

REMEDIAL INVESTIGATION REPORT
for the
NIAGARA FALLS STORAGE SITE

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Contract: W912P4-04-D-0001

December 2007

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ACRONYMS

AEC	Atomic Energy Commission
amsl	above mean sea level
ANL	Argonne National Laboratory
ANOVA	Analysis of Variance
ARAR	Applicable or Relevant and Appropriate Requirement
ATV	All Terrain Vehicle
bgs	below ground surface
BNA	Base-Neutral Acids
BNI	Bechtel National, Inc.
BRA	Baseline Risk Assessment
CDQAR	Chemical Data Quality Assurance Report
CEC	Cation-Exchange Capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Ci	curie
CLP	Contract Laboratory Program
CME	Central Mining Equipment
cm/sec	centimeters per second
COC	Chemical of Concern
COPC	Chemical of Potential Concern
cpm	counts per minute
CQAR	Chemical Quality Assurance Reports
DCE	Dichloroethene
DERP-FUDS	Defense Environmental Restoration Program - Formerly Used Defense Sites
DNAPL	Dense Non-Aqueous Phase Liquids
DNT	Dinitrotoluene
DO	Dissolved Oxygen
DOE	Department of Energy
DOH	Department of Health
DOT	Department of Transportation
DQI	Data Quality Indicators
DQO	Data Quality Objectives
EA	EA Engineering, Science, Technology
EDD	Electronic Data Deliverable
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EPDM	Ethylene Propylene Diene Monomer
ERDA	Energy Research and Development Administration
EU	Exposure Unit
FGR	Federal Guidance Report
FS	Feasibility Study
FSP	Field Sampling Plan
FUSRAP	Formerly Utilized Sites Remedial Action Program
GEL	General Engineering Laboratories
GPR	Ground Penetrating Radar
GPS	Global Positioning System

ACRONYMS (continued)

HELP	Hydrologic Evaluation of Landfill Performance
HGL	HydroGeoLogic Inc.
HMX	cyclotetra methylene tetranitramine
IDW	Investigative Derived Waste
IUC	International Uranium Corporation
IWCS	Interim Waste Containment Structure
KAPL	Knolls Atomic Power Laboratory
L	liter
LCS	Laboratory Control Sample
LCSD	Laboratory Control Sample Duplicate
LOOW	Lake Ontario Ordnance Works
LWBZ	Lower Water - Bearing Zone
Maxim	Maxim Technologies, Inc.
MCL	Maximum Contaminant Level
mCOPC	Migration Chemical of Potential Concern
MDL	Method Detection Limit
MED	Manhattan Engineer District
MS	Matrix Spike
MSD	Matrix Spike Duplicate
NaI	Sodium Iodide
NFSS	Niagara Falls Storage Site
NGS	National Geodetic Survey
NGVD	National Geodetic Vertical Datum
NORM	Naturally Occurring Radioactive Materials
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
NTS	Nuclear Technology Services
NTU	Nephelometric Turbidity Units
ORP	Oxidation Reduction Potential
OU	Operable Unit
PAH	Polynuclear Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PCE	Tetrachloroethene
pCi/g	picocuries per gram
PID	Photo-Ionization Detector
PSRC	Preliminary Site Related Constituent
PVC	Polyvinyl Chloride
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RDL	Reporting Detection Limit
RME	Reasonable Maximum Exposure
RI	Remedial Investigation
ROC	Radionuclides of Concern
ROPC	Radionuclide of Potential Concern

ACRONYMS (continued)

RPD	Relative Percent Difference
SAIC	Science Applications International Corporation
SCA	Service Corporation of America Services, Inc
SDG	Sample Delivery Group
SESOIL	Seasonal Soil Compartment
SI	Site Inspection
SERA	Screening-Level Ecological Risk Assessment
SOP	Standard Operating Procedure
SOW	Statement of Work
SRC	Site-Related Constituents
STL	Severn-Trent Laboratories
SVOC	Semi-Volatile Organic Compound
TCE	Trichloroethene
TNT	Trinitrotoluene
TOC	Top of Casing
TPP	Technical Project Planning
TWP	Temporary Well Point
U.S.	United States
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
UST	Underground Storage Tank
UTL	Upper Tolerance Limit
UWBZ	Upper Water - Bearing Zone
VCP	Vitrified Clay Pipes
VOC	Volatile Organic Compound
WAC	Waste Acceptance Criteria
WOE	Weight-of-Evidence
WWII	World War II
WWTP	Waste Water Treatment Plant
yd ³	cubic yards

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GLOSSARY

ACTIVITY - A measure of the rate at which radioactive material is undergoing radioactive decay; usually given in terms of the number of nuclear disintegrations occurring in a given quantity of material over a unit of time. The special unit of activity is the curie (Ci).

AQUIFER - A water-bearing layer of permeable rock or soil that will yield water in usable quantities to wells. Confined aquifers are bounded on top and bottom by less-permeable materials. Unconfined aquifers are bounded on top by a water table.

BACKGROUND CONCENTRATION (soil, groundwater, surface water, or sediment) – A background concentration is a concentration that occurs in an area that is not impacted by site activities and contains characteristics similar to site conditions. Background concentrations for both chemical and radiological constituents were used in the identification of SRCs presented in this RI and in the evaluation of human health risk presented in the BRA. The determination of background concentrations involved the establishment of a background data set for each medium and the calculation of a background value for each analyte within each medium. The background concentration is often expressed using an upper tolerance limit (UTL) that is statistically derived from the background data set.

BACKGROUND RADIATION - In this RI, background radiation includes both the natural and man-made (e.g., fallout) radiation in the human environment. It includes cosmic rays and radiation from the naturally radioactive elements that occur both outside and inside the bodies of humans and animals. For persons living in the United States, the individual dose from background radiation ranges from about 80 to 200 millirems per year.

BASELINE RISK ASSESSMENT (BRA) - The BRA evaluates current and potential future risks to human health and the environment from site contamination. It is a decision-making tool for use in determining the need for further investigation or site cleanup based upon present site conditions.

BEDROCK - A solid rock formation usually underlying one or more other loose formations.

COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA) - CERCLA was put into place in 1980. It is also known as Superfund. This act concerns releases of hazardous substances into the environment, and the cleanup of these substances and hazardous waste sites.

CONTAINMENT - Confining the radioactive wastes within prescribed boundaries, e.g., within a waste containment structure.

CHEMICAL OF CONCERN (COC) – A chemical parameter that has been identified as posing unacceptable risk to human health and the environment.

CHEMICAL OF POTENTIAL CONCERN (COPC) - SRCs exceeding PRGs, evaluated quantitatively in the BRA.

CURIE (Ci) - A measure of the rate of radioactive decay. One curie is equal to 37 billion disintegrations per second (3.7×10^{10} dis/s), which is approximately equal to the decay of one gram of radium.

CUTOFF WALL - A low-permeability, engineered subsurface structure designed to minimize groundwater flow in a direction perpendicular to the wall.

DECAY CHAIN (DECAY SERIES) - The nuclides in the sequence of radioactive decay from one nuclide to another until a stable (nonradioactive) nuclide is reached. The uranium-238 decay chain starts with naturally radioactive uranium-238 and ends with stable lead-206. The term "decay" is also referred to as "disintegration" or "transformation."

