stigler Series, Mason Series, Spiro Series, Ender Series, and Vian Series. A soils map of the Facility is shown on Figure 7.

The SCS Map of Sequoyah County, Oklahoma (Abernathy, 1970), shows that the Pickwick loam (PcC2) underlies the Process Area. The Pickwick Series (PcB, PcC, PcC2) consists of deep, moderately permeable, well-drained soils on uplands that form in weathered material from sandstone. Soil of the Pickwick Series typically has a surface layer of loam that is light brownish gray in the upper part and very pale brown in the lower part. A typical profile consists of light brownish-gray loam from 0 to 4 inches, followed by a very pale brown loam from 4 to 10 inches. Beneath this is a reddish-yellow light clay loam from 10 to 14 inches underlain by a reddish-yellow clay loam to 28 inches. From 28 inches to about 68 inches is a coarsely mottled reddish-yellow clay loam followed by a mottled light gray and reddish-yellow clay loam. Soils of the Pickwick Loam Series (PcC2) are typically eroded. Generally, the surface soil layer is 7 to 11 inches thick. This soil is suited to growing of small grain crops, sorghum, and tame pasture. This soil has a moderate corrosivity to uncoated steel and a high corrosivity to unprotected concrete. The individual mapping units PcB, PcC, and PcC2 were identified in this Series. The units PcB and PcC are both similar to the description provided above for the Series, with PcB occurring on 1 to 3% slopes and PcC occurring on 3 to 5% slopes.

The Vian Series (VaB and VaC) consist of deep, moderately slowly permeable, moderately well drained soils on uplands and form in loamy alluvium or loess. Soils of the Vian Series typically have a surface layer of silt loam. The upper part of the subsoil is typically a very pale brown silt loam. Below this is a brownish-yellow silty clay loam, and below this, coarsely mottled light-gray, very pale brown and yellow silty clay loam. Two (2) mapping units (VaB and VaC) of Vian silt loam are found at the Facility. Soil unit VaB occurs on 1 to 3% slopes and VaC occurs on 3 to 5% slopes.

The Stigler Series are deep, very slowly permeable, somewhat poorly drained soils on uplands. These soils typically have a surface layer that is light brownish-gray silt loam about 10 inches thick in the upper part with the lower part being a very pale brown silt loam to 18 to 20 inches. The subsoil is a very pale brown silty clay loam that grades to a brownish-yellow mottled silty clay loam or clay at 45 to 60 inches. The mapping unit present at the Facility (LoD3) consists of Linker and Stigler soils with 2 to 8% slopes and is severely eroded. This mapping unit (LoD3) is typical of the descriptions given for the Linker and Stigler Series soils.

The Mason Series (Ma) consist of deep, moderately permeable, well drained soils in bottomlands. This Series typically has a surface layer of brown silt loam about 12 inches thick. The subsoil is brown silty clay loam extending to 72+ inches. The mapping unit, Mason silt loam (Ma), has 0 to 2% slopes and is typical of the Series.

The mapping unit Hector-Linker-Binder Complex (HEF), 5 to 40% slopes, was also identified at the Facility. The soils in this complex range from stony and very shallow to deep. The Hector Series consist of shallow, rapidly permeable, excessively drained soils on uplands that form in material weathered from sandstone. These soils are typically fine sandy loam to about 14 inches.

Soils of the Ender Series are deep, slowly permeable, moderately well drained and occur on sloping uplands. The soil has a fine sandy loam surface that is grayish-brown in the upper part and very pale brown in the lower part, with a combined thickness of 10 inches. The subsoil is red clay with mottling in the lower part and shale depth ranges from 30 to 55 inches.

The Linker Series consist of moderately deep to deep, moderately permeable, well drained soils on uplands that formed in material weathered from sandstone. These soils are typically loam and clay loam to about 30 inches.

The Lonoke Series consist of deep, moderately to slowly permeable, well-drained soils on bottom lands along the Arkansas River. These soils typically have a surface layer of brown or reddish-brown loam or silty clay loam and a subsoil of light-brown loam. Below the subsoil is a light-brown very fine sandy loam. The mapping unit Lonoke loam, nearly level (LrA), is present on the Facility property and has a description consistent with that for the series noted above.

The Rosebloom Series consist of deep, slowly permeable, poorly drained soils on bottom lands along major streams. These soils typically have a subsurface layer of light brownish-gray silt loam, and the subsoil consists of an upper layer of gray light silty clay loam and a lower layer of gray silty clay loam. Two (2) soil mapping units from this series are found at the Facility, Rosebloom silt loam, occasional flooded, 0 to 1 percent slopes (Rs); and Rosebloom and Ennis soils, broken, 0 to 15 percent slopes (Ru).

The Robinsonville Series consist of deep, moderately rapidly permeable, well drained soils on bottom lands along the Arkansas River. These soils typically have a surface layer of light-brown sandy fine loam and a subsoil of light reddish-brown sandy loam. Below the subsoil is a pink loamy fine sand. The soil mapping unit Robinsonville (RoB), is fine sandy loam.

The Spiro Series consist of moderately deep to deep, moderately permeable, well drained soils on uplands. These materials form from material weathered from sandstone, siltstone, and shale. These soils typically have a surface layer of grayish-brown silt loam and a transitional subsurface layer of brown silt loam. The subsoil is a light yellowish-brown silty clay loam and is underlain by sandstone. The mapping unit Spiro silt loam (SnC) has 2 to 5 percent slopes on the Facility property.

Fill Material

Small amounts of fill material are present in various areas at the Facility. Most of the fill materials are located near the MPB area immediately adjacent to buried lines and as sub-base to concrete floors, concrete and asphalt roads, and concrete storage pads. The fill material immediately surrounding the buried utility lines consists mostly of silty sand and silty gravel. A silty clay and/or weathered shale fill material typically overlies the coarser sands and gravels in the utility line trenches. The fill material in the buried utility line trenches occurs from depths of about 0 to 20 feet but averages 5 to 7 feet in thickness and depth. The fill materials beneath the concrete floors, concrete storage pads, and roadways consist mostly of silty sand, sandy clay, sandy gravel, silty clays, and weathered shale that reach a maximum thickness of about 1.5 feet. Fill material also occurs in surface impoundment dikes. These materials consist mostly of clays and reach thickness of up to 20 feet.

Terrace Deposits

A thin veneer of Quaternary-age Pleistocene terrace deposits covers most of the Process Area's surface where fill materials are not present. The terrace deposits consist mostly of silts, sandy silts, silty clays, sandy gravelly clays, silty sandy clays, and clays which overlie the shale and sandstone units of the Atoka Formation. The terrace deposits are remnants of extensive deposition during historical high water stages of the Illinois and Arkansas Rivers thousands of years ago. Downcutting by the river systems has left these deposits high above the present day river valley. From their maximum thickness on the hill tops in the area (including the MPB), the terrace deposits occur between depths from 0 to 16.4 feet and thin rapidly (average about 6.7 feet). The terrace deposits are thickest (16.4 feet) near the southwest corner of the MPB and thin in all directions away from this area. Beneath the MPB, the terrace deposits increase in thickness southward from the north side of the MPB where the terrace deposits range from about 0 to 2 feet in thickness, to about 8 feet on the southeast side of the MPB and about 16 feet on the southwest side. The terrace deposits range in thickness from 5.0 to 8.7 feet in the SX Building area. The terrace deposits exceed 10 feet in thickness near the south Yellowcake Sump area, the Emergency Basin, North Ditch, Sanitary Lagoon area, the southwest corner of the MPB, and near the east property boundary. The terrace deposits are less than 5 feet thick immediately north of the MPB, the Storm Water Reservoir area, northwest of the Fluoride Holding Basin No.2, south of Pond 2, and north of Pond 2. A depth to bedrock isopach map showing the thickness of the terrace deposits in the Industrial Area is shown on Figure 8. A bedrock geologic surface map useful for identifying the stratigraphic sequence beneath a given area at the Facility is shown on Figure 9.

Alluvial Deposits

Quaternary-age alluvial deposits are present beneath the western-most and southern areas of the Facility as shown on Figure 9. The alluvium was deposited by the present-day Arkansas and Illinois Rivers along their courses. The alluvial deposits beneath the Facility consist of silts, clays, sands, gravels, and combinations of these materials. Generally, these deposits range in thickness from 0 to 50 feet, but many reach thickness of 100 feet in the region. At the Facility, the alluvial deposits have been penetrated by approximately 15 borings. Lithological data from these borings indicate that the alluvial deposits are at least 33 feet thick and consist mostly of silts and clays. Directly above the bedrock there is often a clayey sandy gravel or gravelly sandy clay one to three feet thick. At one location southwest from the fertilizer ponds, the alluvial deposits contained significantly more sand than at other areas on the Facility property. The alluvial deposits overlie small portions of Unit 3 sandstone and shale; and Unit 4 shale, where there is the potential for limited hydraulic communication to occur. The alluvial deposits are not in hydraulic communication with the terrace deposits, or the Deep Bedrock Groundwater System.

Atoka Formation

Immediately underlying the terrace and alluvial deposits at the Facility is the Pennsylvanian-aged Atoka Formation. The Atoka Formation is characterized by very irregularly bedded units of sandstone, siltstone, and shale with thin limestones in the lower part. It is common for sandstone units in the Atoka to channel cut into underlying formations. Approximately 390 feet of the Atoka Formation is present beneath the Facility. Near the base of the Atoka Formation is the Spiro Sandstone member. This member occurs from about 300 to 370 feet below ground level (bgl) and contains naturally occurring salt water. The base of the Atoka Formation (390 feet below the surface) rests on an unconformity at the top of the Wapanoka Limestone Formation. The Wapanoka limestone outcrops about 10 miles northeast of the Facility and the top of the Atoka, marked by the Hartshorne Sandstone, outcrops about 6 miles southwest of the Facility. The Hartshorne Sandstone is not present in the Facility area.

Regional dip is generally to the southwest, which is also the direction of thickening of the Atoka. The members of the Atoka exposed at the Facility are about in the middle of the Formation.

A structure map showing the elevation of the Atoka bedrock surface is shown on Figure 10 for the Process Area. This structure map of the bedrock surface indicates that the bedrock slopes toward the northwest, west, and south-southwest from the bedrock high located in the MPB area. The total relief noted on the bedrock surface is about 91.6 feet, ranging from elevation 564.7 feet above mean sea level (AMSL) in BH083 to 473.12 feet AMSL in BH105. This represents a slope of 2.8 percent or a vertical drop of about 2.8 feet per 100 feet of horizontal distance. The bedrock surface map was prepared since perched groundwater appears to follow the slope of the bedrock surface.

The depth to bedrock near the Industrial Area occurs from about 0 to 16.4 feet below ground level. The bedrock (Atoka Formation) beneath the Process Area consists of a shale unit designated as Unit 1 Shale. The thickness of this uppermost Unit 1 Shale ranges from a maximum of 20.1 feet near the northwest corner (BH064) of the MPB to zero where it is not present. The thickest areas of the Unit 1 Shale are found in the SX Building area, the MPB area, and the area west and north of the MPB. The shale thins to the west, north, and south from the MPB area. The Unit 1 Shale is typically dark grayish brown, fissile, silty and sandy near the contacts with adjacent sandstone units. This unit is laterally continuous at the Facility until it is no longer present in the stratigraphic sequence due to its removal by erosion. The thickness of this shale unit is important since it inhibits the downward or upward movement as well as the horizontal movement of groundwater or associated contaminants.

A possible eroded paleo-channel surface on the Unit 1 Shale was noted to begin near the southwest corner of the MPB and trend south-southwesterly. (See Figure 10) This possible paleo-channel is found at the same location where an intermittent drainage was once located and is likely related to an old stream channel. No other major paleo-channels were found at the Facility.

Located beneath the Unit 1 Shale is a highly cemented, very fine to medium-grained, pale brown to dark gray sandstone. This sandstone, referred to as Unit 1 Sandstone, is laterally continuous across most of the Process Area and ranges in thickness from 0 to 12.5 feet (averages about 4 feet in thickness) and occurs between depths of about 2 feet to 27.5 feet. The Unit 1 Sandstone is thickest near the southeast and northeast corners of the MPB and generally thins where it is eventually removed from the section through erosion.

Beneath the Unit 1 Sandstone is an alternating sequence of laterally continuous sandstone and shale units which have been numbered sequentially as Unit 2 Shale, Unit 2 Sandstone, Unit 3 Shale, Unit 3 Sandstone, etc. These individual units have been characterized to a depth of about 90 feet beneath the MPB.

The shale and sandstones for these deeper units have similar lithologies as those described for the Unit 1 Shale and Unit 1 Sandstone. Geotechnical investigations indicate that these units are laterally continuous beneath the Process Area. The Unit 2 Shale ranges in thickness from 2.6 to 9.8 feet (average 5.2 feet) and occurs between depths of 8 to 32.5 feet. The Unit 2 Shale is dark gray to light brownish gray, fissile, sandy, silty and contains thin laterally discontinuous silty sandstone lenses. Unit 2 Sandstone is dark gray to very dark gray, very fine grained, quartzose and well cemented in the upper portion. This laterally continuous unit in the Process Area contains laterally discontinuous beds of silty shale up to 3.8 feet thick. The discontinuous shales are yellowish brown to dark gray, sandy, thin bedded to platy and fissile. The lower portion of the Unit 2 Sandstone is dark gray to medium gray poorly cemented to highly cemented and shaley. The Unit 2 Sandstone ranges in thickness from 3 to 14.3 feet (average 5.0 feet) and occurs between depths of 5.7 to 38 feet below ground level in the Process Area.

Underlying the Unit 2 Sandstone is the Unit 3 Shale which is very dark gray, sandy to silty, carbonaceous, and contains thin discontinuous sandstone layers. Unit 3 Shale is laterally continuous across the Process Area, varies in thickness from 1 to 18 feet and is found between depths of 17 to 45 feet. Unit 3 Sandstone varies in thickness from 1.5 to 3.0 feet and is found between depths of 30 to 45 feet. This sandstone is highly cemented, very fine grained, very dark gray and very hard.

Unit 4 Shale is dark gray to grayish black, fissile and becoming sandy near the lower contact. Unit 4 Sandstone is medium gray to dark gray, very fine grain dense quartz sand, silicious and has a very abrupt lower contact with the Unit 5 Shale. Unit 4 Sandstone ranges in thickness from 15.5 to 18.1 feet and is found between depths of 23.4 to 71 feet.

Unit 5 Shale is dark gray to grayish black, fissile and soft. The Unit 5 Shale has only been penetrated by 10 boreholes. Based on lithological information taken from these borings, the shale is greater than 22 feet thick and is found at depths from 38 to greater than 92 feet.

Selected geological cross-sections (A-A' and B-B') were prepared through the Facility which provide the stratigraphic relationships of each lithological unit encountered between the headwaters of the Robert S. Kerr Reservoir to the Carlile School Fault as shown on Figure 11.

Geological cross section A-A' (Figure 11) is a west to east geological cross section that passes beneath the Process Area eastward to the Carlile School Fault. This cross section clearly shows the various geological units beneath the Process Area, the stratigraphic relationship between these units, and the dip of these units (about 1° to the west-southwest). Figure 11 also shows a north-south geological cross section B-B'. This cross section extends from the north portion of the Process Area southward to the Fertilizer Pond area. The location of each of these cross sections is also presented on Figure 11.

3.4 Hydrogeology

Regional flow of groundwater in the Facility area is generally westward toward the Arkansas or Illinois Rivers, which are potential discharge points for shallow groundwater beneath the Industrial Area. Groundwater may also discharge through springs, evapotranspiration, or recharge to other strata. The Atoka Formation and terrace deposits of the area are likely recharged from precipitation falling over their respective outcrop areas, and to a lesser degree, recharge from underlying formations.

3.4.1 Regional Hydrogeology

Groundwater in the region occurs principally in the thicker alluvial and terrace deposits of the Arkansas, Illinois, and Canadian Rivers. Groundwater also occurs to minor quantities in the Pennsylvanian-age Atoka bedrock formations. The only major bedrock aquifer nearby occurs approximately 10 miles northeast of the Facility which is the Keokuk and Reed Springs formations of Mississippian-age. This aquifer is capable of yielding between three (3) to fifty (50) gallons per minute (gpm) of good quality water. The locations of the Facility with respect to the aquifer is shown on Figure 12. The Facility is located downgradient of these formations.

The only significant fresh water aquifer in the immediate Facility area is the alluvium aquifer deposited along the Arkansas and Illinois Rivers. The lower part of the alluvium consists of up to 15 feet of coarse sand and gravel with a productivity of as much as 900 gpm. The water is classified as "hard to very hard" (greater than 180 mg/l total hardness), but is suitable for irrigation and watering stock.

Although the Facility is located near the edge of this alluvial aquifer, the geological units beneath the Industrial Area are considered least favorable for development of groundwater supplies. Groundwater in the local area is described in United States Geological Survey publications as being of poor to fair quality and considered least favorable for groundwater development (Marcher, 1969). The Facility does <u>not</u> overlie a major alluvial or bedrock aquifer. A map showing the Facility with respect to the major alluvial aquifer is shown on Figure 13. A map showing the general quality of groundwater in the Facility area is provided on Figure 14.

Groundwater in the local area occurs in limited quantities in the Quaternary-aged terrace deposits and within the deeper interbedded sandstones and shales in the Atoka Formation. Because of the very low permeability of the Atoka strata, it is likely that a high percentage of the rainfall is lost by surface runoff. A map depicting the availability of groundwater in the area is shown on Figure 15.

In September 1990, the OSDH sampled seven (7) domestic groundwater supply wells in the general vicinity of the Sequoyah Facility. The sampling effort was initiated at the request of the landowners. These samples were collected by OSDH personnel and analyzed at the State of Oklahoma Environmental Laboratory, Radiochemistry Laboratory, for analyses of gross alpha, gross beta, and in one case, for uranium and radium-226. The analytical results indicate that all water well samples were below the EPA Primary Drinking Water Maximum Permissible Concentrations established for gross alpha of 15 pCi/L, gross beta of 50 pCi/L, and radium-226 of 5.0 pCi/L.

SFC and the Oklahoma State Department of Health (OSDH) initiated a survey in 1991 to identify any water wells which may exist within an approximate 2-mile radius from the MPB. This survey consisted of contacting landowners who live within this 2-mile radius area and requesting permission to sample any water well that may have existed on that property. In addition, SFC conducted an extensive search of old home sites located on SFC or Sequoyah Fuels International Corporation (SFIC) property to determine if there are any water wells on these properties. The U.S. Geological Survey water well database for Sequoyah County, the Oklahoma Water Resources Board (OWRB) files, wells identified in the Reconnaissance of the Water Resources of the Fort Smith Quadrangle Hydrological Atlas 1, and wells identified by a visual inspection of properties in the 2-mile radius area were also reviewed. No water well records were on file with the OWRB for wells within 2 miles of the Facility. Correspondence to this effect has been received from the OWRB which was included in the FEI.

Water wells identified through the above-described survey and their current use are shown on Figure 16. There were a total of ten (10) water wells identified on SFC or SFIC properties. Nine (9) of these wells are not in use and one (1) well, SFC-4, is used for irrigation purposes only.

The Reconnaissance of the Water Resources of the Fort Smith Quadrangle Hydrological Atlas 1 identified a water well believed to be at an old home site in the NW, NW of Section 27, T12N, R21E which appears to have good water quality. This well apparently had a depth of 84 feet, a static water level at 29 feet, and a yield of 1 gpm. The water quality of this well is better than average for the Atoka formation, having approximately 460 mg/l total dissolved solids. This well is apparently abandoned and was not found during the area-wide off-site water well survey conducted May 9-10, 1991. In contrast, water wells drilled at the three former home sites along State Highway 10 did not supply adequate water for domestic purposes. There are a few domestic/stock wells in the area that were used prior to the establishment of rural water district service. However, most of these wells are no longer in use. The Sequoyah County Rural Water Association now supplies potable water to most area residents and Sequoyah Fuels from the Lake Tenkiller Reservoir located about 7 miles to the north. The Facility does not use groundwater resources.

A total of twenty-three (23) off-site water wells were sampled. The OSDH and SFC sampled eighteen (18) off-site wells on May 9 and 10, 1991 (including two (2) wells previously sampled by the OSDH on September 6, 1990). The off-site residence well sampling program, performed jointly by OSDH and SFC, characterized the eighteen (18) wells sampled to include ten (10) wells currently in use for either livestock or domestic purposes, seven (7) wells that are no longer in use and one (1) well that has an unknown current use.

The water wells located on SFC and SFIC properties varied in depth from 12.8 feet (SFC-6) to 132.7 feet (SFC-8). Most wells are constructed of 6-inch PVC. The off-site residence water wells vary in depth from 26.4 feet to greater than 200 feet, and are generally constructed of 6-inch PVC.