DETECT – An analytical result reported above analytical thresholds that is not assigned a rejected (R) or undetected (U) flag, noting that estimated (J-flagged) results are typically accepted as detects.

DISTRIBUTION COEFFICIENT (K_d) - Ratio of the concentration of a constituent absorbed on soil particles to the concentration of the dissolved constituent in water.

DOSE - Total radiation delivered to a specific part of the body, or to the body as a whole.

EXPOSURE UNIT (EU) - A geographic area in which a receptor is assumed to work or live, and where a receptor may be exposed to SRCs detected during the RI.

FEASIBILITY STUDY (FS) – An FS develops, screens, and compares remedial alternatives for a site. The FS incorporates conclusions from the RI, BRA, and groundwater fate and transport modeling.

GROUNDWATER - Usually considered to be the water within the zone of saturation below the soil surface.

GROUNDWATER FATE AND TRANSPORT MODEL – A groundwater fate and transport model simulates the flow of groundwater and the movement of dissolved constituents present in an aquifer system.

HYDRAULIC CONDUCTIVITY - The quantity of water that will flow through a unit cross-sectional area of porous material per unit of time under a hydraulic gradient of 100 at a specific temperature.

LEACH - To remove or separate soluble components from a solid by contact with water or other liquids.

PERMEABILITY - The relative ease with which a porous medium can transmit a liquid under a hydraulic gradient. In hydrology, the capacity of rock, soil, or sediment for allowing the passage of water.

PIEZOMETRIC SURFACE - The surface defined by the levels to which groundwater will rise in tightly cased wells that tap an artesian aquifer.

PLUME - A line or column of water containing chemicals moving from the source to areas further away.

RADIONUCLIDE - An unstable nuclide that undergoes radioactive decay.

RADIONUCLIDE OF CONCERN (ROC) – A radionuclide that has been identified as posing unacceptable risk to human health and the environment.

RADIONUCLIDE OF POTENTIAL CONCERN (ROPC) - SRCs exceeding radiological screening levels, evaluated quantitatively in the BRA.

RADIATION - A very general term that covers many forms of particles and energy, from sunlight and radio waves to the energy that is released from inside an atom. Radiation can be in the form of electromagnetic waves (gamma rays, X-rays) or particles (alpha particles, beta particles, protons, neutrons).

RADIOISOTOPE - An unstable isotope of an element that spontaneously loses particles and energy through radioactive decay.

RADIUM-226 - A radioactive solid produced by the decay of thorium-230. It is an alpha emitter and is hazardous when it gets into the body. Radium-226 has a half-life of 1,600 years and can accumulate in certain parts of the body such as bone.

RADON-222 - A radioactive gas produced by the decay of radium-226. It is hazardous mainly because its solid decay products can be deposited in the lungs where they decay in a matter of minutes, emitting alpha radiation that irradiates nearby tissue. Radon-222 has a half-life of 3.8 days.

REMEDIAL INVESTIGATION (RI) – An RI is a site investigation consisting of a records search, environmental sampling, risk assessment, and groundwater flow modeling to define the identity, amount, and location of contaminants at a site.

RESIDUES - For this RI, the K-65, L-30/F-32, and L-50 residues that resulted from the processing of uranium ores.

RUNOFF - All rainfall and snowmelt that does not soak into the ground, does not evaporate immediately, or is not used by vegetation, and hence flows over the land surface.

SECULAR EQUILIBRIUM - In a radioactive decay series, the state that prevails when the ratios between the amounts of successive members of the series remain constant over time.

SITE-RELATED CONSTITUENT (SRC) - Chemicals or radionuclides that were present in a given medium and EU at concentrations statistically greater than the corresponding background concentrations. SRCs were determined for soil (0 to 10 feet bgs), surface soil (0 to 0.5 feet bgs), sediments, surface water, groundwater, pipeline/utility sediments, and pipeline/utility water.

SOURCE TERM - The quantity of radioactive material (or other pollutant) released to the environment at its point of release (source).

SPECIFIC ACTIVITY - The activity per unit volume of a pure substance (see ACTIVITY).

THORIUM-230 - A radioactive solid produced by the decay of uranium-238. It has a half-life of 77,000 years.

TILL - Unstratified glacial deposits consisting of clay, sand, gravel, and boulders intermingled

URANIUM - A naturally occurring radioactive element that consists of 99.2830% by weight uranium-238, 0.7110% uranium-235, and 0.0054% uranium-234.

VICINITY PROPERTY - Vicinity properties are those properties that were designated by DOE as eligible properties in the FUSRAP and located within the boundaries of the former LOOW but outside the boundaries of what is now the NFSS. Vicinity properties include B, C', D, F, G, N/N' North, P, T, W, E and E'.

WASTES - For this RI, all contaminated materials (primarily soils) not defined as residues.

METRIC CONVERSION CHART

To Convert to Metric			To Convert from Metric		
If You Know	Multiply By	To Get	If You Know	Multiply By	To Get
Length					
inches	2.54	centimeters	centimeters	0.3937	inches
feet	30.48	centimeters	centimeters	0.0328	feet
feet	0.3048	meters	meters	3.281	feet
yards	0.9144	meters	meters	1.0936	yards
miles	1.60934	kilometers	kilometers	0.6214	miles
Area					
square inches	6.4516	square centimeters	square centimeters	0.155	square inches
square feet	0.092903	square meters	square meters	10.7639	square feet
square yards	0.8361	square meters	square meters	1.196	square yards
acres	0.40469	hectares	hectares	2.471	acres
square miles	2.58999	square kilometers	square kilometers	0.3861	square miles
Volume					
fluid ounces	29.574	milliliters	milliliters	0.0338	fluid ounces
gallons	3.7854	liters	liters	0.26417	gallons
gallons	0.00378	cubic meters	cubic meters	264.55	gallons
cubic feet	0.028317	cubic meters	cubic meters	35.315	cubic feet
cubic yards	0.76455	cubic meters	cubic meters	1.038	cubic yards
Weight					
ounces	28.3495	grams	grams	0.03527	ounces
pounds	0.4536	kilograms	kilograms	2.2046	pounds
Temperature					
Fahrenheit	Subtract 32 then multiply by 5/9ths	Celsius	Celsius	Multiply by 9/5ths then add 32	Fahrenheit
Radiation					
picocurie	0.037	Becquerel	Becquerel	27.027027	Picocuries
curie	3.70E+10	Becquerel	Becquerel	2.703E-11	Curies
rem	0.01	sievert	sievert	100	rem
RAD	0.01	Gray	Gray	100	RADs

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EXECUTIVE SUMMARY

ES.1 Introduction

A multi-phase remedial investigation (RI) was conducted at the federally-owned Niagara Falls Storage Site (NFSS) located at 1397 Pletcher Road in the township of Lewiston, Niagara County, New York. The 191-acre parcel is part of the former Lake Ontario Ordnance Works (LOOW) that was used by the War Department beginning in 1942 for the production of trinitrotoluene (TNT). In 1944, the Manhattan Engineer District (MED) began using the site for storage of radioactive residues that resulted from the processing of uranium ores during the development of the atomic bomb. The MED and its successor agencies continued to periodically ship radioactive residues and materials to the NFSS for storage through 1950.

Environmental investigation and remediation activities at the NFSS are managed by the United States Army Corps of Engineers (USACE), Buffalo District, under the Formerly Utilized Sites Remedial Action Program (FUSRAP). The site previously passed through the governmental reorganizations of the MED to the Atomic Energy Commission (AEC), the Energy Research and Development Administration (ERDA) and the United States (U.S.) Department of Energy (DOE). In October 1997, the Energy and Water Development Appropriations Act for Fiscal Year 1998, PL 105-62, was signed into law, transferring responsibility for the administration and execution of FUSRAP from DOE to the USACE. The Energy and Water Development Appropriations Act for Fiscal Year 2000, Public Law 106-60, requires that USACE comply with the Comprehensive Environmental Response, Compensation, and Liability Act, 42 United States Code 9601 et seq., as amended (CERCLA), in conducting FUSRAP cleanup work. Therefore, USACE is conducting FUSRAP cleanups in accordance with CERCLA.

ES.2 Purpose and Objectives

DOE performed various remedial activities at the NFSS prior to transfer of site management to USACE. However, the change in management impacted the regulatory authority and the range of alternatives for the NFSS. Subsequently, as required by law for execution of FUSRAP, USACE selected the CERCLA RI/Feasibility Study (FS) process to reach a decision for the completion of remedial activities at the NFSS. The RI/FS process will consider new alternatives for the site, regulatory changes, stakeholder comments, and additional data which have been generated since alternatives were initially proposed for the site in an Environmental Impact Statement (EIS) issued by DOE in 1986.

This RI was conducted to define the identity, amount, and location of chemicals of concern (COC) and radionuclides of concern (ROC) at the NFSS, and to provide primary data for the FS, which will be used to identify and evaluate various remedial action alternatives and assist in the development of a protective and cost-effective remedy for the site. The long-term objective of this project is to clean up contamination resulting from work related to the Nation's early atomic energy program administered under MED/AEC in a manner that satisfies the requirements of the CERCLA. While chemical contamination is normally addressed only when collocated with radioactive contamination under FUSRAP, USACE will remediate both radioactive and chemical contamination because NFSS is a federally-owned property. An adjacent property, the Niagara-Mohawk property, was also investigated in this RI to determine if radiological constituents have migrated west of the NFSS property boundary. A Baseline Risk Assessment (BRA) and a fate and transport groundwater flow model were completed in support of RI objectives.

ES.3 RI Approach

The RI began with a records review in order to gain an understanding of historic site operations and how these operations may have contributed to potential contamination. Following the records review, site reconnaissance was conducted to identify areas potentially impacted by site operations. Field activities then proceeded in a phased approach in order to refine the understanding of the nature and extent of contamination at the NFSS and their relationships to exposures, risks, and remedial alternatives.

The RI was conducted in three phases. Fieldwork for Phase I occurred from November 1999 until January 2000 and consisted of a wide investigation of the site, involving the collection of groundwater, surface water, sediment, and soil samples that were analyzed for radiological and chemical parameters.

Phase 2 sampling activities were conducted from August through October 2000. Phase 2 of the investigation was guided by sampling results obtained during Phase I and focused on areas that appeared to be adversely impacted by past activities at the site. A sitewide gamma walkover and geophysical survey were conducted during the summer of 2001 to evaluate the presence of surficial gamma-emitting radionuclides and subsurface features that could allow contaminant migration, respectively.

Phase 3 was conducted from May 2001 until October 2003 and focused on the following activities.

- Further characterization of areas that exhibited elevated radioactivity during the gamma walkover survey,
- Further characterization of pipelines and sewers at the site that could serve as sources of contamination and mechanisms of contaminant transport,
- Excavation of exploratory trenches to investigate anomalies identified during a geophysical survey conducted in the summer of 2001,
- Collection of background surface water, sediment, and groundwater samples,
- Collection of soil samples required to support the BRA,
- Sampling and disposal of abandoned drums identified during previous field activities,
- Collection of confirmatory samples from wells and manholes,
- Collection of soil and groundwater samples to further delineate and characterize areas of suspect contamination identified during earlier phases of the RI,
- Collection of samples from the floor drains, the concrete floor slab and below the floor slab of Building 401, and
- Collection of radiological samples from the neighboring Niagara-Mohawk property.

Additional geophysical surveys on the Interim Waste Containment Structure (IWCS) were conducted concurrently with the Phase 3 sampling activities. Resistivity surveys were conducted in May-June 2001 and seismic surveys were conducted in June 2001. Follow-up geophysical investigations, including seismic refraction and electrical imaging/induced polarization were conducted in September 2003.

Since the completion of Phase 3 activities of the RI in October 2003, project work has continued for review and presentation of the RI results. Continued RI activities include: quality review and electronic management of analytical data, preparation of figures and tables to visually summarize environmental sampling results, formulation of a computerized groundwater flow model, performance of human health risk calculations in development of the BRA, and multi-tiered review in preparation of final compilation of this RI report.

In addition to sampling performed during the RI at NFSS, regular sampling of air, surface water, groundwater, and streambed sediment is conducted to support the ongoing environmental surveillance program. Environmental surveillance results are compared to local background conditions and regulatory criteria to determine if radioactive waste stored on-site poses a threat to human health and the environment. By further defining the nature and extent of site-related constituents (SRC) at the site during the RI, goals and objectives of the environmental surveillance program will be better directed to ensure continued safety to human health and the environment.

ES.4 Site Description

Figure ES-1 shows the NFSS and the current surrounding land use. The NFSS is bordered on the north and northeast by the CWM Chemical Services, LLC. hazardous waste disposal facility, on the east and south by the Modern Landfill, Inc. solid waste disposal facility, on the west by a transmission corridor owned by Niagara-Mohawk Power Corporation, and on the northwest by the village of Lewiston (the former LOOW wastewater treatment plant). All of the aforementioned properties were once part of the original LOOW.

The surrounding area land use consists primarily of row-crops and orchards, abandoned agricultural fields, and second-growth forests. The Lewiston-Porter public school property is approximately 1.5 miles northwest of the site and a public campground is approximately 0.5 miles west of the site. The nearest residences are located on Pletcher Road approximately 0.5 miles west-southwest of the site.

Drainage at the NFSS is poor because of the flat terrain and the relatively impermeable nature of surface soils. Much of the NFSS property has the potential to collect and hold standing water for lengthy periods. However, several ditches on site collect surface water runoff. Over most of the site, surface water is conveyed through east-west ditches that empty into the Central Ditch. The Central Ditch flows north and joins Four Mile Creek about 1.5 miles north of the NFSS. Four Mile Creek, in turn, empties into Lake Ontario. Surface water runoff from the western periphery of the site and from the Baker-Smith area in the northwest corner of the site flows to the West Ditch. The West Ditch flows north and joins the Central Ditch approximately 0.5 miles north of the NFSS.

Unconsolidated geologic units present at the NFSS consist mainly of glacial tills containing clay, silt, sand, and gravel. These unconsolidated materials are approximately 40 feet thick at the NFSS and include, in order of shallowest to deepest: surficial soils and fill, the Brown Clay Unit, the Gray Clay Unit, the Middle Silt Till Unit, the Sand and Gravel Unit, and the Red Silt Unit. The

Queenston Formation forms the bedrock at the site and consists of brownish red shale, siltstone, and mudstone. The Queenston Formation is over 1,200 feet thick and is typically encountered 32 to 49 feet below ground surface (bgs) (BNI 1994b, Acres American, Inc. 1981a). A geologic column is shown in Figure ES-2.