There were no identifiable groundwater users between the Facility and the Illinois and Arkansas Rivers, the possible groundwater discharge point for the shallow bedrock groundwater system. No apparent or known impacts to current or past groundwater users have occurred as a result of the Sequoyah Facility operation.

3.4.2 Facility Hydrogeology

There are three hydraulically separate groundwater flow systems beneath the Facility. These groundwater flow systems are the:

- Terrace Groundwater System (perched),
- Alluvial Groundwater System
- Atoka Bedrock
    - Shallow Bedrock Groundwater System (Unit 2 to Unit 4 shale), and
    - Deep Bedrock Groundwater System (Unit 5 Shale).

Site specific data indicate that the shallowest groundwater system is a perched Terrace Groundwater System developed either within the terrace deposits on top of the Atoka bedrock or within the Unit 1 Shale depending on the saturation state of the terrace deposits. This perched groundwater system is in hydraulic communication with the Unit 1 Shale directly beneath the terrace deposits, when present. Very little, if any, hydraulic communication occurs between the perched groundwater in the terrace deposits and underlying sandstone (Unit 1 Sandstone). The water quality within this formation is very poor and yields very little to no groundwater. This formation is considered to be a very poor groundwater system because the soil cover is thin and has poor permeability. Much of the terrace deposits in the local area are unsaturated and therefore are not capable of yielding groundwater. Thus, recharge to this formation is limited because of its aerial extent and the underlying sandstone and shale beds require fracturing to provide storage capacity. Even though most perched groundwater systems generally would not be considered as part of the uppermost groundwater flow system, this perched groundwater has been evaluated.

<u>Terrace Groundwater System</u>

The first groundwater encountered beneath the Facility is the Terrace Groundwater System (Terrace Deposits, Unit 1 Shale). The Terrace Groundwater System generally occurs from depths of 0 to 20 feet. Water level measurements taken during 1998 were essentially the same as those in previous years, (i.e. 1991 - 1997). The terrace deposits were saturated over a portion of their thickness near the MPB. There were several areas at the Facility where the terrace deposits were not saturated, specifically the Pond 2 area, southwest and west of the Fluoride Holding Basin No. 2, around the SX building and west to and including the Clarifier Basins area, along the southern sides of Pond 2 and the Fluoride Holding Basin No. 1, and all along the northern portion of the Facility near the restricted area boundary. The portion of the terrace deposits where the groundwater saturation is the thickest is in the southwest corner of the MPB in the area of the paleochannel developed in the Unit 1 shale (See Figure 10).

The depth-to-groundwater at the Facility is variable, but generally decreases from northeast of the MPB toward the south, west, and northwest. The depth to groundwater varies from about 8 to 11 feet beneath the SX Building and 5 to 12 feet beneath the MPB.

The groundwater potentiometric surface (March, 1998) for the perched groundwater in the terrace deposits indicates groundwater flows radially away from the MPB as shown on Figure 17. The configuration of the Terrace Groundwater System surface is nearly identical to the Atoka bedrock surface configuration. This suggests the configuration of the bedrock surface greatly influences the groundwater flow. The groundwater contained in the terrace deposits is under unconfined conditions and generally is perched on the bedrock surface in most areas. The groundwater flow in this system has been shown to be consistent over the long-term, with no significant changes in flow noted since 1990. The Carlile School Fault is upgradient or cross gradient from the groundwater flow system developed in the terrace deposits and therefore, groundwater cannot move toward the Carlile School Fault from the Process or Industrial Area, through the terrace deposits.

The perched Terrace Groundwater System is not in hydraulic communication with the alluvial deposits or with the underlying Shallow Bedrock Groundwater System. The terrace deposits do not overlie, nor are they in lateral contact with the alluvial deposits. The Terrace Groundwater System is hydraulically separated from the Shallow Bedrock Groundwater System by the Unit 1 sandstone. This sandstone forms an aquitard in the Facility area and underlies the Terrace Groundwater System.

Since groundwater in the perched terrace deposits occur under unconfined conditions, artificial groundwater recharge is believed to be partly responsible for the saturation of the terrace deposits in the MPB area. Significant artificial groundwater recharge occurred historically in these terrace deposits from leakage of fresh-water fire-water lines and unlined basins.

Alluvial Groundwater System

The alluvial groundwater system underlies the extreme western portion of the Facility as shown on Figure 9. Groundwater in the alluvium of the Arkansas and Illinois River is the only significant fresh water aquifer in the Facility area. The groundwater quality in the alluvial deposits is classified as "hard to very hard" (greater than 180 mg/L total hardness), but is suitable for irrigation and watering stock. Regional yields from the alluvial deposits generally vary from 10 to 900 gpm, but higher yields have been reported in some areas. Beneath the SFC Facility, the alluvial deposits are at least 33 feet thick and consist mostly of silt and clays, with local areas where sand is present. The alluvial deposits thicken to the west and south toward the Illinois and Arkansas River, respectively. Groundwater in the alluvium flows to the west and south and toward the Illinois and Arkansas Rivers, respectively. The alluvial deposits are recharged over their outcrop area, and are in limited hydraulic communications with small areas of Atoka Unit 3, and Atoka Units 4 and 5 along the western portion of the Facility. Site-specific data indicates that groundwater production in the alluvial deposits in the Facility areas likely range from 1 to as much as 10 gpm. A yield test conducted on a SFC monitor well in the alluvial deposits southwest of the fertilizer ponds showed short term yields of approximately 7 gpm. There are no known users of groundwater from the alluvial deposits in the Facility area.

The Alluvial Groundwater System overlies small portions of Atoka bedrock Unit 3 sandstone and shale, and Units 4 and 5, where these are the potential for limited hydraulic communication to occur. No alluvial deposits are thought to overlie Atoka bedrock Units 1 and 2. The Deep Bedrock Groundwater System or any subsequent deeper Atoka bedrock groundwater are hydraulically separated by the impermeable Unit 4 sandstone.

Shallow Bedrock Groundwater System

Beneath perched Terrace Groundwater System, but separated by a dense, low permeable, highly cemented, sandstone (Unit 1 Sandstone), is an interbedded shale and sandstone sequence referred to as the Shallow Bedrock Groundwater System (Unit 2 Shale, Unit 2 Sandstone, Unit 3 Shale, Unit 3 Sandstone, Unit 4 Shale). The Shallow Bedrock Groundwater System typically occurs at depths of 10 to 40 feet, depending upon the location at the Facility.

Water level measurements taken during 1998 were essentially the same as those in previous years (i.e. 1991 - 1997). The potentiometric surface map for the Shallow Bedrock Groundwater System shows that the groundwater in the interbedded sandstone and shale strata underlying the terrace generally flows to the southwest, west, and northwest in the Industrial Area as shown on Figure 18. The Carlile School Fault is upgradient from this groundwater flow system and, therefore, groundwater cannot move toward the Carlile School Fault from the Industrial Area.

The interbedded sandstone and shale bedrock sequence beneath the Unit 1 Sandstone is under confined conditions and there appears to be no major communication with the groundwater contained within the overlying shale or terrace deposits. In fact, this sandstone is very dense, highly cemented, very fine grained, and has very little primary or secondary porosity through which groundwater can move. Groundwater in the Shallow Bedrock Groundwater System principally occurs in Unit 2, Unit 3, and Unit 4 shale, with very little, if any, groundwater occurring in the highly cemented sandstones.

The Shallow Bedrock Groundwater System is separated from the Deep Bedrock Groundwater System by the Unit 4 sandstone. Vertical permeability measured in the Unit 4 sandstone were $<9 \times 10^{-9}$ cm/sec and 1.9×10^{-8} cm/sec. There is no hydraulic communication between the Shallow and Deep Bedrock Groundwater Systems.

Deep Bedrock Groundwater System

A third water-bearing horizon was investigated and is referred to as the Deep Bedrock Groundwater System. This groundwater system is a shale strata (Unit 5 Shale) that is separated from the Shallow Bedrock Groundwater System by a dense, low permeable, highly cemented, non-porous sandstone (Unit 4 Sandstone). The Deep Bedrock Groundwater System typically occurs at depths of 5 to

60 feet, depending upon the location at the Facility, and has a maximum thickness penetrated of approximately 33 feet.

A groundwater potentiometric map of the Deep Bedrock Groundwater System prepared from water level measurements collected in March, 1998 shows flow to the west and southwest, as shown on Figure 19, at a gradient of about 0.014 feet/ foot. This incidentally is nearly the same number as the average dip of the geological strata in the area, which indicated that groundwater flow is likely controlled by the bedrock structure. This direction is consistent with the shallow bedrock and perched terrace groundwater flow systems. These groundwater flow directions also appear to be controlled by the structure of the geological strata (dip of beds and erosional surface). Therefore, groundwater cannot move toward the Carlile School Fault from the Industrial Area.

3.4.3 Horizontal Hydraulic Conductivity Testing

There is a significant difference in groundwater potentiometric surfaces between the perched terrace water bearing formation, the shallow bedrock formations, and the deep bedrock formations monitored, which is evidence for hydraulic separation of these three water bearing zones. There were four areas identified at the Facility where groundwater from the shallow bedrock sandstone/shale sequence had a higher vertical potentiometric surface elevation than the perched terrace groundwater. In these areas, groundwater from the shallow sandstone/shale sequence has an upward flow gradient. The areas occur in the Emergency Basin and North Ditch area toward the Fluoride Holding Basin No. 2; the Decorative Pond area and south of the South Yellowcake Sump; and an area near well at the northeast corner of the MPB. These areas appear to be associated with the old drainages or low topographical areas that were present naturally. It is significant to note that because there is an upward flow gradient in these areas, groundwater in the terrace deposits should not move vertically and recharge lower groundwater zones in these areas. However, over most of the Facility, there is a slight downward gradient from the perched Terrace Groundwater System toward the Shallow Bedrock Groundwater System.

There is also a significant hydraulic head difference between the Shallow Bedrock Groundwater System and the Deep Bedrock Groundwater System. The Deep Bedrock Groundwater System wells are all completed in the Unit 5 shale, and groundwater in this formation occurs under confined conditions. The overall head difference between the Shallow Bedrock Groundwater and Deep Bedrock Groundwater Systems vary from 22.72 feet to 6.27 feet. Overall, there is a vertical downward head between the Shallow Bedrock and Deep Bedrock Groundwater System which is additional evidence that the Unit 1 sandstone and Unit 4 sandstone act as confining units for the more permeable shale units.

Slug tests were conducted on 14 terrace wells and 21 shallow bedrock wells at the Sequoyah Facility during the FEI in 1991 and 1992. The permeability or horizontal hydraulic conductivity of the terrace and/or uppermost shale deposits (perched terrace groundwater) ranged from a maximum of 1.28×10^{-2} cm/sec to a minimum of 2.07×10^{-7} cm/sec. The geometric mean from the 14 wells was 2.02×10^{-5} cm/sec. The hydraulic gradient in September, 1994 in groundwater contained in the perched terrace deposits is variable over the Sequoyah Facility and ranges from about 0.007 to 0.03 feet/foot and averages 0.012 across the Sequoyah Facility. The hydraulic gradient averages about 0.03 feet/foot on the south side of the MPB and about 0.007 feet/foot in the vicinity of the MPB and SX Building. The effective porosity for the fractured shale directly beneath and in communication with the terrace deposits unit is estimated at 0.05 or 5 percent. Based upon these values, the average groundwater flow velocity was calculated using Darcy's flow equation:

$$V = KI/n$$

where:

V = average flow velocity, cm/sec

K = hydraulic conductivity, cm/sec

I = hydraulic gradient, feet/foot

n = effective porosity, dimensionless

The average groundwater flow velocity in the perched terrace flow system at the SFC Facility is variable and largely dependent upon the degree and interconnection of fracturing present in the uppermost shale and the extent of the saturated portion of the terrace deposits. The average groundwater flow velocity in the perched Terrace Groundwater System was calculated at 0.014 feet/day or about 5 feet/year, but may vary locally from about 2 feet per year to 16 feet/year.

The slug test results conducted on the Shallow Bedrock Groundwater System indicated that the horizontal hydraulic conductivity of this geologic sequence ranged from a minimum of 4.47×10^{-6} cm/sec to a maximum of 3.49×10^{-4} cm/sec. The geometric mean from the slug tests conducted on the 21 Shallow Bedrock Groundwater System wells was 6.76×10^{-5} cm/sec. The horizontal hydraulic gradient in the Shallow Bedrock Groundwater System averaged 0.027 feet/foot but ranged from 0.06 feet/foot to 0.01 feet/foot in the MPB and SX Building areas. The effective porosity for this system was estimated at 0.05 or 5 percent. Based upon these values, the average groundwater flow velocity in the Shallow Bedrock Groundwater System was calculated at 0.10 feet/day or about 37 feet/year, but may locally vary from 8 to 112 feet/year. Slug test data from the wells in the Shallow Bedrock Groundwater System can also be found in the FEI.

Slug tests were also conducted for four of the Deep Bedrock Groundwater System wells. The horizontal hydraulic conductivity of this geological sequence ranged from a minimum of 7.3×10^{-7} cm/sec to a maximum of 2.4×10^{-5} cm/sec. The geometric mean from the slug tests conducted on the four deep bedrock wells was 2.6×10^{-6} cm/sec. The horizontal hydraulic gradient in the Deep Bedrock

Groundwater System averaged 0.017 feet/foot. The effective porosity for this zone was estimated at 0.05 or 5 percent. Based upon these values, the average groundwater flow velocity in the Deep Bedrock Groundwater System was calculated at 0.0025 feet/day or about 0.91 feet/year, but may locally vary from 0.26 to 16.5 feet/year.

Groundwater flow in units investigated to depths of 90 feet are all to the west, northwest, or southwest; the Carlile Fault is located east and southeast, and upgradient from these areas. Groundwater cannot move toward the Carlile School Fault area from the Process or Industrial Areas based upon the evaluation of all data collected at the Facility.

It is important to note that all of the deep bedrock monitor wells were installed in the Unit 5 Shale, and this shale unit was continuous throughout the Facility, as was the Unit 4 sandstone (except where it is eroded to the west), an aquitard in the area.

3.4.4 Vertical Hydraulic Conductivity Testing

On March 2, 1995, hydraulic conductivity field tests were conducted to evaluate the permeability of the lower confining sandstone (Unit 4 sandstone) at well MW007B. Approximately 24 hours following installation of the six-inch PVC conductor casing at well location MW007B, the borehole was advanced approximately two feet beneath the base of the conductor casing into the Unit 4 sandstone. The borehole was monitored for two hours for groundwater entry. Monitoring was conducted using an electric water-level meter. Following the two hour monitoring period, during which time no groundwater was observed to enter into the borehole (borehole was dry), a 15 psi pressure transducer was lowered into the drilled borehole, and deionized water was introduced into the borehole to perform a falling head slug test. A column of deionized water, (approximately 15 feet) was introduced and monitored for fluid level changes for two hours using an In-Situ Hermit, Model SE 1000B data logger. During the two hour monitoring period, the depth-to-water in the borehole decreased from 55.50 feet to 55.34 feet (0.16 feet) indicating that a rise in the water level occurred. The exact cause for the rise in water level is unknown. However, the rise may be attributed to moisture (i.e., condensation on the inside of the PVC) or atmospheric pressure change. During the test, the ambient atmospheric temperature increased and approximately five inches of snow accumulated on the ground. It is very important to note that there was <u>no</u> loss of water into the sandstone formation during this test, indicating that this strata was indeed impermeable. The vertical permeability tests discussed below confirmed that this sandstone unit is an aquitard.

On March 3, 1995, the USEPA requested samples of rock core from well MW007B to conduct physical laboratory tests. Two core samples from monitor well MW007B, (Sample 2, 63.00 to 63.57 feet, and Sample 1, 66.15 to 66.50 feet), were tested by Core Laboratories, Dallas, Texas. These samples were tested for vertical permeability, porosity, and grain size. The results from these vertical permeability tests indicate that Unit 4 sandstone Sample #1 had a vertical permeability of 0.022 milli-darcy (1.9×10^{-8} cm/sec) and Unit 4 sandstone Sample #2 had a vertical permeability of <0.01 milli darcy (<9 x 10^{-9} cm/sec). These permeability tests showed that this lower sandstone unit was very tight and would act as an aquitard in the Facility area.

3.5 Surface Water Hydrology

The Facility is located on the east bank of the headwaters of the Robert S. Kerr Reservoir along the Illinois River tributary approximately 2.5 miles south-southeast of Gore, Oklahoma. The Illinois River tributary flows in a southwesterly direction about 1 mile to join the Arkansas River tributary of the Robert S. Kerr Reservoir approximately 2 miles downstream from Webbers Falls, Oklahoma. The Illinois River is part of the reservoir near the Facility and the flow is regulated by releases from Tenkiller Ferry Reservoir, which is located on the Illinois River approximately 7 miles upstream of the Facility. The average flow of the Illinois River near the Facility is 1,600 cubic feet per second (cfs).

The Facility setting can be generally described as located on a hillside above the reservoir headwaters with a floodplain on the opposite or west side. Over 1,600 square miles drain into the Illinois River in the local area. The entire Facility drains to the headwaters of the Robert S. Kerr Reservoir. The principal Facility drainage consists of the Facility effluent, identified as the Combination Stream, and storm water which flows west in an unnamed tributary to the Robert S. Kerr Reservoir.

3.5.1 Area Surface Water

Because of the rugged nature of the watershed and the spring-fed streams in the area, the Illinois River carries less sediment than other major rivers entering the Arkansas River in Oklahoma. Thus, the natural quality of the two river systems are quite severe in contrast. The much clearer Illinois River is fed by releases from Lake Tenkiller Ferry Reservoir and by runoff from the steeper and rockier lands of eastern Oklahoma, while the Arkansas River carries much more turbidity from its course through the farming areas of Colorado, Kansas and Oklahoma. The Illinois River near the Facility has an average specific conductance of 170 microsiemen per centimeter (µS/cm) and a turbidity of 3 Jackson Turbidity Units (JTU). Downstream at the Robert S. Kerr Dam, the average values for these parameters are 600 µS/cm and 15 JTU. Comparison of other water quality parameters of the Illinois River in the vicinity of the Facility with the Oklahoma standards for drinking waters are shown in Table 1.

3.5.2 Facility Surface Waters

The Decorative Pond and the Storm Water Reservoir are the only non-process surface impoundments within or downgradient of the Process Area located within the Facility. The Decorative Pond, located south of the MPB is used for aesthetic purposes only. The pond is fed by a pipeline from SFC's raw water supply (Lake Tenkiller), and therefore, does not receive storm water runoff or process discharges. The Storm Water Reservoir currently receives storm water runoff from non-process areas. The headwaters of the Robert S. Kerr Reservoir (the Illinois

River Branch) are downgradient and, except for a narrow strip managed by the Corps of Engineers, border the entire western boundary of the Facility.

There are also eight small man-made farm ponds of less than ½ acre located within the Facility and outside the Industrial Area. For identification purposes herein, these farm ponds have arbitrarily been numbered and are located using distance and direction from the center of the MPB. The eight farm ponds are shown on Figure 20 and identified as follows:

- Farm Pond 1: 3400 feet south;
- Farm Pond 2: 3100 feet south-southwest;
- Farm Pond 3: 3100 feet south-southwest;
- Farm Pond 4: 3700 feet southwest;
- Farm Pond 5: 5500 feet southwest;
- Farm Pond 6: 3650 feet west-southwest;
- Farm Pond 7: 2250 feet north-northwest; and
- Farm Pond 8: 1150 feet north.

None of the farm ponds receive storm water runoff or discharges from the Process Area.

4.0 Extent and Concentration of Contamination

This chapter describes the characterization conducted at SFC to determine the extent and concentration of contamination at the Facility. The Facility operations are described along with the identification of source characteristics associated with various processes. The radiological, chemical and physical characterization for surface water and sediments, soils, groundwater, structures and equipment, and wetlands monitoring are also described. The final sections discuss the findings and conclusions from the characterization effort and the data quality assessment.

4.1 Background Media Investigation

The background media investigation involved the collection of representative soil and groundwater samples to report background levels for total uranium, radium-226 and thorium-230.

4.1.1 Soil Background Evaluation

A total of thirty-one (31) background soil samples were collected from locations outside the Facility. Sample locations were selected based on owner permission, land use and management, vegetation cover, absence of debris and accessibility. Sample locations were selected such that anthropogenic influences were minimized. Drainage pathways, paved surfaces, railroads and agricultural (cropland) areas were avoided. Figure 21 shows the location of each background soil sample.

Soil samples were collected utilizing either a hand auger or split barrel core sampler. Vegetation and surface debris were removed prior to collection of each soil sample. Samples were placed into appropriate containers, a chain-of-custody completed and submitted to the laboratory for analysis. Background sample analytical results have been compiled for each parameter and are included in Table 2.