Within 100 feet of the ground surface, there are two water-bearing zones at the NFSS and surrounding vicinity. The upper water-bearing zone (UWBZ) is present in the Brown Clay Unit. The lower water-bearing zone (LWBZ) is associated with the Queenston Formation and the unconsolidated materials immediately above the bedrock (Red Silt and Sand and Gravel Units). The Gray Clay Unit acts as an aquitard between the UWBZ and the LWBZ. A regional groundwater divide exists approximately two miles south of the NFSS. Regional groundwater flow north of the divide is toward the northwest, whereas groundwater flow south of the divide is toward the southwest (BNI 1982b).

Former production facilities located on the portion of the LOOW that later became the NFSS included the acid area where nitric acid was known to have been stored; the shops area where machine shops and storage areas were located; an administrative area referred to as the Baker-Smith area; the Power Area which housed the original steam plant for the LOOW; and the Freshwater Treatment Plant which included circular clarifiers and several water storage reservoirs.

Currently, the IWCS is the dominant site feature, occupying approximately 10 acres in the southwest portion of the site. During the 1980's, the DOE performed various remedial activities at the site and consolidated the radioactive wastes and contaminated materials at the NFSS into the IWCS, which was engineered to retard radon emissions, infiltration from precipitation, and migration of contamination to groundwater. The base of the IWCS consists of naturally occurring clay. A clay dike, which was keyed 1.5 to 2 feet into the underlying gray clay, surrounds the stored radioactive materials. The IWCS is covered with an interim clay cap consisting of three layers. The bottom layer includes three feet of compacted clay keyed into the dike followed by a one foot layer of fill. The upper layer is a 6-inch topsoil vegetative cover. The cap is considered 'interim' because it does not include a barrier layer (typically a riprap layer at least three feet thick) and the side slopes of the structure, currently 3:1, were not constructed with a slope of 5:1. Also, the side slopes do not have a riprap covering, which is required for a long-term cap (BNI, 1994a).

ES.5 Determination of Exposure Units and Site-Related Constituents

To facilitate accurate estimation of exposure and dose in the BRA, the NFSS was divided into 18 exposure units (EU). An EU is the geographic area in which a receptor is assumed to work or live, and where a receptor may be exposed to SRCs detected during the RI. These EUs provided the geographical framework for the determination of SRCs. SRCs are defined as those compounds that exceed background screening levels in their respective EUs.

The area of investigation considered by this RI, consisting of the NFSS and the neighboring Niagara-Mohawk property, was divided into 14 distinct physical EUs, numbered 1 through 14 as shown on Figure ES-3. These EUs formed the basis for the evaluation of surface soils, subsurface soils, and some of the sediment and surface water samples. SRCs were determined for each EU for soil (0 to 10 feet bgs), surface soil (0 to 0.5 feet bgs), sediments, surface water, groundwater, pipeline/utility sediments, and pipeline/utility water. An additional four EUs (EUs 15 through 18) were created to accommodate special circumstances of the site or needs of the BRA. Throughout

the RI report, references may be made to 14 physical EUs or 18 risk EUs depending on the topic of discussion.

For the purpose of discussing RI results in this document, EUs 1 through 14 were grouped with respect to site features or former site operations. The following EU groupings were identified: Baker-Smith Area and Vicinity, Acid Area and Vicinity, Panhandle Area, IWCS and Vicinity, Shops Area, Niagara-Mohawk Property, and Building 401 and Vicinity. A brief description of each EU, including its grouping, follows.

EU 1 (Baker-Smith Area and Vicinity)

EU 1 is located in the northwest corner of the NFSS. The West Ditch flows to the north through EU 1. During the operation of the LOOW, a pipe shop, machine shop, welding shop, and a store house were located in EU 1 near a rail line that ran roughly parallel to the West Patrol Road. Except for the West Ditch, the ditches in EU 1 are typically dry and carry water only after storm events. During operation of the NFSS by AEC, K-65 and Knolls Atomic Power Laboratory (KAPL) wastes were stored in buildings located in this area. The KAPL wastes were later transferred to Oak Ridge National Laboratory and the K-65 wastes were moved to a silo in EU 6. The DOE performed remedial actions in the Baker-Smith area in 1981.

EU 2 (Baker-Smith Area and Vicinity)

EU 2 is located along the northern boundary of the NFSS property east of EU 1. A small portion of the New Naval Waste Area, where construction debris was stored, was also located in EU 2. The DOE performed remedial actions in the New Naval Waste Area in 1983.

EU 3 (Acid Area and Vicinity)

EU 3 is located along the northern boundary of the NFSS property and is bordered by EU 2 on the west and EU 4 on the east. The major portion of the New Naval Waste Area, where building debris was stored, was located within EU 3. Building 433, also known as the former radium storage vault used to store sealed radium sources, was located in EU 3. The exact location of this building is not known with certainty and during sampling efforts for this RI, areas in both EUs 2 and 3 were investigated as potential former locations of the building.

EU 4 (Acid Area and Vicinity)

EU 4 is located along the northern boundary of the NFSS property and is bordered by EU 3 on the west and EU 5 on the east. During the operation of the LOOW, nitric acid and other materials related to the manufacture of TNT were stored in EU 4. During the 1950's, uranium rods from several uranium metal production facilities in the New York area were stored in Buildings 431 and 432. These buildings, formerly located near the boundary between EU 3 and EU 4, were decontaminated and demolished by the DOE in 1986. Several subsurface pipelines used to transfer acids north to the former TNT production facilities remain in the EU.

EU 5 (Panhandle Area)

EU 5 is located in the northeastern portion of the site property along the northern property boundary and is bordered by EU 4 on the west and EU 6 on the east. It is bordered to the north by CWM Chemical Services Inc. Landfill and Modern Landfill to the south. Ammonia storage facilities were present in EU 5 during operation of the LOOW and some foundation material was found in the EU. In 1953, an explosion and fire that was not related to the storage or use of ammonia occurred immediately south of the Panhandle Area. The cause of the fire is unknown. The pipeline that transferred K-65 slurry from EU 6 to the IWCS passed through EU 5 along O Street.

EU 6 (Panhandle Area)

EU 6 is located in the northeastern corner of the site property and is bordered by EU 5 on the west, CWM Chemical Services Inc. Landfill to the north and east, and Modern Landfill to the south. Building 434, a water tower during the operation of the LOOW and later a storage facility for the K-65 residues, was located in EU 6. In the 1980's under direction of the DOE, the K-65 residues were slurry transferred to the IWCS through a temporary transfer pipeline and the water tower was removed.

EU 7 (IWCS and Vicinity)

EU 7 is a large grassy area north of the IWCS (EU 10). In a 1944 oblique, a large building was located in EU 7; however, no buildings currently exist in this EU. During the remedial actions performed by the DOE in the 1980's, several large temporary ponds, principally used for the management and storage of stormwater, were located in this area. EU 7 is also the location of the former DOE Organic Burial Area where roofing timbers, wooden debris, and organic material from clearing activities were disposed.

EU 8 (Shops Area)

EU 8 is located in the east-central portion of the NFSS, north of Building 401. It is bordered to the north by the acid area, to the south by the Building 401 Area, to the east by Modern Landfill, and to the west by Campbell Street. This area once contained a parking garage, equipment maintenance garage, material shed, general storehouse, combined shops, millwright shop, and riggers shop. None of these buildings remain although some concrete building foundations are still present. Radioactive residues were stored in several of the former buildings and corroded uranium billets were cut into smaller sections in the riggers shop. A debris pile is present in the southeastern portion of the EU.

EU 9 (Niagara-Mohawk Property)

The Niagara-Mohawk property is adjacent to the western boundary of the NFSS. The West Ditch is the principal site feature of the Niagara-Mohawk property. Impacted soils in the West Ditch were removed during a previous removal action.

EU 10 (IWCS and Vicinity)

EU 10 is located along the western border of the NFSS property boundary south of EU 7. The predominant feature in EU 10 is the IWCS. Prior to the construction of the IWCS, the LOOW freshwater treatment plant was located at the southern end of the EU. The Middlesex Sands, F-32, L-30, L-50, and K-65 residues are currently stored in the remnants of the freshwater treatment plant, which are now contained in the IWCS. Likewise, the R-10 pile, formerly unprotected and stored in the open north of the freshwater treatment plant, is also contained in the IWCS.

EU 11 (IWCS and Vicinity)

EU 11 is 'L' shaped and located both east and south of EU 10. During the operation of the LOOW, a fire house was located in the central portion this EU and a parking lot was located in the southern portion. Later, during the remedial actions performed by the DOE in the 1980's, a water treatment plant and several temporary ponds used to hold treated slurry water, decontamination water and stormwater prior to release were located here.

EU 12 (Building 401 and Vicinity)

EU 12 is a vacant wooded tract located between the shops area (EU 8) and Building 401. No production or storage activities are known to have occurred in EU 12. The Building 401 Ditch flows north through the EU where it joins the South 16 Ditch, which continues to the west joining the Central Ditch in EU 10.

EU 13 (Building 401 and Vicinity)

EU 13 is surrounded by EUs 11, 12, and 14. The main feature in EU 13 is Building 401, a large structural steel building. During the operation of the LOOW, Building 401 was a power house, generating steam for use in the TNT production facilities. Later, the building housed a boron-10 (a nonradioactive isotope) separation process. During active use of the NFSS as well as during previous remedial activities, the building was used to temporarily store and stage radioactive waste.

EU 14 (Building 401 and Vicinity)

EU 14, bounded on two sides by Modern Landfill, is a wooded tract. Both the South 31 Ditch and the Modern Ditch flow through the area and join near the northwest corner of the EU. The South 31 Ditch continues to the west joining the Central Ditch in EU 10. No production or storage activities are known to have occurred in EU 14.

EU 15 (Interconnected Drainageways)

EU 15 consists of the Central Ditch, South 16 Ditch, South 31 Ditch, and Modern Ditch. All sediment and surface water samples collected from these ditches were evaluated in EU 15. Sediment and surface water samples collected from ditches other than those in EU 15 were evaluated in the EUs from which they were collected.

EU 16 (Pipelines and Subsurface Utilities)

EU 16 contains on-site subsurface pipelines used in former site operations. These pipelines include acid lines, water lines, sanitary sewers, and storm sewers. All sediment and water samples collected from these pipelines were evaluated in EU 16.

EU 17 (Sitewide Media)

EU 17 is a site-wide EU and includes all areas and media within the property boundary of NFSS. This includes all soil, sediment, surface water, and pipeline material in EUs 1 through 16. In addition, it contains site-wide groundwater, including both the UWBZ and the LWBZ.

EU 18 (Background Samples)

EU 18 consists of all background samples that were used for the determination of SRCs in EUs 1 through 17.

ES.6 Nature and Extent of SRCs

For the purpose of discussing the nature and extent of SRCs in soil within each EU, surface soil samples were considered to be samples collected from 0 to 0.5 feet bgs and subsurface soil samples were considered to be samples collected from 0.5 to 10 feet bgs. Soil samples collected at depths greater than 10 feet bgs were addressed separately. This approach to the discussion of the nature and extent of soil SRCs corresponds to figures presented in Section 4 of this report that show the horizontal and vertical distribution of SRCs in soil within each EU. Additionally, for the purposes of determining nature and extent of SRCs, water and sediment samples included in EUs 15 and 16 are presented in the discussion of the EU from which they were collected.

Table ES-1 provides a summary of SRCs of significance for each media within each EU. SRCs of significance were identified for each media. The criteria used to determine significance of SRCs included, but was not limited to:

- high frequency of detection,
- high magnitude of observed concentrations,
- widespread occurrence,
- multiple depth occurrences in soil,
- clustered concentrations,
- constituent of an identified groundwater plume, and
- high probability of media interaction.

The BRA evaluated soils to depths of 10 feet to remain consistent with reasonable exposure scenarios; however, the RI considered soil samples from depths greater than 10 feet bgs to evaluate SRCs of significance and to define nature and extent of contaminants. General conclusions concerning SRCs developed from the evaluation of RI data collected from EUs 1 through 14 are summarized in this section for each media of concern.

Surface and Subsurface Soil

EUs 4 and 8 appear to be impacted by the most types of SRCs. SRCs of significance identified for the two EUs include radionuclides, volatile organic compounds (VOCs), pesticides, polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), and boron. Metals and semi-volatile organic compounds (SVOCs) were also identified as SRCs of significance in EU 8.

Radionuclides impacted soils in all 14 physical EUs. Radionuclides exceeded the background upper tolerance limits (UTLs) by factors of 100 or greater in EUs 1, 5, 6, 7, 8, 11, 13, and 14. Exceedances of the background UTLs by a factor greater than 100 occurred approximately 10 times or less in each of these EUs. In decreasing order, radium-226, thorium-230, uranium-238, and cesium-137 were the four radionuclides with the highest frequency of detection above the background UTLs in surface soil. However, uranium-234 and uranium-238 exhibited some of the highest exceedances above background UTLs (greater than 4,000 times) in surface soil samples. Several surface soil samples also exhibited concentrations of radium-226 and thorium-230 that exceeded background UTLs by factors greater than 100. Likewise, thorium-230, uranium-238, radium-226, and uranium-234 were the four radionuclides with the highest frequency of detection above the background UTLs in subsurface soil. Radium-226 and thorium-230 exhibited the highest exceedances above background UTLs (greater than 100 times) in subsurface soil samples.

Radionuclides detected above background UTLs may be related to radioactive waste storage operations (EUs 1, 8, and 13), activities conducted at the former radium storage vault (EU 3), activities conducted and waste stored at the New Naval Waste Area (EU 3), wind erosion of the uncovered R-10 pile (sitewide), the storage of K-65 residues in Building 434 (EU 6), dewatering of slurried residues (EU 11), and general transportation and storage practices employed at the NFSS prior to remedial activities in the 1980's. Residual radionuclide contamination could be the result of difficulties encountered during historical cleanup activities. In addition, the soils may have been cleaned up to standards deemed appropriate by DOE at the time; however, technology improvements and the conservative screening criteria used during this RI indicate that further evaluation of contaminants in soil may be warranted. The widespread presence of radionuclides in subsurface soil at the NFSS may also be partly attributed to the migration of constituents along subsurface utility lines. Cracks or leaks in the subsurface utility lines may provide a pathway for constituents to reach subsurface soil where further migration can occur via infiltration of precipitation and interaction with shallow groundwater.