SFC identified a problem with thorium-230 and radium-226 laboratory analyses during the 1995 characterization effort and proceeded to work with the laboratory performing the analysis in an effort to resolve the problem. However, this laboratory went out of business and SFC was required to change laboratories. After submitting site characterization samples to the new laboratory for reanalyses along with a soil standard containing uranium, thorium-230 and radium-226, a problem was discovered with the thorium-230 analyses in source, sediment and soil samples at the new laboratory also. SFC proceeded to work with this laboratory in an effort to resolve the problem so that the thorium-230 and radium-226 analyses performed by this laboratory could be corrected and used for site characterization. During this period, SFC submitted some of the same samples to a third laboratory which had demonstrated the ability to accurately detect thorium-230 and radium-226 in the known standard. Through comparison of analyses on the duplicate samples and standards of both laboratories, SFC has disqualified the second laboratory and will submit all future source, sediment and soil samples to the third laboratory for thorium-230 and radium-226 analyses. Consequently, most of the data collected on these two analytes and reported in the draft SCR has been discarded and removed from the characterization data set. Background sample results were included in the discarded data. Therefore, additional sampling will be required to complete the characterization with respect to thorium-230 and radium-226.

4.1.2 Groundwater Background Evaluation

Background groundwater characterization was accomplished by utilizing terrace groundwater system wells MW005, MW007 and MW072, shallow bedrock groundwater system wells MW005A, MW007A and MW072A, and deep bedrock groundwater system wells MW007B and MW072B. The terrace and shallow bedrock wells have been sampled routinely since their installation during 1990 and 1991. The deep bedrock wells were installed during 1995.

Samples collected from the background monitoring wells have been analyzed for uranium, radium-226, thorium-230, nitrate and fluoride. The analysis results are shown in Table 3. The thorium-230 concentration reported in Table 3 for MW005 is inconsistent with the concentration expected for a background groundwater sample.

Several other groundwater samples collected at the same time also had elevated thorium-230 analyses. Some of these locations were re-sampled and the analyses were low. Therefore, contamination of the samples is suspected as the cause for the elevated results.

4.2 Identification of Sources of Contamination

The contamination found at the Facility is a result of the uranium processing activities that took place during the operating life of the plant. In this regard, a review of prior investigations, types of radiological and chemical materials utilized, and a description of the processing steps is necessary in determining the nature and extent of the contamination.

4.2.1 Prior Investigations

Throughout the operating life of the Facility, there have been on-going evaluations of the impact of the plant operation, including monitoring of airborne and liquid discharges, soil sampling, and groundwater sampling. The most comprehensive, focused evaluation was the Facility Environmental Investigation (FEI), conducted under NRC Order in 1990 and 1991. In the reports prepared as a result of the FEI, detailed descriptions of the processing activities, the waste streams from these activities and the possible sources of contamination, both on and off site were presented. The FEI included the following six major tasks:

Task 1, facility-wide surface water investigation, developed a detailed understanding of surface water flow paths on SFC property. This task identified potential pathways for release of licensed material offsite via surface water.

Task 2, facility process flow and process stream characterization investigation, provided a more complete understanding of the overall Facility unit operations and processes. It serves as reference for identifying and assessing potential sources of licensed material that may be released offsite.

Task 3, past and present operations, historical information investigation, identified 28 operational units at the Facility for which a historical review was conducted, including building areas, ponds, surface water, burial sites, etc. The review determined the scope of operations which had been performed at each unit. Other pertinent data collected included dates of operation, aerial photographs, characterization of material managed at each unit, release and/or migration data, employee interviews, and data from associated environmental monitoring.

Task 4, facility-wide underground utility investigation, characterized the quantity and location of licensed material in the subsurface fill soils in all SFC property utility trenches with potential for transporting licensed material from the Facility. The utility investigation also identified and verified all potential pathways that could contribute to the migration of licensed material to and from past and present operational units.

Task 5, past and present operations, material characterization, and Task 6, groundwater (saturated zone) and unsaturated zone soil investigation, provided a detailed investigation of groundwater and soils in all areas of the Process Area. Data was collected predominantly from soil borings, monitor well installations, and sampling of unsaturated zone soils.

In 1991, SFC conducted additional investigations of soil, groundwater, surface drainage water and sediment, and performed further investigation of the primary water effluent discharge. The results were published as an addendum to the FEI. The addendum summarized the findings of these additional investigations and assessed the findings in relationship to the findings of the original FEI.

4.2.2 Summary of Radiological and Chemical Materials Utilization

Radiological

Natural uranium was the primary form of uranium processed at the Facility and therefore the predominant form of uranium present as contamination at the Facility. Natural uranium (uranium as found in nature) consists of three isotopes having mass numbers 234, 235, and 238. Each isotope comprises on average 0.006%, 0.7%, and 99.3%, of the mass of natural uranium, respectively.

Depleted uranium was the only other form of uranium processed at the Facility. Depleted uranium is created from natural uranium by reducing the mass abundance of uranium-235 relative to the other two isotopes. The mass abundances of the uranium isotopes having mass numbers 234, 235, and 238 for depleted uranium are 0.0005%, 0.3%, and 99.7%, respectively. Depleted uranium was handled at the Facility in much smaller total quantities and for a shorter period of time than natural uranium. Also, the depleted uranium process was an essentially dry, closed loop process. Finally, process upsets did not contribute significant amounts of depleted uranium to the Facility grounds. These conditions provided little or no opportunity for dispersion of depleted uranium as a contaminant at the Facility.

During 1995 site characterization activities, samples from seven locations were analyzed for uranium-234, uranium-235, and uranium-238. A summary of the analyses is presented in Table 4. As expected, the results confirm that the uranium contamination present is natural uranium.

The uranium feed material contained associated transformation products, primarily radium-226 and thorium-230, in non-equilibrium ratios.

Chemical

Natural uranium was delivered to the plant as uranium ore concentrate, predominantly as "yellowcake"; i.e. solid oxides, primarily U_3O_8. A limited amount was delivered as an ammonium diuranate slurry.

The feed material was chemically converted stepwise to uranyl nitrate, uranium trioxide, uranium dioxide, uranium tetrafluoride, and finally, uranium hexafluoride in the process at SFC. The major process chemicals utilized in these steps included nitric acid, tributylphosphate, hexane, anhydrous ammonia, anhydrous hydrofluoric acid, potassium bifluoride, elemental fluorine, and calcium oxide. Ammonium nitrate, raffinate sludge and calcium fluoride were major byproducts of this operation. Minor amounts of refrigerants, cleaning solvents, lubricants, and water treatment chemicals were also utilized on site.

Beginning in 1986, depleted uranium hexafluoride was utilized in a process operation to produce depleted uranium tetrafluoride. Hydrogen, produced from anhydrous ammonia or purchased as elemental hydrogen, was utilized to convert the depleted uranium hexafluoride to depleted uranium tetrafluoride. Byproduct anhydrous hydrofluoric acid was also produced and utilized in the main plant.

4.2.3 Summary of Process Related Contamination Sources

This section provides a summary of the principal FEI findings, SCP evaluations, and other available information regarding identification and characterization of sources of contamination.

FEI and SCP

The FEI identified 28 units at the Facility for investigation. Except for the ammonium nitrate lined ponds (Unit 24), these units are all located in the Process Area. The units include process areas and buildings; the surface water management system; impacted soils, materials, and discarded equipment storage areas; active and inactive impoundments; impacted drainage areas; equipment and sludge burial areas; and underground utilities. These units were identified and labeled based on the increasing potential for releasing licensed material. In similar fashion, additional units were identified as requiring investigation during development of the SCP. During both the FEI and the SCP, historical information was obtained from file searches and interviews. The location of all units is shown in Figure 22.

Historical Information Review

During the FEI, a review of historical information was completed. The review included the following:

- Environmental Department records
- Decommissioning files
- Engineering drawings, blueprints, and records
- Analytical data of environmental and process sampling
- Operating procedures

Information collected from this effort was used to develop sampling plans and complete descriptions of sources and units.

During the summer of 1993, SFC performed a review of historical information in order to collect information potentially relevant to identification of areas of the Facility that may have been impacted by Facility operations. The period of time for which information was reviewed was approximately 1990 forward. The specific information reviewed included:

- ALARA Audit reports,
- Contamination Incident reports,
- Contingency & Emergency Response records,
- Deficiency Reports/Condition reports,
- Environmental Monitoring results,
- Monthly Health and Safety Inspection reports,
- License Amendment Applications,
- Monthly Management Walk Through Inspections,
- 10 CFR 20.403, .405, & 10 CFR 40.60 Notifications,
- Regulatory Compliance Audit reports, and
- NRC Site Inspection reports.

Information collected during the review was documented on individual records. The type of information recorded included a reference to the specific report reviewed and a qualitative and/or quantitative summary of information relevant to a site characterization effort.

Employee Interviews

During the FEI, Facility personnel were interviewed. The interviews were used to provide information necessary to address questions which arose during review of historical information. Additionally, Facility personnel were often able to direct historical information searches to previously unidentified files providing for a more thorough investigation of the history of a unit.

In October 1993, Facility personnel were interviewed in an effort to help identify areas of the Facility that may have been impacted by Facility operations. Interview sessions were scheduled for small groups of current and former employees. The groups included executives, managers, staff, and labor. In order to prepare personnel for the interviews, internal correspondence was issued describing the interview effort and associated objective. During the interview session, several types of props were used to precipitate thought and discussion. These props included aerial photographs, maps and drawings, photographs of Facility operations, a list of major engineering projects conducted over the life of the Facility, a generic list of potential sources of contamination, a list of pre-determined questions regarding activities and events known or suspected to have occurred, and a description of the types of information normally collected during site characterization activities.

The groups were asked to discuss changes in the process, structures, and grounds which may have caused some type of impact to the Facility. Impacts of interest provided to the groups as examples for discussion were changes in the Process Area, storage of material, burial of material, decontamination of equipment, and releases of material to the environment.

The interview sessions were conducted by managers and staff of SFC familiar with the type of information desired from such an effort. Information obtained during the sessions was documented on individual records. These records were compiled by the personnel conducting the interview. The types of information recorded included unique record identification, location description including reference to an SCP unit number, relative date of described event, picture or map identification as applicable, and a quantitative and/or qualitative description of the event.

<u>Operations</u>

Feed material was shipped to the site for processing in 55-gallon drums or by tank trailer in the case of some of the slurry feeds. Typically, the drums were stored outside on concrete pads for varying amounts of time prior to the material being processed. During the early operation of the Facility, the drums were stored on the ground. Drums that corroded through or were physically damaged in handling resulted in some of the uranium being spilled on the ground or the concrete pads. When not promptly discovered and cleaned up, spills of yellowcake were further spread by precipitation. Storm water from the yellowcake pads, which typically contained measurable levels of uranium, was eventually discharged to the headwaters of the Robert S. Kerr Reservoir through the Combination stream (Outfall 001).

Empty yellowcake drums were stored for a number of years in an area on the northwest corner of the plant site. Residual yellowcake contained in these drums may have impacted the ground in this area.

The first step in processing the uranium involved sampling and weighing the feed material to credit each customer with the proper amount of inventory. This step took place inside a building with a vacuum collection system to contain the dust from the sampling operation. Although high efficiency dust collector filters were used, a small amount of uranium escaped to the atmosphere. Some uranium was also discharged through the un-filtered room air exhauster. Since uranium is a very heavy material, most of this uranium was deposited on the rooftops of the processing buildings and on the ground near the buildings. This mechanism is typical of all of the stacks and ventilation exhausts from the processing buildings. Fenceline and "far-field" air samplers demonstrated compliance with relevant NRC limits.

The uranium was then dissolved in an aqueous solution of nitric acid, forming uranyl nitrate. Leaks due to corrosion, overflows, and boil-overs periodically occurred in this step, spilling uranium on the floor of the processing building. Eventually some uranium penetrated the floors due to corrosion.

After dissolution, the uranium was purified in a solvent extraction process. Impurities, including most of the transformation products and metals in the feed were removed in an acidic by-product stream called raffinate. The raffinate was neutralized with anhydrous ammonia and further treated with barium chloride causing the impurities to precipitate out of solution, forming a slurry. This neutralization was done initially in an unlined pond and later in a 4-cell synthetically lined impoundment (Unit 17, Clarifier A Basin Area). Solid and liquid phases subsequently formed due to gravity settling. The solid phase material, raffinate sludge, contains elevated uranium levels which can exceed uranium concentrations in native ores. The solid phase also contains elevated levels of transformation products from the natural uranium which were present with the ore concentrates as naturally occurring impurities. Sludges were routinely pumped from Unit 17 either to Pond 2 or Pond 4, or directly to a transport truck for delivery to a uranium mill for use as an alternate feed material.

The aqueous phase was a weak ammonium nitrate solution. Following further purification, this solution was used for fertilizer on SFC property. Leakage from the solvent extraction equipment and the raffinate treatment impoundments were the primary contributors of contamination in the vicinity of these operations.

Following purification, the uranyl nitrate was concentrated and thermally denitrated to uranium trioxide. Several overflows (boil-overs) from the concentration equipment contributed to contamination of the plant sanitary sewer line and the sanitary waste treatment lagoon. Off-gas from this step contained oxides of nitrogen which were scrubbed out forming recovered nitric acid. This recovered nitric acid, which was reused in the process, contained significant amounts of uranium. As with other nitric acid systems in the plant, leaks due to corrosion and equipment failure contributed to on-site impacts.

The next several process steps, in which the uranium trioxide was converted to uranium hexafluoride (the final product), involved operations with solid and gaseous forms of uranium. Process leaks from this equipment resulted in some airborne uranium contamination of the room air which was subsequently discharged from the MPB via the ventilation exhausters. As mentioned above, detectable levels of uranium were found on the nearby surfaces from these discharges.

Process off-gases from these conversion steps contained hydrogen fluoride, elemental fluorine and small amounts of uranium. These off-gases were water scrubbed prior to discharge to the atmosphere. Some airborne uranium escaped the scrubber and was discharged to the atmosphere. Typical impacts of these discharges are discussed above.

Initially, the scrubber water (dilute hydrogen fluoride with some uranium) was neutralized by spraying onto a large limestone pile on the ground southwest of the Decorative Pond. This practice was discontinued shortly after plant startup.

Eventually, a system was installed in which the scrubber water was neutralized with calcium oxide (quick lime), resulting in the formation of uranium bearing calcium fluoride solids. The solution was then piped to one of several basins where the precipitated solids were allowed to settle. The liquid was decanted from the settling basins to the Fluoride Clarifier which acted as a polishing unit. Additional settling of solids occurred in this unit and the clarified liquid was released into the Combination Stream. This sludge is currently stored in un-lined or clay lined impoundments or burial pits on the site. These include fluoride settling basin numbers 1 and 2, fluoride holding basin numbers 1 and 2, and the fluoride sludge burial areas. The uranium in the calcium fluoride sludge does not appear to be a contributor to contamination of the site soil or groundwater because of its low solubility in this matrix.

Closed loop cooling water and steam/condensate systems were used in the plant. Corrosion induced failures of heating and cooling coils and tubes resulted in the contamination of these systems with uranium. This contamination eventually was discharged via blow-downs and over-flows to the combination stream, contributing in part to the low levels of contamination in the drainage pathways and the sediments.

During the 1970's and early 1980s, low-level radioactive wastes from the operation were buried in two locations in the northwest portion of the Process Area. This waste is expected to have contaminated a limited amount of soil surrounding the burial trenches.

The plant operated a laundry to wash protective clothing after its use. The waste water from this operation was for many years discharged to the sanitary sewer. Uranium from contaminated protective clothing contributed to the contamination levels in the sanitary lagoon.

Failed equipment from the process buildings was removed and accumulated in scrap piles located primarily northwest of the MPB and on the Yellowcake Storage Pad. Residual contamination from this scrap was found to be contaminating the soil and also the storm water runoff in these areas.

In 1986, a shipping cylinder containing heated uranium hexafluoride ruptured, releasing several tons of gaseous uranium hexafluoride into the air. The uranium hexafluoride reacted rapidly with water vapor in the air forming a solid uranyl fluoride compound which quickly settled to the ground and the building surfaces. The MPB and several acres of ground, including a short section of Highway 10, were contaminated with uranium by this release. Although contamination was partially cleaned up immediately following the accident, impacts still exist in some areas between the point of the release and the Facility boundary.

A significant amount of the uranyl fluoride resulting from the 1986 release was washed into the North Ditch and Emergency Basin. The majority of this material remains in these locations and has probably contributed to soil and groundwater contamination in the area.

Contaminated material from the cleanup of the 1986 release was stored in Unit 23 and in drums on the top of the Solid Waste Burial Area No. 1 (South). This material has since been moved to the Interim Storage Cell.

In the late 1980s, the depleted uranium plant was constructed and began operation. The DUF_6 reduction operation was a non-aqueous process. Major powder spills inside the building occurred on at least two occasions resulting in contamination of the building interior surfaces and measurable releases through the building ventilation exhausters and stacks. Contamination on the roof and the surrounding ground resulted from these events. Cleanup of these spills were completed after the releases occurred.

4.3 Design of Survey and Sampling

As described in Sections 1.1 and 1.3, a draft SCP was initially submitted to NRC describing the plans and procedures for determining the extent and concentration of contamination at the Facility. Subsequently, based on NRC comments on the draft SCP and implementation of the draft SCP, it was necessary to deviate from the description provided in the draft SCP. In this regard, this section generally describes the design of the survey and sampling associated with development of this site characterization report. Section 4.4 also provides this type of information, but in a more specific format.

4.3.1 Design

The site characterization effort was developed from specific objectives based on purpose, type, and amount of data to be obtained. The design of the site characterization effort was initiated by subdividing the site into units and strata based on the potential for and type of contamination. The FEI was used as a starting point for this effort. Also consistent with the conduct of the FEI, a division was made with respect to sources of contamination versus media that has been contaminated by a source(s). Characterization requirements were based on knowledge of operations conducted at the site, consideration of prior investigations, review of historical information, and employee interviews. Sampling plans, primarily with regard to sample locations, were developed in order to address requirements not satisfied by existing data sets.

Impounded sludges were characterized without regard to vertical or horizontal stratification. There is no way to estimate how the sludges will be excavated and subsequently dispositioned, thus it is not feasible to develop layer averages.

The parameters being investigated during the site characterization are total uranium, radium-226, thorium-230, nitrate (as nitrogen) and fluoride. Selection of these parameters is based on the discussion in Section 4.2.2 and historical characterization activities.

The State of Oklahoma Zone North Code 3501 NAD 83(93) coordinate system was selected for use at the Facility beginning in 1995 to provide a traceable reference for sampling locations. A registered land surveyor established seven (7) land survey control locations at the Facility utilizing the NAD83(93) system.

The number of survey and sampling points per unit were chosen dependent upon the anticipated extent of contamination, known or suspected cause of contamination, location of known contamination and location and number of historical samples. Sampling was performed to characterize the extent of contamination in structures, soils, impoundments, surface water, and sediments. Historical characterization data indicates that contaminants are not migrating via these media. In contrast, groundwater is sampled on a periodic basis as contamination is known to be migrating via this media.

Specific information on the design and frequency of sampling during site characterization is provided in section 4.4 for each respective unit. However, the surface water, groundwater, structures and wetlands were characterized on a facility rather than a unit basis. The design and sampling for these media are discussed in section 4.5.

4.3.2 Gamma Scan Survey

During the course of operations at SFC, radioactive materials may have been deposited in outlying areas as a result of unexpected buildup from chronic air emissions, spills, or unknown causes. In some cases, incomplete remediation efforts may have led to undocumented areas of radioactive contamination. These areas may not be readily identified by conventional soil sampling procedures if contamination exists in small, discrete locations. A gamma scan can provide a means of detecting such conditions, and may provide some additional level of assessment when used with other sampling regimes. SFC conducted a gamma scan to aid in defining the location and extent of radiological contamination at the site.

Performance

The gamma measurements were made with a NaI(Tl) radiation detector (Ludlum Model 44-10) coupled to a hand held scaler/ratemeter (Ludlum Model 2221). Measurements were collected by keeping the detector within two feet above the ground surface while walking or driving over the area at a rate comparable to a casual walk. In open areas, the measurements were made along a straight path between opposite borders of the area being surveyed and the distance between paths was approximately five feet. In wooded areas, the measurements were made along paths allowed by brush and trees. The scaler/ratemeter, along with global positioning system (GPS) equipment (Trimble model), was coupled to a data logger (Trimble Model TDC-1). A gamma measurement taken from the ratemeter and a location reading taken from the GPS unit were recorded approximately every two seconds by the data logger. The typical density of measurements for an area is 60 to 80 measurements per 100 square meters. Each gamma measurement was recorded as gross counts per minute. The location was recorded with respect to the aforementioned coordinate system.

Application

A gamma scan was performed for each of the background soil sample locations (Figure 21). An average gross counts per minute was derived for each background soil sample location from the respective data set. A grand average and standard deviation were developed from this set of background location averages. A baseline value was then established as the grand average plus two standard deviations. The data from which the baseline value was derived is provided in Table 5.

At the beginning of each day of survey, the radiation survey instrumentation was operationally checked to ensure proper function and setup. Also, a GPS location reading was recorded at a land survey control location to allow a post-survey evaluation of the operation of the GPS.

The results of the gamma scan are discussed on an unit basis in Section 4.4. Discussion is provided only for those units that are wholly or partly in the unaffected area.

4.4 Radiological, Chemical and Physical Characterization of Contaminants

This section describes the radiological, chemical and physical characterization of impacted materials within each unit. The unit designations and locations (Figure 22) are consistent with the unit assignments for the 28 units described in the FEI. The boundaries have been changed for some of the original FEI units and some new units have been added. Unit descriptions and general information are provided below followed by a discussion of historical information associated with each unit. The historical information includes events which had the potential to result in significant impact to the unit or adjacent units. There were numerous process upsets, leaks and spills during operation of the Facility; these are not specifically presented. Sampling and survey results from 1990 through 1994 are also presented with the historical information. Sampling and survey results from 1995 are included in the characterization sample results section. Where sufficient information and data were available, volume and total activity values have been estimated for impacted materials. A summary discussion of findings is also provided with each unit.

Source, sediment and soil results are presented in Tables 6 and 7. Each table includes the sample location, unit number, sampling date, and the uranium, thorium-230, radium-226, nitrate and fluoride concentrations. Table 6 is sorted by sample location and Table 7 is sorted by unit number. More than one unit number is often listed since soil samples may be useful for defining the extent of impact for several different units.

A preliminary estimate of the volume of soil containing total uranium concentrations in excess of 35 pCi/g is presented for the site as a whole in Section 4.5.5. Preliminary estimates have been made of the volume of the various sources (raffinate sludge, calcium fluoride, etc.) in the unit discussions. Attachment III contains the basis for the volume estimates provided herein.

The evaluation which was completed to define the contamination of structures and equipment is described in Section 4.5.7. Previous investigations and historical monitoring have provided enough information to conclude that impacts to the two uppermost groundwater zones have occurred and that the impacts are not localized beneath any single unit. Investigations have also revealed that there are multiple sources contributing to groundwater impact. Finally, since each groundwater system exists as a continuous media spanning numerous unit boundaries, the groundwater at the Facility was not characterized on a unit basis but rather on a system basis. The extent of contamination in the groundwater is presented in Section 4.5.6.

4.4.1 Main Process Building Area (Unit 1)

Description and General Information

The Main Process Building (MPB) is located near the eastern edge of the Process Area. The MPB is a four story metal building with approximately 95,000 sq. ft. on the ground floor. It is the largest building at the Facility and contained the major UF_6 conversion processing operation, fluorine generation facilities, utility and maintenance areas, administrative offices and a chemical process laboratory. Construction of the MPB began in 1968 and reached completion in 1969. Plant operations began in 1970 and ceased in 1992.

Historical Information Review

Review of information on file indicates that uranium bearing materials were released from process systems or containers. Numerous leaks and spills occurred throughout the process area during operation of the Facility. A large amount of UF_6 was released from an overfilled cylinder which ruptured just north of the MPB. Overflow of material from the boil-down tanks released UNH to the northwest area of the MPB. On at least one occasion this material flowed outside the building, near the northwest corner of the MPB. The UF_4 ash receivers removed from the MPB were sources of contamination to adjacent areas. Releases of UF_4 ash would have been in a solid powder form.

On September 19, 1990, the NRC issued SFC an Order Modifying License (OML) to complete actions at the Facility to investigate and prevent further releases of licensed material from the MPB. As part of the effort to respond to this order SFC characterized the quantity (volume and activity) and location of licensed material under the MPB floor and outside the MPB. Samples were collected to determine the nature and extent of impacts to the soils. A groundwater monitoring program was also established to evaluate the impact to the upper two groundwater systems in the area. The results of these investigations are included in a report titled "Sequoyah Fuels Corporation, Revision 2, Main Process Building Investigation Final Findings Report", prepared by Roberts/Schornick and Associates, dated December 15, 1990.

Characterization Sample Results

Sources

Sources of contamination in the MPB included the gaseous, liquid and solid compounds associated with operation of the Facility. Section 4.2 of this SCR described the chemical and physical properties of the compounds. Routine process control samples were collected during operation of the Facility and provided information regarding uranium concentrations. These concentrations were in the gram per liter or gram per gram range. Bulk materials have been removed from the process equipment.

Soils

Soil samples have been collected from fifty-seven (57) locations in and around this unit. Sample depths ranged from the surface to seventy-nine (79) feet deep. Of the 851 uranium analyses, 758 (89.1%) were less than 35 pCi/g and 784 (92.1%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 7,100.

Summary of Findings

The soils underlying the MPB area are impacted by uranium, generally to depths of fifteen (15) feet. To a lesser degree, there are impacts from nitrate and fluoride, with the highest concentrations of these contaminants in the western portion of the unit. This is consistent with known leaks and spills that have occurred in the UF_6 Plant. See Section 4.5.4 for a discussion of the MPB structures, foundations and the process equipment.

4.4.2 Solvent Extraction Building Area (Unit 2)

Description and General Information

Unit 2 includes the Solvent Extraction (SX) Building, RCC Evaporator and Cooling Tower. The SX Building is a two story metal building with dimensions of approximately 80 feet by 50 feet. The building is located approximately 150 feet west of the MPB. Construction began in 1968 and was completed in 1969. Operations began in 1970 and ceased in 1992. The solvent extraction process involved the separation of uranium and impurities such as heavy metals using a hexane solvent and tributylphosphate to float the impurities for easier removal.

The RCC evaporator is located north of the SX Building and west of the Cooling Tower and was built in 1980. The RCC Evaporator stands atop a concrete pad which measures approximately 35 feet by 30 feet. The mechanical recompression evaporator is approximately 40 feet tall.

The Cooling Tower is located north of the SX Building and south of the North Ditch and was part of the original construction completed in 1969. The Cooling Tower is approximately 35 feet wide and 100 feet long and was designed to cool the process cooling water which was then recirculated to various heat exchangers throughout the Facility. The equipment is made up of two basins, the hot side basin and the equalization basin, which are used to keep a constant level in the recirculation process.

Historical Information Review

Review of information on file indicates that uranium bearing materials were released from process systems or containers. Numerous leaks and spills occurred during operation of the SX Building. During 1990, uranium contaminated water was discovered adjacent to the SX Building in an open excavation. Water samples collected from the excavated area averaged 1.6 g/l uranium, with a maximum concentration of 8.2 g/l. Soil removed from the area had an average uranium concentration of 1,500 pCi/g. During the excavation of the SX tank, a french drain was installed. Contaminated rock from Pond 2 and contaminated limestone from the 1986 accident were used as backfill in the french drain.

Characterization Sample Results

<u>Sources</u>

Process equipment and tanks associated with Unit 2 have been emptied. A sample of cooling tower sediment collected on November 16, 1995, had uranium, nitrate and fluoride concentrations of 31,500 pCi/g, 4,680 µg/g, and 1,840 µg/g, respectively. During operation of the Facility, uranyl nitrate solution from solvent extraction had a uranium concentration of approximately 50 to 70 grams uranium per liter. During a UST excavation, a sewer pipe which conveyed laundry effluent to the Sanitary lagoon was damaged and replaced. A sample was later retrieved from the damaged pipe and found to have a uranium concentration of 61,403 pCi/g.

<u>Soils</u>

Soil samples have been collected from sixty-one (61) locations in and around this unit. Sample depths ranged from the surface to seventy-nine (79) feet deep. Of the 426 uranium analyses, 316 (74.2%) were less than 35 pCi/g and 349 (81.9%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 7,500 pCi/g. Although there are no thorium-230 or radium-226 soil analyses available for this unit, SFC believes that these constituents are present at elevated levels in the soils under and around the SX Building.

Summary of Findings

The soils underlying the SX building are impacted by nitrate, fluoride and uranium, particularly in the northern portion of the unit around the SX Vault, where there are impacts to over 30 feet. radium-226 and thorium-230 are also expected to be present. See Section 4.5.4 for a discussion of the SX Building structures and foundations and process equipment.

4.4.3 Initial Lime Neutralization (Unit 3)

Description and General Information

Unit 3 is located southwest of the Decorative Pond, approximately 150 feet south of the Sequoyah Facility entrance road. Lime neutralization was conducted in this area for a brief time after plant startup in 1970 until construction of the Fluoride Settling Basins could be completed. Upon completion of the Fluoride Settling Basins in 1971, the scrubber wash water was re-routed for neutralization through these settling basins. A limestone pile consisting of a pile of approximately 50 tons of crushed limestone functioned as the initial neutralization for hydrogen fluoride scrubber wash water. The scrubber wash water was discharged on top of the limestone pile. Limestone was added to the pile as the limestone dissolved. The unit depth from surface to underlying sandstone ranged from one (1) to four (4) feet during operation. During 1992, the limestone and surrounding soil were removed and placed into the Interim Storage Cell (Unit 35). Currently, the depth to sandstone is 6 inches or less over much of the unit.

Historical Information Review

Unit 3 was sampled on March 17, 1993, after the limestone and impacted soils had been excavated and moved to the Interim Storage Cell. Samples were collected on a ten (10) foot grid at a depth of 0 to 6 inches from each location and have been designated HA102 through HA220.

Characterization Sample Results

Sources

The source has been removed from this unit.

Soils

Soil samples have been collected from eighty-two (82) locations in and around this unit since contaminated soil was removed in 1992. Sample depths ranged from the surface to two (2) feet deep. Of the 82 uranium analyses, 79 (96.3%) were less than 35 pCi/g and 82 (100%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 61 pCi/g.

Gamma Scan Survey

A gamma scan survey was performed at Unit 3 during 1995. The scan indicates that some residual radioactive material may remain in the northern portion of this unit.

Summary of Findings

The soils in the Initial Lime Neutralization Area were significantly impacted by fluoride and uranium as a result of the use of this area to neutralize HF scrubber water during initial plant operation. In 1992, the majority of the contaminated soil was removed and placed in the Interim Storage Cell. As indicated by the post-removal sampling and the recent gamma walkover survey, there are a few isolated spots of slightly impacted surface soil remaining in this unit.

4.4.4 Surface Water, Entire Facility (Unit 4)

Description and General Information

Unit 4 addresses surface water from the Process Area as well as surface water runoff points and outfalls. Surface water for the Process Area was identified as an operational unit during the FEI. The scope of Unit 4 investigation during the FEI was extensive. Section 4.0 of the FEI Report describes the surface water management system and the associated surface water investigation. Unit 4 was also assessed as part of the FEI Addendum.

Historical Information Review

During the FEI, a comprehensive network of 20 monitoring stations was established to characterize the surface water in the Process Area. These monitoring stations included all pertinent outfalls plus additional sites selected at key transitional drainage locations based on a detailed areal topographic survey and site map developed in the FEI. Figure 23 depicts the surface water drainage areas, runoff patterns, exit points and outfalls. Two (2) sampling events were performed during separate rainfall events to characterize surface water during the FEI. These events were conducted on January 15, 1991 (Event No. 1) and March 1, 1991 (Event No. 2). A third sampling event (Event No. 3) was conducted on October 24, 1991 during the FEI Addendum. An additional surface water monitoring location (SW21) was established during this event.

The concentrations of fluoride measured at all monitoring sites during Events No. 1, No. 2 and No. 3 were below the MCL for drinking water (4.0 mg/L). The fluoride concentrations of storm water at all locations sampled during each event were below the discharge limits specified in SFC's NPDES (EPA) and State permits.

The nitrate concentrations for the three (3) storm water events ranged from 0.9 mg/l to 179.0 mg/l. Nitrate concentrations from Event No. 3 showed a decrease from the concentrations measured during Event No. 2 at fourteen (14) of the monitoring sites.

The uranium concentrations for the three storm water events ranged from <3.4 pCi/l to 5,321 pCi/l. There was only one monitoring site (SW13) which had a uranium concentration during Event No. 3 that was higher than during Event No. 2, and three monitoring sites (SW09, SW13 and SW17) that had higher concentrations during Event No. 3 than during Event No. 1. The potential source of uranium appears to be Unit 10 where a diversion dike was constructed downstream to reduce the uranium concentrations exiting in the vicinity of SW16. As a result of the diversion dike, runoff from Unit 10 is now conveyed to the North Ditch. Uranium concentrations for all monitoring sites were below the allowable 10 CFR 20 discharge limits for all three events. The uranium discharge limit at the time of the FEI was 30,465 pCi/l.

SFC monitored uranium concentrations in storm water as part of discharge permit analysis until the practice was discontinued in January 1995. The flow weighted average concentration of uranium in storm water collected at Outfall 008 from

January 1993 to January 1995 was 46 pCi/l. The maximum uranium concentration during this period was 219 pCi/l. These values are below the current 10 CFR 20 discharge limit of 300 pCi/l (450 µg/l).

Summary of Findings

There have been documented events of which impacted surface water from the Process Area and other portions of the Facility have been discharged. The primary areas of impact from this discharge are the storm water drainage pathways where sediments are likely to accumulate. These areas have been investigated and are discussed in Unit 34, Drainage/Runoff Areas.

4.4.5 Solid Waste Burial Area No. 1 (South) (Unit 5)

Description and General Information

The Solid Waste Burial Area No. 1 (South), is located in the Process Area north of the Emergency Basin and was operated from September, 1970 to January, 1981. The 0.6 acre burial area was used for disposal of approximately 51,115 cubic feet of low level radioactive waste materials such as equipment, drums, laboratory sample containers and other solids. The burial activity complied with federal regulations (10 CFR 20.304).

Historical Information Review

Burial records were reviewed and indicate that various materials were placed into the solid waste burial areas. The materials buried include contaminated equipment, scrap metal, lab sample bottles, defective 55 gallon yellowcake drums, insulation, combustible trash, pipe containing calcium sulfate deposits, UF_4 ash, yellowcake, incinerator ash, and miscellaneous material from spill cleanups.

Drums containing incinerator ash and soil from the SX yard were stored above the ground surface in this unit. Some of these drums were in poor condition and resulted in leaks and spills of uranium bearing materials. The drums were removed from Unit 5 during 1994 and placed into the Interim Storage Cell. After removal of the drums, a survey was performed to evaluate impacts to the surface soils.

Characterization Sample Results

<u>Sources</u>

Due to the physical nature of the burial area contents, SFC has concluded that it is not possible to obtain representative samples without full exhumation. Since the burial area may include containers such as drums, there also is a concern that sampling may cause the spread of contamination by disturbing or penetrating the drums with a sampling device. Therefore, the burial area will not be characterized by direct sampling during site characterization. For characterization purposes, information relating to the burial areas has been obtained from site records, employee interviews and adjacent soil and groundwater investigations.

Soils

Soil samples have been collected from twenty-five (25) locations in and around this unit. Sample depths ranged from the surface to thirty-four (34) feet deep. Of the 85 uranium analyses, 67 (78.8%) were less than 35 pCi/g and 77 (90.6%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 1,060 pCi/g.

Summary and Findings

Based on plant records, the Solid Waste Burial Area No. 1 (South) contains approximately 43,000 cubic feet of low level wastes containing about 0.64 Ci (945 kg) of natural uranium. The soil covering the burial area is impacted near the surface by uranium from the materials that were formerly stored on the ground in this area. Soil in the areas surrounding the burial area are also impacted, though not necessarily from the buried wastes.

4.4.6 Emergency Basin (Unit 6)

Description and General Information

The Emergency Basin is located within the Process Area just west of the North Ditch (Unit 9). The unlined basin has an estimated capacity of approximately 133,300 cubic feet. Unit 6 was constructed in 1969 to provide temporary storage of surface runoff water from controlled areas within the plant. Water collected in the basin was sampled and, if not impacted, discharged to the Combination Stream. If the water was impacted, the water was to be combined with other waste streams and disposed of by injection into a proposed deep well. When authorization for use of deep well disposal was not obtained, the basin was used for raffinate storage during the four month period after plant start-up while a lined storage pond was being constructed. Since that time period, the basin has been used for the containment of accidental spills, wash-down of surrounding pads, environmental laboratory waste water, and contents of sumps and pits, including the North Yellowcake Sump (Unit 21), and the North Ditch (Unit 9).

Historical Information Review

In 1986, rinse water from the recovery effort associated with the UF_6 release was collected in Unit 6. A sample of this liquid was collected and the analysis indicated a uranium concentration of 23,018 pCi/l.

Characterization Sample Results

Sources

Source samples have been collected from eight (8) locations from the Emergency Basin. Sample depths ranged from the surface to one-half foot. Uranium concentrations ranged from approximately 1,600 to 6,000 pCi/g, nitrate from 3.8 to 210 µg/g and fluoride from 1,800 to 9,900 µg/g.

Twelve locations were probed during 1995 characterization activities to determine the depth of the sediment. The sediment depth varied from a maximum of 8 inches to a minimum of 1 inch, averaging about 4½ inches.

Soils

The underlying soils are assumed to be impacted from exposure to the sediment and liquid contained in the Emergency Basin. The extent of the impact will be determined by sampling the basin bottom once the sediments have been removed.

Soil samples have been collected from nineteen (19) locations around the Emergency Basin. Sample depths ranged from the surface to four and a half (4.5) feet deep. Of the 75 uranium analyses, 50 (66.7%) were less than 35 pCi/g and 66 (88.0%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 3,500 pCi/g.

Summary of Findings

The Emergency Basin area contains approximately 14,600 cubic feet of sediment containing about 0.54 Ci (806 kg) of natural uranium. Soils surrounding the unit are impacted, primarily by uranium, generally at depths of less than 5 feet.

4.4.7 Sanitary Lagoon (Unit 7)

Description and General Information

Unit 7, the Sanitary Lagoon, which includes the adjacent storm water drainage areas, was built in 1971 and was used for microbiological oxidation of waste water from toilets, lavatories, showers, and laundry facilities. The lagoon water was discharged via the Combination Stream (Unit 27). The Sanitary Lagoon became primarily a backup storage pond prior to sanitary treatment when a waste treatment package plant was installed in 1988. Since production operations ceased and the staff has been reduced, insufficient waste material was available for efficient use of the sanitary treatment package plant and its use was discontinued. The lagoon has been drained and is currently out of service. A synthetic liner was installed to eliminate any potential hydraulic head caused by impounded rainwater. The lagoon is located in the Process Area west of the MPB (Unit 1) and SX Building (Unit 2). The lagoon is approximately 233 feet long (East-West), 148 feet wide (North-South), and eight (8) feet deep, with a capacity of approximately 129,000 cubic feet.

Historical Information Review

During 1990, uranium contaminated water was discovered adjacent to the SX Building in an open excavation. Movement of the solution away from the SX Building potentially contributed uranium to the Sanitary Lagoon via sand-filled utility trenches.

During a UST excavation, a sewer pipe which conveyed laundry effluent to the sanitary lagoon was damaged and replaced. A sample was later retrieved from the damaged pipe and found to have a uranium concentration of 90,700 pCi/g.

Characterization Sample Results

Sources

The sludges in the Sanitary Lagoon are comprised primarily of solids derived from microbial oxidation of domestic wastewater. Sludge samples have been collected from nine (9) locations from the Sanitary Lagoon. Uranium concentrations ranged from approximately 2,300 to 26,000 pCi/g, nitrate from 7 to 440 µg/g and fluoride from 160 to 5,200 µg/g.

Six locations were probed during 1995 characterization activities to determine the depth of the sludge. The sludge depth varied from a maximum of 12 inches to a minimum of 4 inches, averaging 6.7 inches. The volume of sediments contained within this unit is estimated to be 10,400 cubic feet.

Soils

Soil samples have been collected from fourteen (14) locations around the Sanitary Lagoon. Sample depths ranged from the surface to twenty-nine (29) feet deep. Of the 87 uranium analyses, 74 (85.1%) were less than 35 pCi/g and 80 (92.0%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 6,200 pCi/g.

The soils underlying the Sanitary Lagoon are assumed to be impacted from exposure to the sludge and liquid contained in the Sanitary Lagoon. The extent of the impact will be determined by sampling the basin bottom once the sludges have been removed.

Summary of Findings

The Sanitary Lagoon Area contains approximately 10,400 cubic feet of sludge containing about 1.28 Ci (1909 kg) of natural uranium. Soils surrounding the unit are impacted, primarily by uranium, generally at depths of less than 5 feet.