It should be noted that migration of contaminants along subsurface utilities is limited to those outside of the IWCS. During construction, the pipes, culverts, and canals within the footprint of the IWCS were excavated and/or sealed to close pathways for possible migration of radionuclides out of the IWCS (BNI, 1986c). Those pipelines utilities that extended off-site have also been sealed to prevent any contamination from migrating across the site boundary.

VOCs were considered to be SRCs of significance in all 14 physical EUs except EUs 9 and 11. Acetone was the most frequently detected VOC in surface and subsurface soils. However, roughly 75% of all acetone detections in surface and subsurface soil samples were at concentrations less than 20 µg/kg. Chlorinated solvents (i.e. TCE, cis/trans-1,2-dichloroethene (DCE), PCE, 1,1,1-trichloroethane, and 1,1-DCE), benzene, toluene, methylene chloride, carbon disulfide, and 2-butanone were also commonly detected in soils. VOCs were frequently detected below a depth of 10 feet bgs. The source of VOCs in soils at the NFSS is most likely associated with activities conducted at former LOOW buildings. Transportation of supplies and chemicals along haul roads and inappropriate disposal of drums and debris could also have contributed to releases of VOCs in soil.

Pesticides, PCBs, PAHs, and metals were identified as SRCs of significance in soil in several EUs. SVOCs were infrequently identified as SRCs of significance in soil. Pesticides may have been used for insect control across most of the NFSS, especially near building and former work areas. However, no specific pesticide storage facility could be identified in historical documents. PCBs may be the result of spills during transportation, disposal of debris as observed in excavation trenches, or from PCB-containing oil that may have been used for dust control on the site roads. Pesticides, PCBs, PAHs, SVOCs, and metals may also be related to general site activities conducted at the NFSS, including storage of chemicals and materials within some of the buildings.

Groundwater

Over 200 groundwater samples were collected from temporary and permanent wells at the NFSS. Groundwater plumes containing radionuclides, metals and organic compounds were identified in the UWBZ; however, no groundwater plumes were identified in the LWBZ because the nature and extent of SRCs detected in the LWBZ did not warrant the identification of a plume. Most of the plumes are geographically associated with past site uses or activities. There are some site areas where materials were buried or where drums were found that may have contained the constituents identified in groundwater plumes. In some cases, there appears to be a relationship between buried utilities and groundwater concentrations of SRCs; infiltration of precipitation that can promote the migration of constituents to shallow groundwater or the interaction of utility lines with shallow groundwater may allow utility lines to act as preferential pathways for constituent migration.

Groundwater plumes were identified for dissolved total uranium, thorium-230, manganese, boron, tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-DCE, trans-1,2-dichloroethene, vinyl chloride, and bis(2-ethylhexyl)phthalate. The plumes are briefly described in the following paragraphs.

Dissolved total uranium groundwater plumes impact ten EUs and were located in the following areas:

- In EUs 1 and 2 extending from the west-central portion of EU 2 through the northwest portion of EU 1,

- In the north-central portion of EU 4 near the former nitric acid concentrator,
- In the northwest corner of EU 7 near the West Ditch,
- In the southeastern portion of EU 8 near the area of the former storehouse Buildings 420 and 421 and the debris pile and in the southwestern portion of EU 8 between Buildings 422 and 423,
- On the west and north sides of the IWCS in EU 10,
- In the southern portion of EU 10 and in areas of EU 11, and extending along the water line that cuts diagonally across the southeastern corner of EU 10,
- In EUs 10 and 11 in the vicinity of some former dewatering ponds,
- Just north of Building 401 in EU 13 and across the northwest corner of EU 12, and
- In EU 13 covering the entire southwestern portion of the EU from Building 401 to the EU boundary.

Other groundwater plumes identified at the NFSS include:

- A dissolved manganese plume in the central portion of EU 3,
- A dissolved boron plume in the central portion of EU 4,
- A dissolved boron plume in the central portion of EU 13,
- A dissolved thorium-230 plume spanning the boundary between EUs 7 and 10,
- A small dissolved thorium-230 plume in the north central portion of EU 4,
- A dissolved thorium-230 plume extending from EU 11 into EU 10 in the area south of the IWCS,
- PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride groundwater plumes in EU 4 at a depth of approximately 10 to 15 feet bgs where PCE and TCE (dense non-aqueous phase liquids (DNAPL)) sources may exist, and
- A small bis(2-ethylhexyl)phthalate groundwater plume along the east side of the IWCS.

Other SRCs of significance were identified in groundwater for several EUs as shown on Table ES-1; however, groundwater plumes for these SRCs were not identified.

Sediment

Samples collected from locations that are inundated at least 50% of the year were considered to be representative of sediment.

EU 5 was the only physical EU where SRCs of significance were identified for sediment. Cesium-137 and total uranium exceeded the background UTLs in sediment by factors less than

10. Radionuclides may be present in EU 5 due to transportation and storage practices employed at the NFSS prior to the remedial activities in the 1980's. Also, because the R-10 pile was uncovered and unprotected for a number of years, wind erosion of the pile and the subsequent downwind deposition and migration of constituents to surface water and sediment likely account for some of the wide-spread low-level radionuclide SRCs observed here and elsewhere on the site.

Surface Water

SRCs of significance in surface water were only identified for EUs 7 and 9, and in the interconnected drainageways (EU 15). General conclusions concerning SRCs of significance in surface water include:

- Thorium-228 and thorium-230 were identified in surface water at EU 7 at concentrations greater than 40 times their respective background UTLs.
- Uranium-234, uranium-235 and uranium-238 exceed the background UTL in the dissolved phase at several locations along the West Ditch in EU 9.
- Several metals were found in the Central Drainage Ditch at levels approximately 2 times the background UTL. Dissolved silver was detected at levels approximately 20 times the background UTL at one location just inside the site boundary in the Modern Ditch and at the next three samples downstream in the South 31 Ditch. The three samples collected from the South 16 Ditch also exhibited dissolved silver at these levels.
- Thorium-232 was detected at five locations, three in the Central Ditch and two in the South 31 Ditch. Radium-226 was also detected at levels slightly above the background UTL at two of these locations. However, the fact that radionuclide concentrations do not exceed background UTLs at sampling locations near the northern boundary of the property suggests that radiological SRCs are not migrating off-site (i.e. radionuclide concentrations near the northern boundary of the property are within the expected range of naturally occurring concentrations suggesting that radiological impacts from the site have not extended beyond the northern property boundary).
- Two VOCs, 4-methyl-2-pentanone and benzene, were detected in an isolated sample collected at the conjunction of the South 31 Ditch and the Modern Ditch.

Although metals were not identified as an SRC of significance in surface water in any other EUs, dissolved silver was detected at levels 20 times greater than the background UTL in EUs 5 and 8. No known source for the silver was identified in the historical review.

- Dissolved silver was detected at levels 20 times greater than the background UTL in four samples collected from the O Street North Pond and a pond in the northern portion of the EU 5.
- Dissolved silver was detected at levels 20 times greater than the background UTL in three samples collected from small ditches in the northern and eastern portions of EU 8.

The elevated concentrations of thorium and uranium isotopes in surface water in EUs 7 and 9 can likely be attributed to runoff from surface soil. Metals and radionuclides in the interconnected drainageways may be the result of past activities including the construction and filling of the

IWCS. Metals, specifically dissolved silver, may also be entering the site from surface water to the east and south. The VOCs are likely a result of the nearby AEC sludge pit as surface and subsurface soil samples near this location also exhibited concentrations of VOCs above the background UTL.