4.4.8 Pond 1 Spoils Pile (Unit 8)

Description and General Information

Unit 8, the Pond 1 Spoils Pile is located west of the Emergency Basin (Unit 6) and Sanitary Lagoon (Unit 7). This area consists of residual clays removed from the old raffinate Pond 1 during construction of Clarifier A in May 1980. The spoils pile area measures approximately 400 feet by 50 feet and approximately 15 feet deep, consisting of approximately 437,000 cubic feet of residual material from Pond 1 and cover soil.

Historical Information Review

Originally, SFC had planned to land apply the residual clays from Pond 1 due to the high nitrate content of this material. However, this plan was abandoned because of the thorium content of the residual materials.

In 1987, fifty-nine (59) samples were collected from the spoils pile at eight locations to a depth of four feet. These samples were analyzed for nitrates, radium-

226, thorium-230 and uranium. Results ranged from <10 µg/g to 1950 µg/g nitrate, 0.72 to 4.32 pCi/g radium-226, 0.11 to 155 pCi/g thorium-230 and 0.4 to 12.9 pCi/g uranium.

Characterization Sample Results

Sources

Samples have been collected from ten (10) locations from the Pond 1 Spoils pile. Uranium concentrations range from approximately 0.5 to 13 pCi/g, thorium-230 from 0.1 to 155 pCi/g, radium-226 from 0.7 to 4.3 pCi/g, nitrate from 3 to 1,950 µg/g and fluoride from 120 to 520 µg/g.

Soils

Soil samples have been collected from nine (9) locations in and around this unit. Sample depths ranged from the surface to thirty-eight (38) feet deep. Of the 75 uranium analyses, 75 (100%) were less than 35 pCi/g. The maximum uranium concentration observed was approximately 15 pCi/g. One sample was analyzed for thorium-230 and radium-226. The thorium-230 and radium-226 concentrations were 2.6 and 0.4 pCi/g, respectively.

Summary of Findings

The Pond 1 Spoils Pile Area contains about 437,400 cubic feet of material removed from Pond 1. This material contains an estimated 0.1 Ci (157 kg) of natural uranium. The soils in the area surrounding the Pond 1 Spoils Pile are impacted by fluoride, nitrate, and uranium. The impact is generally less than a depth of 5 feet.

4.4.9 North Ditch (Unit 9)

Description and General Information

Unit 9, the North Ditch, was constructed in 1972 when an additional berm was added to the north end of the Emergency Basin retaining dike. The North Ditch is located within the Process Area, immediately east of the Emergency Basin (Unit 6) between the Incinerator Area (Unit 10) and the Solvent Extraction Area (Unit 2). Unit 9 is a triangular area with an estimated capacity of 12,500 cubic feet. The North Ditch is primarily utilized to contain storm water runoff, which historically was pumped to the Combination Stream. Presently, the North Ditch gravity drains to the Emergency Basin.

Historical Information Review

In 1979, SFC concluded that a drain tile from the new tank farm was the source of uranium in the North Ditch. The drain tile suspected of containing uranium was removed. Samples taken in June 1979 from the North Ditch, prior to tile removal and clay backfill, indicated uranium levels of 67,023 pCi/l, while samples taken November 1, 1979, after tile removal and 2.4 inches of rainfall, indicated uranium levels reduced to 18,956 pCi/l.

In February 1982, a pipeline ruptured and resulted in the release of approximately 3,000 gallons of raffinate into the North Ditch (Unit 9). The breach in the containment ditch, which allowed the spill to enter the North Ditch, was repaired.

During 1992, a leak of dilute HF from the HF Off-gas Scrubber system occurred, draining approximately 300 gallons of fluid to the surrounding area. The fluids and wash water drained to the North Ditch. Sample analysis of the fluid determined the uranium concentration to be 60,930 pCi/l.

Characterization Sample Results

<u>Sources</u>

Sediment samples have been collected from seven (7) locations from the North Ditch. Uranium concentrations ranged from approximately 0.1 to 22,000 pCi/g, nitrate from 2.5 to 930 µg/g and fluoride from 810 to 15,000 µg/g.

Ten locations were probed during 1995 characterization activities to determine the depth of the sediment. The sediment depth varied from a high of 40 inches to a low of 10 inches, averaging 19.1 inches.

<u>Soils</u>

Soil samples have been collected from fourteen (14) locations around the North Ditch. Sample depths ranged from the surface to five (5) feet deep. Of the 62 uranium analyses, 37 (59.7%) were less than 35 pCi/g and 48 (77.4%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 510 pCi/g.

The soils underlying the basin are assumed to be impacted from exposure to the sediment and liquid contained in the North Ditch. The extent of the impact will be determined by sampling the basin bottom once the sediments have been removed.

Summary of Findings

The North Ditch Area contains approximately 20, 770 cubic feet of sediment containing about 0.77 Ci (1,147 kg) of natural uranium. Soils surrounding the unit are impacted, primarily by uranium, generally at depths of less than 5 feet.

4.4.10 Contaminated Equipment Area (Unit 10)

Description and General Information

Unit 10, Contaminated Equipment Area, is located to the east of the North Ditch (Unit 9) and the Solid Waste Burial Area No. 1 (Unit 5) within the Process Area. Unit 10 includes an incinerator and the Solid Waste Management Building. An open-pit incinerator was used to burn non-radioactive combustibles such as boxes, crates, wood pallets, paper and rags. The incinerator was removed from service in 1994. Contaminated scrap materials were previously stored in this unit. Fluorinator tower ash was once drummed in this area and recycled to a miscellaneous digester and fed back through the solvent extraction system. Drumming of ash in this area was discontinued in approximately 1972 when an ash grinding unit was added to the MPB (Unit 1). The Solid Waste Management Building was constructed in 1989 and is approximately 30 feet by 50 feet. The building provides an enclosed area to sort trash and compact low level radioactive waste.

Historical Information Review

Soil sampling from 1985 indicates uranium levels of 50 to 2,370 pCi/g in Unit 10. Soil nitrate levels ranged from <40 to 260 µg/g. Sampling of the incinerator sump in August and October 1990 indicated uranium levels of <0.01 g/L of liquid sampled.

Characterization Sample Results

Sources

No sources are currently contained in this area.

Soils

Soil samples have been collected from twenty-one (21) locations in and around this unit. Sample depths ranged from the surface to forty (40) feet deep. Of the 119 uranium analyses, 86 (72.3%) were less than 35 pCi/g and 99 (83.2%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 12,200 pCi/g.

Summary of Findings

The soils in the Contaminated Equipment Area are impacted by uranium and fluoride, generally to depths of less than 3 feet. Soils surrounding the unit are impacted, primarily by uranium, generally at depths of less than 5 feet. Significant soil impacts are present south east of the Solid Waste Management Building.

4.4.11 Drainage Areas Around Emergency Basin and North Ditch (Unit 11)

Description and General Information

Unit 11 includes the drainage areas around the Emergency Basin (Unit 6) and the North Ditch (Unit 9). The Drainage Area flows from the northern side of Unit 6, the southern side of Unit 6 and between Units 6 and 7. The area provides drainage for storm water runoff to the headwaters of the Robert S. Kerr Reservoir via a permitted and monitored outfall. Runoff from this area has occurred since plant construction. Initially, storm water from this area was discharged to Outfall 005. In 1989 a storm water collection trench was constructed which diverted storm water flow from Outfall 005 to 008.

Historical Information Review

Analysis of water samples from January and February 1985 detected uranium levels ranging from 79 to 7,427 pCi/l. Soil analyses from the drainage area in September 1990 indicated uranium concentrations of <270 to 4,752 pCi/g.

No releases or remedial actions were discovered in the research of this unit.

Characterization Sample Results

Sources

No sources are currently present in this unit.

Soils

Soil samples have been collected from thirty-three (33) locations in and around this unit. Sample depths ranged from the surface to thirty-eight (38) feet deep. Of the 167 uranium analyses, 127 (76.0%) were less than 35 pCi/g and 151 (90.4%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 6,200 pCi/g.

Summary of Findings

The soils in the drainage areas around the Emergency Basin and the North Ditch are impacted to varying degrees by uranium generally to depths less than five (5) feet.

4.4.12 Fluoride Holding Basin No. 2 (North) (Unit 12)

Description and General Information

Fluoride Sludge Holding Basin No. 2 is located in the northwest corner of the facility west of Solid Waste Burial Area No. 2 and north of the Pond 1 Spoils Pile. The 150 foot by 220 foot by nine (9) foot clay-lined basin was built in 1985 to store calcium fluoride (CaF_2) sludge from the lime neutralization process with an estimated capacity of 201,000 cubic feet. After settling occurs the water is decanted and transferred to the Fluoride Clarifier. The sludges in Fluoride Holding Basin No. 2 (North) are comprised of CaF_2 solids derived from the neutralization of hydrogen fluoride off-gas scrubber water with calcium oxide (lime).

Historical Information Review

The basin was originally hypalon-lined and temporarily used upon completion for storing treated raffinate. The treated raffinate was transferred to the Clarifiers and the liner was removed. The basin has since been used for storage of calcium fluoride sludge.

Directly north of Fluoride Sludge Holding Basin No. 2, a drum crusher was utilized for compacting empty 55 gallon yellowcake drums. Approximately 40,000 empty yellowcake drums were also stored, prior to crushing, in the area north of the basin.

Sulfuric acid, used for pH control of the waste stream, leaked from a storage tank located at the southeast corner of the basin during the mid 1980's. Information gathered during employee interviews indicated that approximately 50 gallons of acid leaked onto the ground in the immediate area around the tank. This tank was emptied and moved to the yellowcake storage pad during 1995.

Characterization Sample Results

Sources

Source samples have been collected from two (2) locations from Fluoride Holding Basin No. 2. Uranium concentrations ranged from approximately 210 to 840 pCi/g, nitrate at 375 µg/g and fluoride from 11,200 to 39,600 µg/g.

Fluoride Holding Basin No. 2 is estimated to contain 186,000 cubic feet of CaF_2 sludge.

Soils

Soil samples have been collected from fifteen (15) locations in and around this unit. Sample depths ranged from the surface to thirty (30) feet deep. Of the 121 uranium analyses, 120 (99.2%) were less than 35 pCi/g and 121 (100%) were less than 110 pCi/g. One (1) sample was analyzed for thorium-230 and radium-226. The thorium-230 and radium-226 concentrations were 1.8 and 1.4 pCi/g, respectively.

Summary of Findings

Fluoride Holding Basin No. 2 contains an estimated 186,000 cubic feet of calcium fluoride sludge with a uranium content of about 1.02 Ci (1522 kg) of natural uranium. Soils surrounding the basin are slightly impacted by fluoride and uranium in the surface layer.

4.4.13 Fluoride Holding Basin No. 1 (South) (Unit 13)

Description and General Information

Fluoride Sludge Holding Basin No.1 is located south of the Fluoride Settling Basins. The holding basin was constructed in 1981 to hold calcium fluoride (CaF_2) sludge generated from the Lime Neutralization Area. Prior to 1981, CaF_2 sludge had been buried in pits. Due to changes in regulations prohibiting the burial of process sludges, Holding Basin No.1 was built. This material flowed to the Settling Basins (Unit 14). When these basins became full, the sludge was transferred to one of the two holding basins (Unit 12 or 13). Basin No. 1 is constructed of clay and measures 190 feet by 130 feet by 16 feet deep, with an estimated capacity of 186,800 cubic feet. The sludges in Fluoride Holding Basin No. 1 (South) are comprised of CaF_2 solids derived from the neutralization of hydrogen fluoride off-gas scrubber water with calcium oxide (lime).

Historical Information Review

In about 1989, Fluoride Holding Basin No. 1 overflowed at the southeast corner of the basin.

Characterization Sample Results

Sources

Source samples have been collected from two (2) locations from Fluoride Holding Basin No. 1. Uranium concentrations ranged from approximately 310 to 320 pCi/g, nitrate at 375 µg/g and fluoride from 22,100 to 27,700 µg/g.

Soils

The underlying soils are assumed to be impacted from exposure to the sludge and liquid contained in Fluoride Sludge Holding Basin No.1. The extent of the impact will be determined by sampling the basin bottom once the sludges have been removed.

Soil samples have been collected from five (5) locations in and around this unit. Sample depths ranged from the surface to twenty-eight (28) feet deep. Of the 52 uranium analyses, 52 (78.8%) were less than 35 pCi/g. The maximum uranium concentration observed was approximately 3.4 pCi/g.

Summary of Findings

Fluoride Holding Basin No. 1 contains an estimated 171,400 cubic feet of calcium fluoride sludge with a uranium content of about 0.82 Ci (1224 kg) of natural uranium. Soils surrounding the basin are slightly impacted by fluoride and uranium in the surface layer.

4.4.14 Fluoride Clarifier and Settling Basins (South) (Unit 14)

Description and General Information

Unit 14 is located south of Unit 17 (Clarifier A Basin Area) and west/northwest of Unit 15 (Fluoride Sludge Burial Area). The unit consists of three (3) separate basins, a fluoride clarifier and two settling basins, which were built in 1971. The clarifier is approximately 14 feet deep. The fluoride clarifier is located in the western portion of this unit and is 220 feet long by 85 feet wide. The two settling basins are located in the eastern portion of this unit and are each 190 feet long by 75 feet wide. Each settling basin varies in depth, from about 6 feet at the east end to a maximum depth of 12 feet at the west end. Estimated capacities are 102,100 cubic feet and 46,800 cubic feet for the fluoride clarifier and each settling basin, respectively. None of the these basins have synthetic liners.

Historical Information Review

The settling basins were designed to allow CaF_2 solids from the lime neutralization process to settle. After the solids settle, the liquid was decanted and flowed to the fluoride clarifier. Liquid from the fluoride clarifier was routed to the Combination Stream.

During operation of the Facility, settled solids from the settling basins were periodically transferred to burial areas (Unit 15) and holding basins (Units 12 and 13). Solids have not been removed from the fluoride clarifier due to the limited volume of sludge accumulated.

A release occurred from a leak in the fluoride clarifier discharge line located on the south side and near the east end of the south fluoride settling basin. This discharge line runs from the west end of the fluoride clarifier to the combination stream.

Characterization Sample Results

Sources

Source samples have been collected from eight (8) locations from the Fluoride Clarifier and Settling Basins. Uranium concentrations ranged from approximately 56 to 1,100 pCi/g, nitrate from 16 to 375 µg/g and fluoride from 980 to 51,000 pCi/g. One sample was analyzed for thorium-230 and radium-226. The thorium-230 and radium-226 concentrations were 4.8 and 0.8 pCi/g, respectively.

Soils

Soil samples have been collected from three (3) locations around the Fluoride Clarifier and Settling Basins. Sample depths ranged from the surface to thirty-two (32) feet deep. Of the 28 uranium analyses, 27 (96.4%) were less than 35 pCi/g and 28 (100%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 54 pCi/g. One sample was analyzed for thorium-230 and radium-226. The thorium-230 and radium-226 concentrations were 0.8 and 1.6 pCi/g, respectively.

Summary of Findings

The Fluoride Settling Basins No. 1 and No. 2 and the Fluoride Clarifier contain an estimated 114,300 cubic feet of calcium fluoride sludge with a uranium content of about 0.92 Ci (1365 kg) of natural uranium. Soils surrounding the basin are slightly impacted by fluoride and uranium in the surface layer.

4.4.15 Fluoride Sludge Burial Area (Unit 15)

Description and General Information

The Fluoride Sludge Burial Area, is located directly east and south of the Fluoride Settling Basins and was used prior to 1981 for the burial of CaF_2 sludge. These consist of three (3) distinct sections. The northern section measures approximately 100 feet by 200 feet and was filled in two phases, resulting in a West Pit and an East Pit. Burial occurred in the West Pit in September, 1978, and in the East Pit in December, 1979. The second section is located directly south of the East and West Pits and measures approximately 50 feet by 275 feet. It is divided into Pit 3 and Pit 4. Burial occurred in Pit 3 in December, 1980, and in Pit 4 in January, 1981. The third section is located at the southwest corner of the area and contains CaF_2 sludge that has not been buried and is currently used for the retention of sludge. None of these areas are lined.

Historical Information Review

Materials other than calcium fluoride, such as UF_4 ash and drums of hardened yellowcake, are believed to have been buried in these areas.

The burial activity complied with federal regulations (10 CFR 20.304). A total of 96,830 cubic feet of fluoride sludge was buried, with a total activity of 1.5 curies of natural uranium. A survey was conducted of the burial areas by a registered land surveyor to document the location of each burial. Monuments were placed near the burial areas for identification purposes.

Characterization Sample Results

Sources

A composite sample (SD013) was collected from the Fluoride Sludge -Southwest Area during 1995. Uranium, nitrate and fluoride concentrations were 313 pCi/g, 22 µg/g and 34,300 µg/g, respectively. This area was used for holding fluoride sludges and was never covered.

Due to physical nature of the burial area contents, SFC has concluded that it is not possible to obtain representative samples without full exhumation. Since some of the burial areas may include containers such as drums, there is also a concern that sampling may cause the spread of contamination by disturbing or penetrating the drums with a sampling device. Therefore, the fluoride sludge burial areas will not be characterized by direct sampling during site characterization. For characterization purposes, information relating to the burial areas has been obtained from site records, employee interviews and soil and groundwater media investigations.

Soils

Samples were not collected within close proximity to the burial trenches around burial area perimeters because of limited access. Sufficient data is available from the burial areas to bound the impacts. Therefore, additional sampling is not planned at this time. Sampling to determine the extent of impacted soils will be performed during remediation of the unit.

Soil samples have been collected from six (6) locations near or around this unit. Sample depths ranged from the surface to twenty-six (26) feet deep. Of the 44 uranium analyses, 44 (100%) were less than 35 pCi/g. The maximum uranium concentration observed was approximately 7.7 pCi/g.

Summary of Findings

Based on plant records, the Fluoride Sludge Burial Area contains approximately 96,380 cubic feet of buried calcium fluoride sludge with a uranium content of 1.52 Ci (2268 kg) of natural uranium. Additionally an estimated 57,200 cubic feet of calcium fluoride sludge containing 1.55 Ci (2,300 kg) of natural uranium is stored uncovered in the west end of burial pit 4.

4.4.16 South Yellowcake Sump (Unit 16)

Description and General Information

Unit 16, the South Yellowcake (SYC) Sump, was built in 1980 and is located inside the Process Area, directly south of the Yellowcake Storage Pad (Unit 21).

The unit is constructed of concrete and measures 75 feet by 75 feet by eight (8) feet deep. It receives surface water runoff from the Yellowcake Pad (Unit 21).

Historical Information Review

The sediments contained in the SYC Sump are comprised of soils and debris deposited in the basin from collection of surface water runoff from the Yellowcake Pad. These sediments were removed periodically.

Characterization Sample Results

Sources

Only one sample was collected during these characterization activities. A composite sediment sample was collected from the sump in 1995 (SD015) and analyzed for uranium, nitrate and fluoride. The uranium, nitrate and fluoride concentrations were 2003.9 pCi/g, 30 µg/g and 424 µg/g, respectively.

Soils

Soil samples have been collected from three (3) locations in and around this unit. Sample depths ranged from the surface to twenty-five (25) feet deep. Of the 21 uranium analyses, 20 (95.2%) were less than 35 pCi/g and 20(95.2%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 160 pCi/g. One sample was analyzed for thorium-230 and radium-226. The thorium-230 and radium-226 concentrations were 0.6 and 1.2 pCi/g, respectively.

The soils underlying the sump may be impacted by leakage from the sump. The extent of any impacts will be determined by sampling the soils once the sump structure has been removed.

Summary of Findings

The South Yellowcake Sump has collected impacted storm water runoff and sediments from the yellowcake pads. The sediment was removed from the sump during 1995 and placed in the 2A Clarifier. The soils surrounding the sump have been impacted by uranium.

4.4.17 Clarifier A Basin Area (Unit 17)

Description and General Information

Unit 17, the Clarifier Basin Area is located directly north of the Fluoride Settling Basins and east of Pond 2. This area consists of the Clarifier A Basins, the New BaCl Mixing Area (WPC Building) and the Centrifuge Building. The Clarifier A Basins consist of four (4) clay and hypalon-lined ponds, each measuring approximately 250 feet by 200 feet by thirteen (13) feet deep. The Clarifiers received raffinate from the solvent extraction process. The raffinate was treated with ammonia and barium chloride to precipitate metals and radionuclides within these ponds. The treated ammonium nitrate solution was then transferred by a pipeline to the fertilizer ponds. Raffinate sludge accumulated in the bottom of the clarifiers. The raffinate sludge was shipped to New Mexico for additional uranium recovery until 1992. The remainder of the sludge is stored in the clarifier area.

The New BaCl Mixing Area (WPC Building) is located south of the Clarifiers and is approximately 21 feet by 26 feet in size and was built in 1982. The metal building was originally built to house a research project that attempted to solidify raffinate sludge in asphalt (WPC Project). The experiment lasted for less than 1 year and afterwards the building was used for storage until 1992. In 1992, the building was used for mixing and storing BaCl, utilized for raffinate treatment until 1995.

The Centrifuge Building is located south of the Clarifiers and is approximately 25 feet by 35 feet in size and was built in 1989. The metal building housed four de-watering tanks. The centrifuge process was utilized in an attempt to de-water the raffinate sludge by-product prior to disposition.

Historical Information Review

Clarifier Area

Prior to construction of Clarifier A in 1980, one surface impoundment, Pond 1, existed in this area. Pond 1 measured approximately 400 feet by 500 feet by ten (10) feet deep. As with the Clarifier A Basins, Pond 1 was utilized to treat raffinate. Raffinate was transferred from the SX building to Pond 1 via a trough. Spills or leaks that occurred from the trough would have flowed toward the Outfall 005 drainage pathway. The raffinate sludge that was stored in Pond 4 was transferred to the clarifier basins between 1993 and 1995.

Centrifuge Building

A valve in a raffinate sludge transfer line located on top of the centrifuge building failed and released material outside the building. The ground near the northeast corner of the building was impacted.

Characterization Sample Results

Sources

Source samples have been collected from eleven (11) locations from this unit. Uranium concentrations ranged from approximately 2,500 to 19,200 pCi/g, thorium-230 from 2,930 to 48,200 pCi/g, radium-226 from 14 to 190 pCi/g, nitrate from 18,000 to 49,000 µg/g and fluoride from 9,400 to 34,000 µg/g.

No source samples were collected from either the Centrifuge Building or the New BaCl Mixing Area (WPC Building).

Soils

Soil samples have been collected from thirteen (13) locations in and around this unit. Sample depths ranged from the surface to forty-four (44) feet deep. Of the 104 uranium analyses, 101 (97.1%) were less than 35 pCi/g and 102 (98.1%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 210 pCi/g. Twelve samples were analyzed for thorium-230 and radium-226. The thorium-230 concentrations ranged from 1.6 to 790 pCi/g and the radium-226 from 0.1 to 4.6 pCi/g.

Summary of Findings

Section 1, 2 and 4 of Clarifier Basin A currently contain about 7.5 million gallons of raffinate sludge at 15-20% solids, which translates to approximately 200,000 cubic feet of dry sludge. Based on an average of existing sample results, the sludge contains 37.1 Ci (54,861 kg) of natural uranium. The synthetic liners in the clarifier basins have been damaged in the past, impacting the clay liner and possibly some of the underlying soil. Samples taken from the clay liner in the 3A clarifier indicate that approximately 332,400 cubic feet of clay liner material contain 0.47 Ci (697 kg) of natural uranium. The soils surrounding the clarifier basins is impacted by fluoride, nitrate, uranium, radium-226 and thorium-230.

4.4.18 Pond 2 (Unit 18)

Description and General Information

Pond 2 is located west of the Clarifier Basins and the Fluoride Settling Basins, spanning the length of both units. The pond was constructed in 1971 and measures approximately 300 feet by 700 feet by 18 feet deep, with an estimated total capacity of 2,963,000 cubic feet. Pond 2 contained raffinate and sludge byproducts until it was taken out of service in the early 1980's due to historically documented leaks. A remediation plan was developed and implemented in 1991. Sludge and residual clays from Pond 2 were removed and transferred to the hypalon-lined, Pond 4. Pond 2 was then covered with a synthetic liner and the southwest corner of the berm was breached to allow rainfall to drain. This action was intended to help eliminate any potential hydraulic head caused by impounded rainwater.

Historical Information Review

Construction of Pond 2 began in June of 1971. Raffinate was first placed in the pond in October 1971. Pond 2 was operated almost continually until December 1980. The only time the pond was not in service was during August 1973 when the pond embankments were modified.

Throughout the operation of the pond, contaminated rock, yellowcake drums, soda ash, anode blades, drum liners, electrolyte sludge and laboratory waste were discarded into Pond 2.

Detection of leakage from Pond 2 was first noted in an adjacent monitor well in May 1974. A comprehensive background report describing the geologic and hydrologic conditions, leakage rates and estimated solution travel time was submitted to NRC in January 1977. Pond 2 conditions were monitored continually which included installation of additional monitoring wells, implementing revised sampling techniques and conducting geophysical surveys.

In March 1984, Facility personnel discovered stained areas approximately 500 feet south of Pond 2. Analysis of water collected from these seeps indicated the presence of nitrates in concentrations up to 1,000 mg/l. Based on the location of the seeps and the magnitude of nitrate contamination in the area, two collection trenches and flow barrier slurry walls were constructed to intercept contaminated groundwater. All recovered groundwater was pumped back into Pond 2. A french drain system, Catchment Trench #3 (CAT#3), was installed on the southern end of Pond 2 in 1985. This system was designed with an automatic pumping system to keep the area de-watered. The east-west french drain system was constructed with a gravel filled trench connected to a buried concrete tank installed approximately 4 feet below ground level. Groundwater collected from the trench gravity flowed into the tank and was subsequently pumped back to Pond 2. Pumping was discontinued prior to 1990 after the area failed to yield enough water to pump. Intermittent pumping was resumed during 1995 and automated pumping was established in 1997.

A remediation plan for Pond 2 was submitted to NRC in March 1989. After a subsequent revision, NRC approved the remediation plan in 1990. Pond 2 remediation activities were conducted in 1991. All liquids in the pond were removed and the pond sludges were removed to levels which exhibited uranium levels less than 2,000 pCi/g. A high density polyethylene (HDPE) liner was then placed over the remaining sludges. In addition, a portion of the west pond embankment was breached to facilitate gravity drainage of rainwater.

Characterization Sample Results

Sources

Source samples have been collected from twenty-one (21) locations from this unit. Uranium concentrations ranged from approximately 3.4 to 2,060 pCi/g, thorium-230 from 1.8 to 6,800 pCi/g, radium-226 from 0.4 to 230 pCi/g, nitrate from 770 to 12,700 µg/g and fluoride from 290 to 7,500 µg/g.

Soils

Soil samples have been collected from twenty-four (24) locations in and around this unit. Sample depths ranged from the surface to forty (40) feet deep. Of the 218 uranium analyses, 215 (98.6%) were less than 35 pCi/g and 218 (100%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 49 pCi/g. Six samples were analyzed for thorium-230 and radium-226. The thorium-230 concentrations ranged from 0.6 to 14 pCi/g and the radium-226 from 0.7 to 2.8 pCi/g.

Summary of Findings

The impacted clay liner and residual sludge in the bottom and sides of Pond 2 is estimated to be 749,000 cubic feet. Based on samples taken prior to the installation of the temporary cover, there is 10.8 Ci (16,074 kg) of natural uranium contained in this material. Soils surrounding the basin do not appear to be impacted by uranium, radium or thorium.

West of Pond No. 2 (Unit 19)

... and General Information

... sists of the area located along the west side of Pond 2 and lies outside ... d area boundary. A natural drainage ditch was previously located ... nit and was used for storm water drainage which discharged from the ... concrete culvert designated as permitted Outfall 004.

... nformation Review

... e area was backfilled during the storm water collection trench project ... ench drain type recovery system was simultaneously installed within ... drainage area. The french drain construction consisted of a gravel ... to west trench connected to a concrete tank buried approximately 30 ... the present ground elevation. An automatic pumping system was ... the tank and pumping from the recovery system, Ditch West of Pond 2 ... gan that same year.

... egan malfunctioning in July 1993 and failed in December 1993 due, in ... g of the subsurface collection tank. Attempts to completely pump the ... ment out of the tank were unsuccessful. A new submersible pump ... d in the automatic pumping system in January 1995. Water recovered ... lection system typically averages <3.4 pCi/l uranium and 250 mg/l

... ation Sample Results

... are present in this unit.

... s have been collected from eleven (11) locations in and around this ... le depths ranged from the surface to forty-six (46) feet deep. Samples ... collected from depths which correspond to the ground surface prior to ... DWP2. Of the 118 uranium analyses, 118 (100%) were less than 35 ... maximum uranium concentration observed was approximately 3.9 ... samples were analyzed for thorium-230 and radium-226. The tho- ... ncentrations ranged from 1.2 to 1.5 pCi/g and the radium-226 from 1.2 ... g.

... can

... scan was performed at Unit 19 during 1996. The scan indicates that ... dual radioactive material may exist in this unit. The gamma scan results ... th end of this unit may be influenced by the material in Clarifier A Basin ... 7)-

... of Findings

... in the area west of Pond 2 are not impacted based on the sampling con- ... date.

The North Tank Farm is located north of the South Tank Farm and east of the Bechtel Building and was constructed as part of an expansion that began in 1975. The 48 foot by 46 foot curbed area consisted of a sandblasting building, bulk chemical tanks, a diesel fuel tank and an emergency water supply tank. The curbed area where bulk chemicals were stored is lined with limestone rock bed for neutralization in case of a spill or upset. The North Tank Farm consisted of two (2) 15,000 gallon 40% nitric acid tanks, one (1) 15,000 gallon anhydrous hydrogen fluoride, and one (1) 15,000 gallon aqueous hydrogen fluoride tank. Accumulated rainwater drains into the North Ditch. The diesel fuel tank has an earthen berm and rainfall is discharged to the North Ditch. The remainder of the area drains naturally to the North Ditch. Prior to 1975, the location of the present north tank farm was used as a storage area for drums of oil, equipment and trash.

Historical Information Review

Review of information on file indicates that there were incidents in which uranium bearing materials were released from process systems or containers. Drainage from the HF scrubber building drains out onto the roadway south of the south tank farm. Liquid with a uranium concentration of about 12 g/l was discovered on the ground by the main plant stack. Uranium released during the 1986 accident occurred in and contributed to uranium contamination in the southeast portion of Unit 30. After the 1986 accident approximately 280 drums of contaminated limestone were removed from the south tank farm. This material was used as backfill for the SX Vault french drain system installed in 1990. Prior to installation of the cylinder storage pad, the location of the north tank farm was used as a storage area for drums of oil and contaminated bags of trash. Fire hoses were used in front of the Bechtel Building to wash potentially contaminated equipment prior to maintenance. Excess water from this operation ran across the ground surface toward the North Ditch. The nitric acid tanks were occasionally overfilled, resulting in nitric acid running over into the limestone containment. Materials in the tanks were suspected as being contaminated with uranium from process transfers. Ash receivers were handled (de-smoked and ash removed) in the area between the nitrogen tanks and the steam chests.

Characterization Sample Results

<u>Sources</u>

No source samples were collected from this unit.

<u>Soils</u>

Soil samples have been collected from thirteen (13) locations in and around this unit. Sample depths ranged from the surface to forty-six (46) feet deep. Of the 171 uranium analyses, 162 (94.7%) were less than 35 pCi/g and 165 (96.5%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 650 pCi/g.

Summary and Findings

The soils in the Tank Farm and Cylinder Storage Area are impacted by uranium, primarily in the area just north of the MPB. Additional near surface impact is expected under the concrete pads.

4.4.31 Front Lawn Area (Unit 31)

Description and General Information

This unit consists of lawn areas, access roads and a parking lot. The area extends from just south of the front of the new Administration Building to the fence along the south side of the South Guard house, and from the Right of Way along the west side of Highway 10 to near the access road from the South Guard House to the MPB.

Historical Information

The uranium release during the 1986 rupture of a UF_6 cylinder impacted the surface soil within a portion of Unit 31. Some soils were removed and stored in the 1986 Incident Storage Area from 1986 until 1992. Impacted soils in this storage area were ultimately removed to the Interim Storage Cell.

Characterization Sample Results

Sources

There are no sources in the area.

Soils

Soil samples have been collected from sixteen (16) locations in and around this unit. Sample depths ranged from the surface to thirty-seven and a half (37.5) feet deep. Of the 147 uranium analyses, 146 (99.3%) were less than 35 pCi/g and 146 (99.3%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 1,550 pCi/g. Seven samples were analyzed for thorium-230 and radium-226. The thorium-230 concentrations ranged from 0.5 to 1.2 pCi/g and radium-226 from 0.1 to 2.3 pCi/g.

Gamma Scan

The gamma scan for this unit was completed during 1995. The results of the scan are consistent with the historical assessment and soil samples from this unit; i.e. indicative of impacted soils.

Summary of Findings

Soils in the Front Lawn Area have residual impacts from the uranium released during the 1986 incident along the northern boundary of the area and in the storm water drainage pathway.

4.4.32 South Perimeter Area (Unit 32)

Description and General Information

The primary feature in this area is a storm water reservoir which was completed in May of 1991. The storm water reservoir has a capacity of 8,960,000 cubic feet and covers 16 acres. The normal water level is at an elevation of 510 feet (approximately 8 acres) and the flood stage at 520 feet. The reservoir was constructed to control nitrate and ammonia exceedances through the storm water outfalls. In 1990, SFC constructed a collection trench around the Process Area to divert surface water runoff from the northern and western portions of the Process Area through Outfall 008.

The reservoir was designed to collect storm water from the Process Area to facilitate a reduction of nutrient levels by biological processes prior to discharge. However, the State did not act upon the permit modification request to include the storm water reservoir and SFC chose not to include the reservoir in the new permit renewal. The storm water reservoir collects water from non-process areas only.

Historical Information

Characterization Sample Results

Sources

No sources are currently present in this unit.

Soils

Soil samples have been collected from forty (40) locations in and around this unit. Sample depths ranged from the surface to thirty (30) feet deep. Of the 168 uranium analyses, 161 (95.8%) were less than 35 pCi/g and 167 (99.4%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 120 pCi/g. Eleven samples were analyzed for thorium-230 and five for radium-226. The thorium-230 concentrations ranged from approximately 0.8 to 910 pCi/g and radium-226 from 1.2 to 4.7 pCi/g.

Seven sediment samples were collected from this unit and were analyzed for uranium. Three of the samples were analyzed for thorium-230 and radium-226. The uranium concentrations ranged from 4.5 to 43 pCi/g, thorium-230 from 1 to 1.3 pCi/g and radium-226 at 0.1 pCi/g.

Gamma Scan

The gamma scan for this unit was completed between 1995 and 1998. The area immediately surrounding Fluoride Holding Basin No. 1 (South)(Unit 13) is influenced by the material stored in the basin to the north (Unit 15) and the south (Unit 13) and is not indicative of impacted soils. Otherwise the results indicate the potential for impacted soils associated with intermittent drainages but do not indicate the presence of impacted soils across the remainder of the unit.

Summary of Findings

Soils in the South Perimeter Area just south of the Initial Lime Neutralization Area (Unit 3) have limited impact from fluoride and uranium. Additionally, the gamma scan identified an area with slightly elevated readings in the southeast portion (just north of Pond 4 and west of Pond 6).

4.4.33 Northeast Perimeter Area (Unit 33)

Description and General Information

This unit lies north of the Industrial Area and consists of field and timbered areas. A gravel access road runs through the area.

Historical Information

Characterization Sample Results

Sources

No sources are currently present in this area.

Soils

Soil samples have been collected from six (6) locations in and around this unit. Sample depths ranged from the surface to twenty-nine (29) feet deep. Of the 32 uranium analyses, 32 (100%) were less than 35 pCi/g. The maximum uranium concentration observed was approximately 6.8 pCi/g.

Gamma Scan

The gamma scan for this unit was completed between 1997 and 1998. The elevated readings in the south center are attributed to the material stored in the Interim Storage Cell (Unit 35) and the DUF_4 Building. Otherwise, the gamma scan does not indicate the presence of impacted soils in this unit.

Summary of Findings

Soil samples do not indicate any impact in the Northeast Perimeter Area.

4.4.34 Drainage/Runoff Areas (Unit 34)

Description and General Information

There are several drainage areas which historically originated in or near the Process Area and flow towards the headwaters of the Robert S. Kerr Reservoir. These drainage pathways consist of permitted Outfalls 004, 005, 007 and 008. Outfalls 004, 005, and 007 have been inactive since the construction of a surface water runoff collection trench in June 1990. The collection trench conveys the storm water which previously exited the Process Area via these outfalls to permitted Outfall 008.

Historical Information Review

In 1986, SFC personnel collected sediment samples from the surface drainage paths of Outfalls 004, 005, and 007. These drainage pathways have been eroded down to bedrock and sediment that is carried along the stream beds settles where water flow velocities are insufficient for the sediment to remain in suspension. Subsequently, sediment samples were collected in pooled areas which fill more easily with sediment than flat bedrock surface areas. These samples were analyzed for uranium, radium-226 and thorium-230.

On June 10, 1991, NRC and SFC personnel collected sediment samples from Outfalls 004 and 005. Sediment samples were obtained from the surface of the stream bed at approximately the same locations in 1986. One (1) sample was collected from Outfall 004 and five (5) samples were collected from Outfall 005.

On September 10, 1991 SFC further characterized the uranium concentrations in the sediment along the drainage segment designated during the June 10, 1991 sample event as SFC-C and SFC-E (Drainage Segment C-E). Sediment samples were also collected along the drainage pathways and along Outfalls 004, 007 and 008.

Sediment samples were collected along the approximately 600-foot Drainage Segment C-E of Outfall 005. Drainage Segment C-D was sampled at 50-foot increments (5 samples). Drainage Segment D-E was sampled at 10-foot increments (40 samples).

Outfall 004 and 007 drainage paths were sampled in approximately the same locations sampled by SFC in 1986, for a total of six (6) samples from Outfall 004 drainage path and six (6) samples from Outfall 007 drainage path. Outfall 008 drainage path was sampled at 100-foot increments for a total of approximately nine (9) sediment samples. All sediment samples were analyzed for radium-226, thorium-230, and total uranium.

Characterization Sample Results

<u>Sediments</u>

Sediment samples have been collected from eleven (11) locations from the 004 drainage. Sample depths ranged from the surface to three-tenths (0.3) feet deep. Of the 11 uranium analyses, 11 (100%) were less than 35 pCi/g. The maximum uranium concentration observed was approximately 6.1 pCi/g. Eight samples were analyzed for thorium-230 and radium-226. The thorium-230 concentrations ranged from 0.4 to 2.1 pCi/g and radium-226 from 0 and 1.4 pCi/g, respectively.

Sediment samples have been collected from fifty-six (56) locations from the 005 drainage. Sample depths ranged from the surface to three-tenths (0.3) feet deep. Of the 56 uranium analyses, 19 (33.9%) were less than 35 pCi/g and 42 (75.0%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 520 pCi/g. Fifty-one samples were analyzed for thorium-230 and radium-226. The thorium-230 concentrations ranged from 1.7 to 354 pCi/g and radium-226 from 0.5 and 3.7 pCi/g, respectively.

Sediment samples have been collected from eleven (11) locations from the 007 drainage. Sample depths ranged from the surface to three-tenths (0.3) feet deep. Of the 11 uranium analyses, 8 (72.7%) were less than 35 pCi/g and 11 (100%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 80 pCi/g. Six samples were analyzed for thorium-230 and radium-226. The thorium-230 concentrations ranged from 1.8 to 3.4 pCi/g and radium-226 from 0.8 and 2.2 pCi/g, respectively.

Sediment samples have been collected from ten (10) locations from the 008 drainage. Sample depths ranged from the surface to two-tenths (0.2) feet deep. Of the 10 uranium analyses, 10 (100%) were less than 35 pCi/g. The maximum uranium concentration observed was approximately 7 pCi/g. Nine samples were analyzed for thorium-230 and radium-226. The thorium-230 concentrations ranged from 0.6 to 2.0 pCi/g and radium-226 from 0.7 and 1.3 pCi/g, respectively.

Gamma Scan

The gamma scan for this unit was completed during 1995. The results of the scan are consistent with the historical assessment and soil samples from this unit; i.e. indicative of impacted soils in Outfall 005 and possibly the upper portion of 007.

Summary of Findings

Several of the drainage runoff area sediments are impacted by uranium, radium-226, and thorium-130.

4.4.35 Scrap Metal Storage Area (Unit 35)

Description and General Information

Unit 35, the Scrap Metal Storage Area and the Interim Storage Cell, are located north of the Unit 29. A graveled fenced portion of this unit served as a storage area for scrap metal in 1975. The area was used to store leftover construction materials such as pipe, beams, and siding that were previously stored near the North Tank Farm. The area was also used as a staging area for storage of decontaminated equipment prior to release as clean scrap. However, some radiologically contaminated equipment was stored in this area.

In 1991 SFC began plans to consolidate, stabilize and store contaminated soils on site on an interim basis pending future treatment or disposal. The selected interim storage method was an above-ground containment cell.

The Interim Storage Cell was constructed on an existing concrete pad (north cylinder pad) at the north end of the Process Area. The wall structure of the cell is formed from concrete inverted-tee sections. A 38 mil thick liner was placed on the bottom of the storage cell. A geotextile fabric was used for added strength and physical protection of the liner. The geotextile fabric and the liner are physically secured to the storage cell wall. The overall outer dimensions of the storage cell are approximately 100 feet in width and 160 feet in length.