Metal SRCs in surface water and sediment within the interconnected drainageways are likely migrating offsite at concentrations above background levels. SRCs in groundwater could migrate to surface water and sediment in drainageways where the groundwater table is above the elevation of the bottom of the drainageway. This likely occurs in the Central Ditch, which appears to be hydraulically connected to the UWBZ. SRCs in surface water have the potential to migrate to groundwater only when surface water in the drainageways is flowing above the elevation of the groundwater table.

Sediment and Water in Pipelines and Subsurface Utilities

Pipelines and subsurface utilities are present on the majority of the NFSS property, particularly in EUs 3, 4, 8, 10, 11, 12 and 13, and to a lesser extent in EUs 2, 5 and 6. SRCs of significance were identified for EUs 2, 4, 8, 10, 11, and 13; however, EUs 4, 8 and 13 exhibited the most frequent and widespread occurrence SRCs of significance in pipelines and subsurface utilities. Most of the SRCs identified in EU 13 occurred in floor drain samples from beneath Building 401. Background UTLs for sediment and water in pipelines and subsurface utilities are based on sediment and surface water background samples.

- Radionuclides were identified as SRCs of significance in sediment in subsurface utility lines in EUs 2, 4, 8, 10, and 13. Radiological SRCs were detected above the background UTLs in several water samples collected from pipelines and subsurface utilities in EUs 4, 8 10, 11, and 13.
- Three metals (boron, cadmium and mercury) in subsurface utility sediments from EU 13 exceeded their respective background UTLs by more than a factor of 100. A number of others metals exceeded their respective background UTLs by a factor of 10 to 100 in EU 13. Several metals in water samples collected from the subsurface utility lines in EU 11 exceeded their respective background UTLs by factors of up to 27. Numerous metals exceeded the background UTL in both the dissolved and total phase in four drain samples from Building 401 and two samples outside the building in EU 13.
- PAHs were identified as SRCs of significance in sediment in subsurface utility lines in EUs 2, 4, 8, 11, and 13. Several PAHs were detected in water from the subsurface utilities within EU 4 at concentrations up to approximately 280 times the background UTL.
- VOCs were detected in multiple locations in sediment from the drain samples in Building 401 within EU 13. VOCs were also detected above the background UTL at four locations in the EU 8 subsurface utilities. VOCs were detected in water from the subsurface utilities within EU 4 with two locations having concentrations of PCE greater than 20 times the background UTL.
- Several pesticides were found in six subsurface utility samples in EU 4 with concentrations exceeding the background UTL by as many as 600 times. Pesticides were also found in the floor drains in Building 401 at concentrations up to approximately 27,000 times the background UTL.

- PCBs in sediment from the drains in Building 401 in EU 13 exceeded their background UTLs by factors ranging from 14 to approximately 1,400. Aroclor-1260 concentrations exceeded the background UTL in 5 locations in EU 4 by factors ranging from 14 to 100 times.

Radionuclides may exist in the pipeline and subsurface utility line sediments and water as a result of residues being stored and staged in various buildings onsite, primarily in EUs 4, 10, and 13. Constituents found in subsurface utilities in the EU 8 shops area, including metals, SVOC, VOCs, PCBs and PAHs, are likely from historical operations conducted in these buildings. Pesticides may be present in the pipelines and subsurface utilities as a result of a possible spill in a storage area or surface drainage into manholes. It is possible that the pipelines/subsurface utilities and surrounding gravel-fill provide a pathway for SRCs to travel between EUs and may explain the existence of constituents in many of the areas. Some of the results, especially in EU 4, are very high but not wide-spread. Also, many manholes are damaged and allow surface water to enter the sewer system. Finally, given the age and generally poor repair of the system, infiltration and exfiltration are likely occurring.

ES.7 Identification of COCs and ROCs

The process of identifying SRCs, COCs, and ROCs is outlined in the BRA. SRCs are initially identified in the BRA using a series of statistical methods to consider whether a chemical is site-related or naturally occurring including a comparison to background. Chemicals and radionuclides that are determined to be site-related are identified as SRCs. Further screening against preliminary remediation goals (PRG) or site-specific radiological risk-based screening levels, as appropriate, is performed to eliminate SRCs that pose negligible risk to human health. SRCs exceeding PRGs or radiological screening levels are identified as chemicals of potential concern (COPC) or radionuclides of potential concern (ROPC), respectively and are evaluated quantitatively in the BRA. COCs and ROCs are constituents (COPCs and ROPCs) that were determined in the BRA to pose unacceptable risk.

Table ES-1 summarizes the COCs and ROCs identified for each media within each EU for the subsistence farmer scenario, only. Due to the extensive number of risk scenarios evaluated in the BRA, only the most conservative risk scenario generating the highest number of COCs is discussed here. It should be noted that the subsistence farmer land use scenario is overly conservative for the NFSS and is highly unlikely due to proximity of the site to surrounding landfills and poor yield and quality of on-site groundwater resources. A more detailed evaluation of COCs for each risk scenario that will provide the basis for identifying COCs and remedial action objectives (RAO) in the FS is presented in the BRA. Table ES-1 also identifies constituents considered to be risk drivers in the exposure pathways. The subsistence farming scenario includes the development of a working farm with livestock for meat and dairy products plus cultivated land for grains, fruits, and vegetables. It is assumed that a subsistence farmer could be exposed to contaminated surface soil, surface water/sediment, impacted home-grown produce, impacted meat and dairy products, and upper and lower groundwater while on site. Carcinogenic COCs and ROCs are constituents that exceed the 10^{-5} risk level. A risk of 10^{-5} is defined as the probability that one additional person in a population of 100,000 people may develop cancer as a result of exposure to contaminants at NFSS. Non-carcinogenic COCs are constituents that show risks exceeding a hazard index (HI) of one. A HI greater than one is defined as the level of concern for potential adverse non-carcinogenic health effects. Risk was determined for the following media pathways: surface soil (0-0.5 feet), soil (0-10 feet), sediment,

surface water, groundwater, and food. COCs identified for the food pathway correspond to soil samples collected from 0-0.5 feet.

The majority of COCs and ROCs identified for the adult/child subsistence farmer pose risk in soil only; however, COCs and ROCs were also identified for the groundwater and food pathways. No COCs or ROCs were identified in sediment or surface water in any of the 14 physical EUs. Sediment and surface water COCs and ROCs also were not identified for pipelines and subsurface utilities (EU 16) or for interconnected drainageways (EU 15). No COCs or ROCs were identified for EU 16 because the BRA assumes that the subsistence farmer will not be exposed to the subsurface utilities. However, the high concentrations of constituents found in both the sediment and water in pipelines and subsurface utilities could remain a potential source for groundwater migration. Additionally, no COCs or ROCs were identified for EU 10 in the BRA because the subsistence farmer will not be exposed to the constituents in or around the IWCS.

COCs were identified as posing risk in soil at EUs 2, 4, 8, and 12. Several PAHs, arsenic, boron, and Aroclor-1260 were identified as soil COCs in one or more of these EUs. Of these soil COCs, arsenic, benzo(a)anthracene, benzo(a)pyrene, and Aroclor-1260 were identified as risk drivers in soil at one or more EUs. ROCs were identified as posing risk in soil at EUs 1 through 9, 11, 12, 13, and 14. Radium-226 was identified as a risk driver in soil at all of these EUs. Additionally, uranium was identified as a soil risk driver to the child subsistence farmer in EUs 8 and 11.