Historical Information Review

Several drums of dirt and gravel containing uranium bearing materials leaked on the north cylinder pad. Rain had washed some of the material from the drums into a drainage ditch located along the edge of Unit 35. Soil samples collected from the impacted area indicate a maximum uranium concentration of 765 pCi/g.

Soils were placed into the Interim Storage Cell in the fall of 1991. Three primary sources of uranium-contaminated soils were initially placed into the Interim Storage Cell. These sources were the soil (sod) contaminated by the 1986 cylinder rupture; limestone gravel associated with a former hydrofluoric acid neutralization area; and soils from various excavation activities around the solvent extraction building which were temporarily stored on the yellowcake storage pad. Another main source placed into the storage cell was from Pond 4. Impacted sand and clay from beneath the liner was transferred to the cell in 1998. The volume and uranium concentration of each of these units of contaminated soils are provided in the following table.

Soils Stored In The Interim Soil Storage Cell			
	Approximate Volume (ft^3)	Natural Uranium Average Concentration (pCi/g)	Natural Uranium Range (pCi/g)
Soil from 1986 accident	12,150	150	98 - 262
Gravel and soil from hydrofluoric acid neutralization pile	65,880	14	4 - 430
Soil excavated from around solvent extraction building	44,550	1220	<270 - 4082
Soil and ash drums	18,375	105	<3.4 - 6770
Sand and clay from Pond 4	13,932	7	<3.4 - 39
Total Volume	154,887		

As additional soils are identified, SFC evaluates their suitability for storage in the cell on a case by case basis. Some additional soils from other areas have also been placed in the cell. The respective volumes and concentrations, however, are small compared to the four primary units described above.

Characterization Sample Results

<u>Sources</u>

One sample (BH149) was collected from the Interim Soil Storage Cell. The uranium concentration for this sample was 1,560 pCi/g uranium.

Soils

Soil samples have been collected from fourteen (14) locations in and around this unit. Sample depths ranged from the surface to thirty-six (36) feet deep. Of the 75 uranium analyses, 68 (90.7%) were less than 35 pCi/g and 70 (93.3%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 1,560 pCi/g.

Summary of Findings

The Interim Storage Cell contains approximately 154,800 cubic feet of contaminated soils and other materials containing an estimated 2.84 Ci of natural uranium.

4.4.36 1986 Incident Plume Area (Unit 50)

Description and General Information

Unit 50, the 1986 Incident Plume Area, was impacted when a 14-ton UF_6 cylinder ruptured resulting in a release of uranium hexafluoride (UF_6). The incident occurred outside of the process building and the plume was carried downwind in the SSE direction. Unit 50 is located outside the Restricted Area south of the Front Lawn Area (Unit 31) and the Decorative Pond Area (Unit 26), and to the east of the South Perimeter Area (Unit 32).

Historical Information Review

A report was prepared by an Interagency Public Health Assessment Task Force following the accidental release of UF_6 from the Facility in January 1986. The Task Force concluded that measurable and highly variable uranium and fluoride contamination of soil and vegetation was located offsite in the path of the plume. Concentrations in soil ranged from 5 to 150 µg/g uranium and from <5 to 160 µg/g fluoride over this unit. The report is found in NUREG-1189, Assessment of the Public Health Impact From the Accidental Release of UF_6 at the Sequoyah Fuels Corporation Facility at Gore, Oklahoma, dated March 1986.

To resolve some of the identified uncertainties, the Task Force recommended that additional data be collected. SFC conducted the recommended resurvey and published the findings in a report entitled, "Environmental Resurvey Related to UF_6 Release on January 4, 1986 Sequoyah Facility Near Gore, Oklahoma" dated October, 10, 1986. The report stated that "The results of the resurvey confirmed that there was no significant impact to the soils and vegetation from the released material. Initially elevated levels were significantly lower during the intervening six month period after the release." The area east of Highway 10, designated as Unit 50B, has been surveyed to ensure that there was no residual contamination present. Following submittal of a Final Radiological Status Report for Unit 50B to NRC, NRC concluded that "this area meets criteria for release for unrestricted use". Therefore, Unit 50B is of no further regulatory interest.

Characterization Sample Results

Sources

No sources are currently present in this unit.

Soils

Soil samples have been collected from twenty-three (23) locations in and around this unit. Sample depths ranged from the surface to two (2) feet deep. Of the 23 uranium analyses, 22 (95.7%) were less than 35 pCi/g and 22 (95.7%) were less than 110 pCi/g. The maximum uranium concentration observed was approximately 200 pCi/g. Two samples were analyzed for thorium-230 and five for radium-226. The thorium-230 concentrations ranged from approximately 0.5 to 2.0 pCi/g and radium-226 from 1.3 to 3.1 pCi/g.

Gamma Scan

The gamma scan for this unit was completed between 1995 and 1998. The results of the scan are consistent with the historical assessment and soil samples from this unit; i.e. indicative of impacted soils in an intermittent drainage. Otherwise, the gamma scan does not indicate the presence of impacted soils in this unit.

Summary of Findings

Soils in the 1986 Incident Plume Area have residual impacts from the uranium released during the 1986 incident. The gamma scan identified some elevated areas.

4.4.37 Northeast Perimeter Area (Unit 52)

Description and General Information

Unit 52 lies east of Highway 10 and north of Carlile Lane (county road), excluding the area contained in Unit 50. The unit consists of wooded areas and pastures.

Historical Information

Portions of this unit have been fertilized by SFC with Facility generated ammonium nitrate (treated raffinate) Fertilizer. The results of this fertilizer program are well documented and can be found in Annual Fertilizer Completion Reports submitted to NRC as part of License conditions.

Characterization Sample Results

Sources

No sources are currently present in this unit.

Soils

Soil samples have been collected from nine (9) locations in and around this unit. Sample depths ranged from the surface to one-half (0.5) foot deep. Of the 9 uranium analyses, 9 (100%) were less than 35 pCi/g. The maximum uranium concentration observed was approximately 1.3 pCi/g.

Gamma Scan

The gamma scan for this unit was completed between 1996 and 1998. The gamma scan does not indicate the presence of impacted soils in this unit.

Summary of Findings

Samples of the soils in the Northeast Perimeter Area did not reveal any impact from either plant operation or the 1986 incident.

4.4.38 Northwest Perimeter Area (Unit 53)

Description and General Information

This unit lies on the north and west of the Process Area and north of the Port Road, excluding areas contained in other designated units.

Historical Information

Characterization Sample Results

Sources

No sources are currently present in this unit.

Soils

Soil samples have been collected from nineteen (19) locations in and around this unit. Sample depths ranged from the surface to forty-six (46) feet deep. Of the 148 uranium analyses, 148 (100%) were less than 35 pCi/g. The maximum uranium concentration observed was approximately 13 pCi/g.

Two pond sediment samples were collected from this unit. The uranium concentrations were 9.3 and 14.2 pCi/g.

Gamma Scan

The gamma scan for this unit was completed between 1996 and 1998. The results for the central region of this unit are influenced by the sludge stored in the Clarifier A Basins (Unit 17). However, the results indicate the presence of impacted soils at the southwest and northwest corners of Fluoride Holding Basin No. 2 (North) (Unit 12).

Summary of Findings

Soil samples in the Northwest Perimeter area indicate surface impact from uranium at only one sample location.

4.4.39 Southwest Perimeter Area (Unit 54)

Description and General Information

Unit 54 lies south and west of the Industrial Area, and includes the area west of Highway 10 and south of the Port Road, excluding areas contained in other designated units.

Historical Information

Characterization Sample Results

Sources

No sources are present in this unit.

Soils

Soil samples have been collected from thirty-two (32) locations in and around this unit. Sample depths ranged from the surface to forty (40) feet deep. Of the 64 uranium analyses, 64 (100%) were less than 35 pCi/g. The maximum uranium concentration observed was approximately 30 pCi/g.

Six sediment samples were collected from this unit. The uranium concentrations ranged from 0.7 to 2.0 pCi/g. One of the sediment samples was analyzed for thorium-230 and radium-226. The thorium-230 concentration was 0.3 pCi/g and the radium-226 concentration was 0.1 pCi/g.

Gamma Scan

The gamma scan for this unit was completed between 1996 and 1998. The results indicate the potential presence of impacted soils in an intermittent drainage west of the Storm Water Reservoir dam.

Summary of Findings

Samples of the soils in the Southwest Perimeter Area indicated uranium impact in three shallow, 0 - 2 foot, sample locations immediately south and west of the fertilizer ponds.

4.4.40 Southeast Perimeter Area (Unit 55)

Description and General Information

Unit 55 lies south and east of the Industrial Area, and includes the area east of Highway 10 and south of Carlile Drive (county road), excluding areas contained in Unit 50.

Historical Information Review

See the Historical Information Review Section of Unit 50 for a discussion of information available regarding impacts from the accidental release of UF_6 from the Facility in January 1986.

Characterization Sample Results

Sources

No sources are currently present in this unit.

Soils

Soil samples have been collected from nine (9) locations in and around this unit. Sample depths ranged from the surface to one-half (0.5) foot deep. Of the 9 uranium analyses, 9 (100%) were less than 35 pCi/g. The maximum uranium concentration observed was approximately 1.7 pCi/g.

Summary of Findings

Samples of the soils in the Southeast Perimeter Area did not reveal any impact from either plant operation or the 1986 incident.

4.5 Extent of Contamination

This section summarizes characterization information on the distribution and concentration of constituents in surface water, sediments, soils and groundwater. This section also includes discussion of gamma scan results relative to background. Radiation and radiological contamination information is also provided for buildings and structures.

4.5.1 Gamma Scan

The results of the Facility gamma scan are shown in Figure 24. The area covered by the gamma scan survey is represented by shaded count rate ranges and non-shaded areas represent either ponds, rock piles, roads, timber/brush too thick to traverse, or areas not surveyed. The lowest gross count rate range of Figure 24 covers gamma scan results less than or equal to the baseline value described in section 4.3. The other two categories are presented relative to the background described in section 4.3. Measurements above the baseline value were considered greater than background and were candidates for further investigation (e.g. soil sampling). Samples were collected from locations shown on Figure 25 as a result of the gamma scan.

4.5.2 Sources

Materials at the Facility which are considered to be sources include raffinate sludge, calcium fluoride sludge, sanitary sludge, sediments in basins and impacted materials in storage. Detailed descriptions and current status information regarding these sources are included in Section 4.4.

The location of characterization samples collected from sources that were analyzed for uranium are included in Figure 26. Each location is depicted according to the uranium concentrations found at that location. The ranges included are less than 35 pCi/g, greater than or equal to 35 pCi/g but less than or equal to 110 pCi/g, and greater than 110 pCi/g. Most of the results are greater than 110 pCi/g, with the exception of samples collected from the Pond 1 Spoils Pile. All of the samples collected from the Pond 1 Spoils Pile had uranium results which were less than 35 pCi/g. The majority of the other uranium analyses, with a few exceptions, were greater than 110 pCi/g.

The location of characterization samples collected from sources that were analyzed for thorium-230 and radium-226 are included in Figure 27. Thorium concentrations are shown as less than 5 pCi/g, greater than or equal to 5 pCi/g but less than or equal to 12 pCi/g, and greater than 12 pCi/g. Radium concentrations are shown as less than 1 pCi/g, greater than or equal to 1 pCi/g but less than or equal to 1.8 pCi/g, and greater than 1.8 pCi/g. Samples collected from the raffinate impacted sources (Pond 1 Spoils Pile, Clarifier Basins and Pond 2) indicate that these sources contain thorium-230 and radium-226 in concentrations greater than 12 and 1.8 pCi/g, respectively. Thorium-230 and radium-226 concentrations were less than 5 and 1 pCi/g, respectively, for the sample collected from the Calcium Fluoride Settling Basin.

Tables 6 and 7 contain the sample analyses results for the sample locations shown on

Figures 26 and 27. Table 6 is organized by sample location and Table 7 by unit number.

4.5.3 Surface Water and Sediments

SFC has historically monitored various surface water bodies in and around the vicinity of the Facility for many years. This data has historically been presented in Environmental Reports to the NRC. This monitoring remains part of the SFC monitoring program as conditions of SFC's NRC license. SFC conducts analyses of the Illinois River upstream (2201-U.S. Highway 64 Bridge) and downstream (2202-Headwaters of Robert S. Kerr Reservoir) of SFC's discharge, the Arkansas River, both upstream (2203) and downstream (2204) of its confluence with the Illinois River and various other surface water bodies near the Facility. The analyses include uranium and radium-226. Historically, additional analyses for nitrate, fluoride and thorium-230 have been part of the license requirements. These results are presented in Table 8. Figure 28 shows the surface water sampling locations.

A review of historical analytical data from SFC's surface water monitoring program does not indicate any significant impacts to the various surface water bodies from activities conducted at the Facility. Therefore, SFC has concluded that an additional surface water evaluation is not warranted.

4.5.4 Sediments

Sediment sampling along the various drainage pathways at or near the Facility is highly variable. In general, the ultimate location of each sample is dictated by the availability of sediments along any given pathway.

The location of sediment samples collected that were analyzed for uranium are included in Figure 29. Each location is depicted according to the uranium concentrations found at that location. The ranges included are less than 35 pCi/g, greater than or equal to 35 pCi/g but less than or equal to 110 pCi/g, and greater than 110 pCi/g. Most of the results are less than 35 pCi/g, with the exception of samples collected along the 005 drainage and south of the initial lime neutralization area.

The location of sediment samples collected that were analyzed for thorium-230 and radium-226 are included in Figure 30. Thorium concentrations are shown as less than 5 pCi/g, greater than or equal to 5 pCi/g but less than or equal to 12 pCi/g, and greater than 12 pCi/g. Radium concentrations are shown as less than 1 pCi/g, greater than or equal to 1 pCi/g but less than or equal to 1.8 pCi/g, and greater than 1.8 pCi/g. Samples collected from the 005 drainage indicate that these sediments contain thorium-230 and radium-226 in concentrations greater than 12 and 1.8 pCi/g, respectively. Thorium-230 and radium-226 concentrations were less than 5 and 1 pCi/g, respectively, for the majority of other samples collected.

Impacts of sediments in the various drainage pathways west and south of the Facility were documented in 1986. Subsequent investigations conducted in 1991 and 1995 have confirmed this impact. In addition, uranium impact was confirmed on the banks along the headwaters of the Robert S. Kerr Reservoir, downgradient of the drainage pathway.

4.5.5 Soils

The results for uranium, thorium-230, radium-226, nitrate and fluoride analyses are included in Table 6. Maps of the uranium levels in soils were prepared from this data for the depth intervals 0 to 1, 1 to 5, 5 to 10, 10 to 15, 15 to 20, 20 to 25, 25 to 30 and greater than 30 feet (See Figures 31 - 38). A map of thorium-230 and radium-226 content in soils was also prepared from data in Table 6 for the 0 to 1 foot depth interval (See Figure 39). These maps show the location of each sample collected within the selected depth interval, and each location is depicted according to the concentration found at that location. Concentration ranges were selected to provide a visual assessment of impact as it relates to the proposed cleanup criteria.

The soil uranium map for the 0 to 1 foot depth interval depicts uranium impacts generally throughout the Process Area (See Figure 31). Most of the uranium is found in the upper six (6) inches of soil. There is a dramatic decrease in the areal extent and concentrations of uranium found in the soils in the 5 to 10 foot depth interval as shown on Figure 33. The uranium found in soils at depths below 10 feet were generally located in the area around the SX Building and the MPB. Uranium levels in the Unit 4 Sandstone (> 40 feet) and below are at background for the measurements taken. Unit 4 Sandstone is believed to effectively limit the vertical extent of contamination in soils and bedrock.

Since the criteria for soil remediation at the SFC site has not yet been established, it is not possible to determine with reasonable certainty the volume of contaminated soil and bedrock to be remediated. For purposes of establishing a preliminary estimate, a contour was drawn from the data at each depth interval approximating the area impacted with uranium above the Facility Action Level of 27 pCi/g (40 µg/g). The area at each depth interval was used to calculate the volume of impacted soil and bedrock. The results of this evaluation are as follows.

Interval: (ft)	Contour Area: (ft^2)	Volume: (ft^3)
0 to 1	916,000	916,000
1 to 5	507,000	2,028,000
5 to 10	50,000	250,000
10 to 15	49,000	245,000
15 to 20	19,000	95,000
20 to 25	0	0
25 to 30	8,000	40,000
Total	-	3,574,000

4.5.6 Groundwater

SFC currently conducts groundwater monitoring through a comprehensive monitoring well network as part of requirements imposed by SFC's Source Materials License issued by the Nuclear Regulatory Commission (NRC). Groundwater investigations and monitoring at SFC have been ongoing for over twenty years. Investigations since 1990 have resulted in a comprehensive groundwater monitoring system at the Facility. The groundwater monitoring system installed during an environmental investigation which is described in the Facility Environmental Investigation Findings Report (FEI) July 1991, provides the majority of the wells used to monitor groundwater at the Facility. The monitoring wells are normally found in clusters at each location. Each well in the cluster is completed at different depths to monitor separate groundwater systems. Wells monitoring the Terrace Groundwater System are identified as "MWXXX" (MW072). Well identifications which end with an "A" (MW072A), monitor the Shallow Bedrock Groundwater System and well identifications ending with a "B" (MW072B) designation monitor the Deep Bedrock Groundwater System. The exception to this system of designation is the pre-FEI wells that were incorporated into the groundwater monitoring network. The pre-FEI wells have numerical identifications only, i.e., 2351., (there are no "MW" designations).

Routine groundwater monitoring is conducted for constituents of concern that have previously been identified in the groundwater at the Facility normally in April and October of each year. The primary constituents of concern present in the Facility groundwater are uranium, nitrate and fluoride. Another radiological parameter, radium-226, is also monitored in selected wells. The results of groundwater monitoring for these parameters is presented in Table 9.

The groundwater monitoring schedule that was initially specified in the Groundwater Monitoring Interim Measures (GMIM) Workplan developed for EPA's RCRA Facility Investigation and adopted by the NRC, was changed during 1997 to refine the original GMIM monitoring program objectives. In the 1996 Annual Groundwater Report, SFC described a project to review the current groundwater monitoring program which was submitted to EPA Region 6 in 1996. Titan Environmental Corporation (Titan) based in Englewood, Colorado, provided an independent technical review of the GMIM and recommended changes based on current conditions for continued long term monitoring. Titan recommended reducing the number of wells for long term monitoring, changing the frequency of sampling from semi-annual to annual and analyzing only select parameters in and around known impacted areas. The Titan report was submitted to EPA Region 6 on July 31, 1996, along with a request to incorporate the recommendations for the GMIM. SFC's request to modify the GMIM was approved by the EPA in April 1997 based on Titans recommendations. As a result of the changes, the number of GMIM wells sampled in 1997 was reduced from 209 wells to 151 wells.

The Nuclear Regulatory Commission (NRC) approved groundwater monitoring program changes through an amendment of SFC's License in 1996. This amendment reflected changes in the number and frequency of monitoring wells to be sampled. In addition, the NRC License amendment included additional wells to be sampled on a semi-annual frequency. These changes resulted in a groundwater monitoring system consisting of 164 wells sampled on annual and/or semi-annual basis. The wells specified in the NRC License are noted and included on this table.

The following is a summary of the 1998 sampling. Refer to the annual groundwater monitoring report for subsequent sampling events.

Uranium

Uranium has been a common parameter monitored in groundwater at SFC for many years. Uranium impacts continue to be centered near the MPB and the Solvent Extraction Building (SX Building). Automated recovery systems continue to influence groundwater movement and are continuously operated to help reduce existing uranium impacts and to attempt to limit the movement of the plumes away from their present locations.

Total uranium continues to be detected above the SFC Environmental Action Level (EAL) of 152 pCi/l (225 μg/l) in the Terrace Groundwater System and the Shallow Bedrock Groundwater System. Uranium has not been detected above the EAL in the Deep Bedrock Groundwater System.

The total uranium found in the Terrace Groundwater System varied from <0.7 pCi/l in several wells to 75,824 pCi/l. The high of 75,824 pCi/l occurred in well MW025 located north of the SX Building. Monitor well MW025 appears to have increased due to the heavy influence of groundwater recovery efforts nearby. Two wells with uranium levels above the EAL outside the Process Area boundary are MW035 (421.8 pCi/l), located west of the emergency basin and MW010 (4955.6 pCi/l), located at the southwest corner of the MPB. Recovery systems have also been operating in both these areas since 1991. Other terrace wells that exceeded the EAL for uranium were MW014 and MW018. These wells are located in previously identified impacted areas around the MPB and SX Buildings. Uranium impacts continue to be monitored in groundwater southwest, west and northwest of the MPB, north and west of the SX Building, west of the Emergency Basin, in the Clarifier Basins area and the Solid Waste Burial Areas. The uranium in the Terrace Groundwater System is shown on Figure 40.

The total uranium concentrations found in the shallow bedrock groundwater varied from <0.7 pCi/l in several wells to 5179.1 pCi/l. The high of 5179.1 pCi/l occurred in MW012A located at the northwest corner of the MPB. Other shallow bedrock wells where uranium in groundwater exceeded the EAL were MW025A MW050A, and MW067A. Uranium impacts continue to be monitored in groundwater at the northwest corner of the MPB, north of the SX Building, northwest of the Emergency Basin, east of the Solid Waste Burial Area No.2, the Clarifier Basins area, and north of Fluoride Holding Basin No.2. The uranium in the Shallow Bedrock Groundwater System is shown on Figure 41.

<u>Nitrates</u>

Nitrate has also been a common parameter monitored early on in groundwater at SFC. Nitrate continues to be detected above the MCL of 10 mg/l in the Terrace Groundwater System and the Shallow Bedrock Groundwater System. Nitrate was not detected above the MCL in the Deep Bedrock Groundwater System.

The nitrate levels found in the Terrace Groundwater System varied from <0.6 mg/l to 1190 mg/l. The high of 1190 mg/l occurred in well MW040 located north of Clarifier 1A. Other terrace wells with nitrate levels above the MCL were MW008, MW010, MW012, MW014, MW015, MW018 MW024, MW025, MW036, MW054, MW055, MW065, MW066, MW082, MW103, MW107 and MW108. The nitrate impacts to the terrace groundwater are mostly found around the MPB and Pond 2 area. The nitrate in the Terrace Groundwater System is shown on Figure 42.

The nitrate levels found in the Shallow Bedrock Groundwater System varied from 0.8 mg/l to 5650 mg/l. The high of 5650 mg/l occurred in well MW057A located at the southwest corner of Pond 2. Other shallow bedrock wells where the highest nitrate values occurred in 1996 above the MCL were 2303B, 2322A, 2340A, 2341, 2342, 2443, 2344, 2346, 2347, 2348, 2349, 2351, 2352, 2353, 2354, 2355, 2356, 2302B, 2303A, MW012A, MW013A, MW014A, MW024A, MW025A, MW035A, MW036A, MW037A, MW039A, MW040A, MW041A, MW042A, MW046A, MW047A, MW049A, MW050A, MW051A, MW053A, MW057A, MW058A, MW059A, MW060A, MW075A, MW076A, MW082A, MW093A, MW094A, MW095A and MW103A. The nitrate impact to shallow bedrock groundwater continues to occur adjacent to and west of Pond 2, west of the Pond 1 Spoils Pile, in the SX Building area, the North Ditch and Emergency Basin area and the Fertilizer Pond Area. The nitrate in the Shallow Bedrock Groundwater System is shown on Figure 43.

<u>Fluorides</u>

Fluoride has been a common parameter monitored early on in groundwater at SFC. Although fluoride concentrations for the most part have decreased since

1991, fluoride continues to be detected above the MCL of 4.0 mg/l in the Terrace Groundwater System and the Shallow Bedrock Groundwater System. Fluoride has not been detected above the MCL in the Deep Bedrock Groundwater System.

The fluoride levels in the terrace groundwater varied from <0.3 mg/l in numerous wells to 8.5 mg/l. The high of 8.5 mg/l occurred in MW014 located north of the MPB. The other terrace well in which fluoride level was above the MCL was MW040 and MW063. The fluoride impacts to the terrace groundwater are southwest of the MPB and northeast of the SX Building. The fluoride in the Terrace Groundwater System is shown on Figure 44.

The fluoride found in the Shallow Bedrock Groundwater varied from <0.2 mg/l in several wells to 4.7 mg/l. The high of 4.7 mg/l occurred in well MW057A located west of the Emergency Basin. No other shallow bedrock wells had fluoride levels above the MCL. The fluoride impacts to the shallow bedrock groundwater are at the south end of Pond 2, the Fluoride Holding Basin No.I and the Fluoride Settling Basins. The fluoride in the Shallow Bedrock Groundwater System is shown on Figure 45. One background well (MW007A) also was above the MCL (4.1 mg/l). This result appears to be an outlier.

Radium-226 is also monitored in select wells associated with the NRC License. The results for this radiological parameter is presented in Table 9. There is not an impact from radium and since the positive data is sparse, no maps were prepared for this constituent.

4.5.7 Structures and Equipment

Contamination and radiation surveys of structures and equipment at the SFC Facility have been performed with respect to each of the restricted and unrestricted areas. Although predominantly historical data is presented, it is nonetheless representative considering the shutdown of the Facility in November 1992.

Restricted Area

A characterization of structures and equipment in the restricted area was performed to provide information concerning the degree of radioactive contamination and radiation levels associated with these items. The characterization was performed in order to provide a basis for identifying contamination control efforts that will be required during decommissioning. The characterization was not performed in any regard to release of structures or equipment for unrestricted use. Also, the characterization cannot be used for development of any source term since no measurements have been made of residual material in equipment. Surveys and sampling in this regard will be performed during and/or after dismantling of structures and equipment in order to necessarily account for inherent decontamination or recovery of residual process materials.

The characterization data was compiled from routine and special surveys performed during 1994, 1995, and 1996. Routine surveys target generally accessible locations with higher potential for exhibiting elevated contamination and radiation levels due to activities or conditions in and around an area. Special surveys are those conducted in direct support of projects; e.g. equipment maintenance. The structures and equipment characterization data provided in this report represent the most recent data available. Attachment II Tables contain a listing of maximum results by process area, level, and structure for removable surface contamination and exposure rate. Attachment II Figures show the various site structures and characterization results.

Volume Estimate

A preliminary estimate was developed of the volume of materials requiring disposition following dismantlement of the process equipment, structure and buildings. The approximate standing volumes of the main structures are as follows:

DESCRIPTION	VOLUME
MPB	2,178,300
Solvent Extraction Building	180,000
DUF_4 Building	281,250
ADU/Misc Digest Building	75,000
Laundry Building	12,500
Centrifuge Building	15,000
Bechtel Building	27,000
Solid Waste Building	18,000
Cooling Tower	30,000
RCC Evaporator	18,750
Incinerator	7,500
Total Standing Volume	2,843,300
Estimated Disposal Volume @ 20%	568,660
Volume of Concrete/Asphalt Pads and Roads	315,000
Total	883,660

Unrestricted Area

Extensive surveys were conducted of surfaces, equipment, and materials located in the unrestricted area of the protected area. during 1991 and 1992. The survey effort was performed relative to limits for release of materials for unrestricted use from the Facility. Items that were identified as contaminated were either decontaminated, removed to the restricted area, or identified in the Decommission File. Those items identified in the Decommission File as a result of the unrestricted area survey are listed below. Also in each case, the levels are such that neither a contamination control problem nor a health risk is present.

Locations in SFC's unrestricted area with direct beta/gamma radiation greater than SFC's limits for unrestricted release.

- Former Administration Building
  - First floor lunch room window frames
  - First floor lobby floor
  - First aid office
  - Men's change room bench
  - Women's change room bench
  - Stairwell floor
  - Second floor men's room
  - Second floor women's room
  - Crawl spaces in ceiling
  - HVAC - change rooms, control room, first floor offices
- Fire box southeast of the MPB
- Paved walkway east of Decorative Pond
- Roof drain of South Guard House
- Asphalt drive south of MPB
- Interior roof of old warehouse offices
- Drainage trench and wind room of old warehouse
- Truck scale outside MPB
- Light poles south of the MPB
- Protected area fence
- Liner of Pond 3E
- Fertilizer load house
- North booster pump
- North air sampling platform

4.5.8 Wetlands Monitoring

The U.S. Army Corps of Engineers (COE) and the U.S. Environmental Protection Agency (EPA) jointly define wetlands as follows:

"Those areas that are inundated or saturated by surface or groundwater at a frequency and duration to support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas."

According to COE/EPA guidance documents, wetlands must have the following characteristics for classification purposes:

1. Vegetation Indicators - at least periodically, the land supports predominantly hydrophytes (any plant growing in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content);
2. Soil Indicators - the substrate is predominantly undrained hydric soil (hydric soil is defined as soil which is wet long enough to periodically produce anaerobic conditions, thereby influencing the growth of plants); and
3. Hydrology Indicators - the substrate is non-soil and is covered with water or covered by shallow water at some time during the growing season of each year.

Unless an area has been altered or is a rare natural situation, wetland indicators of all three characteristics must be present for an area to be classified as a wetland.

SFC contacted the Webbers Falls office of the COE to determine if the COE had identified and/or designated any wetland areas at or near the vicinity of the Facility. According to COE personnel, no wetland areas have been identified by the COE in the area of the Facility.

SFC contacted the Sequoyah County Soil Conservation Service (SCS) to ascertain those soils that are encountered in the area of the Facility that would be classified as "hydric soils". The SCS has identified the following soils in Sequoyah County as hydric soils:

Brewer Silt Loam (Bw)

Lela Clay (Lm)

Mason Silt Loam (Ma)

Muldrow Silty Clay Loam (Mu)

Rosebloom Silt Loam (Rs, Rt)

Rosebloom and Ennis Soils (Ru)

Several of these soils are present at or near the vicinity of the Facility.

SFC obtained National Wetlands Inventory maps which were prepared by the U.S. Department of the Interior, Fish & Wildlife Service (USF&W) to determine if any areas located within one-half (½) mile of the Process Area have been identified to be potential wetland areas. The Facility is found on a portion of two wetland maps, the Gore, Oklahoma and the Stigler NE, Oklahoma maps. To show the Facility and surrounding areas for presentation purposes, these maps have been combined and are presented as Figure 46.

The wetland inventory maps were prepared primarily by stereoscopic analysis of high altitude aerial photographs. Potential wetlands were identified on the aerial photographs based on vegetation, visible hydrology and geography. None of the potential wetlands on or near the Facility were field examined by the USF&W Service. Twenty seven (27) potential wetland areas were identified within one-half (½) mile of the Process Area. These areas are listed in Table 10. For identification purposes the potential wetland areas are arbitrarily numbered and listed by direction and distance from the center of the MPB.

The wetlands identified within one half mile of the Facility are classified as palustrine wetlands which are typically dominated by trees, shrubs, persistent emergents and emergent mosses or lichens on the Illinois River floodplain. These areas are described on Table 10.

Five (5) of the twenty seven potential wetland areas were determined to meet the criteria for wetlands classification. These areas are identified as Area Nos. 1, 15, 23, 24 and 26 in Table 10. These areas are located northwest of the Facility with the exception of area No. 15 which is located southwest of the Facility. As shown on Figure 46, these wetland areas are located primarily downwind of the Process Area. Uranium was the most prevalent airborne constituent at the Facility. The airborne pathway is the most probable route for impact to these areas. Therefore, SFC collected soil samples from these wetland areas and performed uranium analysis only. Each soil sample from the respective wetland area had uranium analysis results of <3.4 pCi/g. These results are presented in Table 6 as HA310-HA314. Based on the analytical results of the wetland soil samples, SFC has concluded that further wetland evaluation is not warranted.

4.6 Findings and Conclusions

Site characterization has been performed in an effort to obtain the information needed to complete an evaluation of the nature, extent and concentration of contamination at the Facility. Although SFC has collected the majority of this information, there are areas where characterization activities will be completed later. The following findings and conclusions are provided with respect to the draft Site Characterization Report.

- The contents of burials will be characterized during exhumation of the buried material.
- The soils beneath impoundments and burial areas will be characterized following removal of their respective contents.
- The soils beneath structures, pads, sumps, and roadways will be characterized following removal of the respective item.

- The trenches for underground lines outside the main restricted area will be characterized when the respective line is removed.
- The FEI and SCR data appears inconsistent for thorium-230. Review of historical and recent data for units where thorium-230 is known to be present revealed an unexplained difference in concentrations. A discussion of this situation is provided in Section 4.1.1. Additional sampling will be required to complete the characterization with respect to thorium-230 and radium-226. The additional sampling will include the following:
  - Background samples will be recollected and/or reanalyzed;
  - Additional soil samples will be collected from units where raw raffinate and/or raffinate sludge were handled or stored and analyzed for thorium-230 and radium-226.
  - Some archived soil samples will be reanalyzed for thorium-230 and radium-226 to confirm boundaries of impacted areas.
- The impacted areas are the Process Area including adjacent CaF_2 burial and holding basin, front lawn (part of units 26 and 31), Initial Lime Neutralization Area (Unit 3), Combination Stream (Unit 27), surface soil outside Pond 2 to south, west, and north, 1986 Incident Soil Storage Area (Unit 23), drainage pathways south, west and north of the Facility, and Pond 4 including some surface soil to the north and east.

4.7 Data Quality Assessment

The quality of data generated during site characterization was controlled and monitored throughout the characterization effort. The types of controls and monitoring applied are described in Section 3.0 "Data Collection Quality Assurance Plan" of the Site Characterization Plan. In general, each of precision, accuracy, representativeness, completeness, and comparability were assessed for the data collected during site characterization. The assessments are described in the following sections and pertain to the data set presented in this report. The data from which the assessments were derived is provided in Attachment IV.

4.7.1 Precision

Precision was evaluated with respect to either sampling or laboratory analysis. Duplicate samples were prepared in the field by splitting one sample per day into two separate samples and submitting them to the laboratory as a test for precision. The duplicate analysis was compared with the sample analysis by calculating a relative percent difference between the two samples results.

Review of field duplicates revealed several instances of a relative percent difference (RPD) greater than 50 percent. In most instances, such an RPD was considered acceptable considering that the data pairs were very low values, or at or near the analytical methods detection limit. In the other cases such an RPD is attributed to inhomogeneity of the sampled source or media.

4.7.2 Accuracy

Accuracy was evaluated with respect to either field measurement or sampling, and laboratory analysis. Specifically, each of equipment blanks, matrix spikes, lab duplicates, and method controls were used to evaluate accuracy of the site characterization data. In one case, accuracy was evaluated with respect to a standard.

Review of the QA/QC data for site characterization showed that the data was acceptable without qualification. Equipment blanks were collected during groundwater sampling and did not detect significant levels of any parameter. Accuracy, as described by matrix spikes, lab duplicates, and method controls was acceptable. Accuracy, as described by laboratory analysis of blind standard was acceptable.

4.7.3 Representativeness

Representativeness was qualitatively assessed. As provided by the Site Characterization Plan, representativeness was assured by sampling as described in the individual sampling plans. Representativeness was evaluated with respect to adherence to the sampling plans as reflected by the field log books, photographs, and the completed chain-of-custody's. The field log books reflect adherence to the individual quality assurance sampling plans (sampling plans) included as appendices of the Site Characterization Plan.

Photographs of the sampling efforts reveal that the sampling methods were conducted as described by the individual sampling plans.

The completed chain-of-custody's indicate that the sample parameters were selected as described in the Site Characterization Plan.

4.7.4 Completeness

Completeness was evaluated by comparison of valid data collected to the amount of data expected to be obtained. Data completeness was also evaluated with respect to sample location access, sample loss, and holding time.

The completeness criteria included assurance of use of proper analytical methods, review of quality control (QC) data, check and confirmation of calculations, and approval of final data by the laboratory. Review of chain-of-custody's and final laboratory reports confirmed that the proper analytical methods were used during analysis of samples collected during site characterization. Review of the associated QC data revealed no instances of unacceptable data sets. Checks and confirmations of calculations indicated no unresolved discrepancies. Each data set was approved by the laboratory from which it was supplied.

4.7.5 Comparability

Several aspects of site characterization lend themselves to evaluation with respect to whether subsequent data sets can be compared to the data collected during site characterization. These aspects, described as conditions, are:

- Individual sampling plans provided for collection of representative samples;
- Sample constituents (analysis) measured in each sample were reported in the units or a direct mathematical relation was available;
- Individual sampling plans provided for comparability for the collection and analysis of constituents between units;
- Data Quality and calculations were checked and documented by the laboratory.

Each of these conditions received a positive evaluation under the data quality assessment parameters of representativeness and completeness.

5.0 Dose Assessment

This chapter addresses various aspects of dose assessment as a part of the site characterization process. A dose assessment is needed to demonstrate that decommissioning will ultimately allow release of the Facility in accordance with the applicable criteria of Subpart E of 10 CFR 20. The general process for conducting the dose assessment is described in the following subsections.

5.1 Characterization of Exposure Setting and Potentially Exposed Population

Information describing the human populations and environmental systems that may be susceptible to constituent releases from the Facility is important to assessment of remediation strategies. Such information includes demography, land use, threatened and endangered species, biota, floodplains and wetlands, and water usage. This information is described in sections 3.6 through 3.10 of SFC's "Preliminary Report: Descriptions of Current Conditions and Investigations".

Information collected during site characterization will be used to establish source terms of radiological contamination corresponding to site specific conditions and to identify potential exposure pathways and exposure points. This information is contained in Chapters 3 and 4 of this report.

5.2 Identification of Potential Exposure Pathways

This section discusses the primary aspects associated with evaluation of exposure pathways.

5.2.1 Sources and Receiving Media

Contaminated materials at the SFC site have been identified from review of available information on the site's operational history and waste disposal practices. Contamination exists in structures, equipment, soil, waste burials, ponds, storm water runoff pathways, and groundwater. Specific descriptions of this contamination may be found in Chapter 4 of this report. Current release and exposure mechanisms for the contaminated material include storm water runoff, infiltration, and groundwater leaching and transport. Receiving media for contaminants includes surface water, groundwater, soil and sediments.

5.2.2 Transport and Fate of Contaminants

Evaluation of potential doses from residual radioactivity (i.e. source) necessarily includes consideration of how the contaminants move through the environment (transport) and where they become available for exposure (fate). The information required for this evaluation includes:

- lateral and vertical extent of impacted soil zones, and distribution of concentrations of radioactive materials in site soils within these zones,

This information is either provided in or may be derived from Section 4.0 of this report.

- characterization of site hydrogeology, including characterization of soil zones (composition, thickness, total and effective porosity, gradients, hydraulic conductivities, rate of water infiltration, extent of communication between zones, etc.)

This information is provided in Section 3.0 of this report.

- distribution of radioactive contaminants in soil zones,

This information is either provided in or may be derived from Section 4.0 of this report.

- distribution coefficient (K_d) (i.e. environmental availability) for radioactive contaminants of interest in the soil zones,

This information will be taken from general sources.

5.2.3 Identification of Exposure Points and Exposure Routes

Potential uses of the site and anticipated site radiological conditions will be evaluated to identify where (i.e. exposure points) and how (i.e. exposure routes) the potentially exposed population are likely to contact contaminated media. This evaluation will take into account reasonably expected public use of portions of the site likely to be released for unrestricted use and reasonably expected intrusion scenarios for any portion of the site to which access is likely to remain restricted after termination of SFC's license. The exposure scenario analyzed for determining potential doses associated with residual radioactivity will be a residential scenario. Specifically, the scenario will be comprised of direct exposure to external radiation, and inhalation and ingestion of radioactive material to an individual who lives on the site and ingests food grown on the site.

5.3 Quantification of Exposure

Exposure will be quantified in two basic steps. The first step involves estimation of radionuclide concentration; the second pertains to quantification of the resulting exposure from each relevant exposure route.

Contaminant concentration will be estimated primarily by direct determination of radionuclide concentration in the affected media (e.g. soil, groundwater, and surfaces). The estimates will be derived from the data presented in Chapter 4. In some cases, computational models may be used with the direct measurement data to obtain a more complete estimate of contaminant concentration.

Exposures will be quantified for those exposure routes identified as relevant to assessment of decommissioning alternatives. The derived specific radionuclide concentrations for each pathway will be substituted into the dose formula, along with other known parameters such as intake rates, exposure duration, and pathway specific period of exposure, for calculation of the intake.

5.4 Estimation of Radiation Dose

Industry standard dose conversion factors and assessment code(s) will be used for estimation of dose received from each specific intake. In some cases hand calculations for certain pathways may be used in conjunction with code estimates. Doses will be expressed in terms of total effective dose equivalents due to intakes of radionuclides by inhalation, ingestion, or direct exposure. The assessment will provide an estimate of the total external and internal individual dose from all selected pathways as well as the proportion of the dose attributable to each individual radionuclide and each significant exposure pathway. Site-specific data will be used as often as possible. Otherwise site-specific information will be used to choose between default or generic data when site-specific data is not available. The dose assessment calculations will be carried out to 1000 years.

The dose assessment will include a sensitivity analysis that compares the effect of changes of input parameters on the resulting estimates of dose, concentration, or other dependent variables. The dose assessment will describe the uncertainties and limitations associated with the results and consider these factors in applying the results of the assessment.

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