COCs were identified for the food pathway in EUs 2, 4, 8, 11, 12, 13, and 14. PAHs, arsenic, boron, copper, zinc, Aroclor-1254 and -1260, PCE, di-n-octylphthalate, carbazole, and heptachlor epoxide were identified as posing risk in the food pathway at one or more of these EUs. ROCs were identified in the food pathway at EUs 1 through 9, 11, 12, 13, and 14. Actinium-227, protactinium-231, lead-210, radium-226 and -228, thorium-230 and -232, and uranium-234 and -238 were identified as food ROCs in one or more of these EUs.

Groundwater COCs and ROCs were identified for EUs 4, 13, and 17. Several metals, bis(2-ethylhexyl)phthalate, and several VOCs were identified as groundwater COCs in one or more of these EUs. Of the groundwater COCs, arsenic was identified as a risk driver in EU 13, while PCE was identified as a risk driver in EUs 4 and 17. Cesium-137, lead-210, radium-226 and -228, thorium-228, and uranium-234 and -238 were identified as groundwater ROCs in one or more of these EUs. Of the groundwater ROCs, radium-226 was identified as a risk driver in EUs 4 and 17.

ES.8 Groundwater Fate and Transport Modeling

The fate and transport of groundwater at the NFSS is detailed in the modeling report prepared by HydroGeoLogic, Inc. (HGL 2007). The groundwater flow and transport model indicates that organic and metal plumes located outside the area of the IWCS exhibit only minor dispersion due to low infiltration rates. VOCs in groundwater will continue to degrade and maximum concentrations of metals are not expected to increase above the current concentrations of the plumes.

Within 1,000 years, the maximum concentrations of uranium isotopes are predicted to occur in the Brown Clay Till beneath the IWCS, near Building 411. Additionally, model results indicate that the screening levels for uranium-234 and uranium-235 will be exceeded in even the deepest of the aquifers (the upper Queenston Formation) within 1,000 years. This is likely the result of potential leaching of residues within Building 411 in the IWCS. Groundwater modeling also

predicts that metals that may leach from within the IWCS will not migrate offsite in groundwater at concentrations above screening levels.

Uranium isotopes are predicted to migrate offsite within 1,000 years at concentrations that exceed the screening levels in EUs 1 and 11. This offsite migration is due to continued migration of existing groundwater contamination, contributions predicted from SESOIL modeling, or a combination of both. However, the conclusions made regarding the fate and transport of uranium isotopes in site groundwater are somewhat dependant on the conservative K_d value of 3.6 L/kg that was used in the modeling simulations. Use of this K_d value causes the model to predict greater concentrations of radionuclides in groundwater due to increased leaching of site soils. The results of a sensitivity analysis for the uranium K_d value are discussed later in this report in Section 6.6.4. A modified K_d value for uranium may be used in the FS for determining cleanup criteria.

ES.9 Recommendations

The presence of COCs and ROCs identified in the BRA as posing risk in soil for the adult/child subsistence farmer are recommended to be further addressed in the FS at each EU in which they were identified. There are soil COCs and ROCs that are recommended to be addressed in the FS at all 14 physical EUs.

Groundwater modeling results support the conclusion that no further action or evaluation is needed for COCs and ROCs in groundwater in EUs 3, 5, 6 and 14. Further evaluation of COCs and ROCs in the FS is recommended for all of the other 14 physical EUs, with the exception of EU 9 where no groundwater samples were collected. Additionally, further evaluation of COCs and ROCs in sitewide groundwater (EU 17) is recommended.

No human health COCs or ROCs were identified for sediment or surface water at any of the 14 physical EUs or in interconnected drainageways (EU 15) due to the short duration of exposure for individuals who may come in contact with surface water or sediment at NFSS.

The presence of SRCs in sediment and water within pipelines and subsurface utilities is recommended for further consideration in the FS as it pertains to groundwater plume and soil remediation. As mentioned previously, high concentrations of constituents found in both the sediment and water in pipelines and subsurface utilities could remain a potential source for groundwater migration..

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Table ES-1. Summary of SRCs of Significance, COCs, and ROCs for Exposure Units 1 through 17

Exposure Unit	SRCs/COCs/ROCs¹	Soil	Food²	Groundwater	Sediment	Surface Water⁵	Utilities³
EU 1	SRCs	Radionuclides VOCs Pesticides	NA	Radionuclides	See Footnote 7	See Footnote 7	NA
	COCs	None	None	None	See Footnote 7	See Footnote 7	NA
	ROCs	Actinium-227 Cesium-137 Protactinium-231 Lead-210 Radium-226*, 228 Thorium -230, 232 Uranium-234, 235, 238	Actinium-227 Protactinium-231 Lead-210 Radium-226, 228 Thorium -230, 232 Uranium-234, 238	None	See Footnote 7	See Footnote 7	NA
EU 2	SRCs	Radionuclides VOCs PAHs PCBs Pesticides	NA	Radionuclides	See Footnote 7	See Footnote 7	Radionuclides PAHs
	COCs	Benzo(a)anthracene Benzo(a)pyrene* Benzo(b)fluoranthene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene Boron	Benzo(a)anthracene Benzo(a)pyrene* Benzo(b)fluoranthene Benzo(k)fluoranthene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene Boron	None	See Footnote 7	See Footnote 7	None
	ROCs	Actinium-227 Cesium-137 Protactinium-231 Lead-210 Radium-226*, 228 Thorium-230, 232	Actinium-227 Protactinium-231 Lead-210 Radium-226, 228 Thorium-232	None	See Footnote 7	See Footnote 7	None

Table ES-1. Summary of SRCs of Significance, COCs, and ROCs for Exposure Units 1 through 17

Exposure Unit	SRCs/COCs/ROCs¹	Soil	Food²	Groundwater	Sediment	Surface Water⁵	Utilities³
EU 3	SRCs	Radionuclides VOCs PCBs Pesticides	NA	Manganese	NA	NA	None
	COCs	None	None	None	NA	NA	None
	ROCs	Actinium-227 Protactinium-231 Lead-210 Radium-226*	Actinium-227 Protactinium-231 Lead-210 Radium-226	None	NA	NA	None
EU 4	SRCs	Radionuclides Boron VOCs PAHs PCBs/ Pesticides	NA	Radionuclides Metals SVOCs VOCs	NA	See Footnote 7	Radionuclides VOCs PAHs PCBs Pesticides
	COCs	Arsenic Aroclor-1260* Benzo(a)pyrene	Arsenic Boron Aroclor-1254 Aroclor-1260* Benzo(a)pyrene Benzo(b)fluoranthene Indeno(1,2,3-cd)pyrene Tetrachloroethene	Arsenic Barium Boron Copper Lead ⁶ Manganese Nickel Vanadium Bis(2-ethylhexyl)phthalate cis-1,2-Dichloroethene Methylene Chloride Tetrachloroethene* Trichloroethene Vinyl Chloride	NA	See Footnote 7	None
	ROCs	Cesium-137 Lead-210 Radium-226*	Lead-210 Radium-226	Lead-210 Radium-226*, 228 Thorium-228 Uranium-234, 238	NA	See Footnote 7	None

Table ES-1. Summary of SRCs of Significance, COCs, and ROCs for Exposure Units 1 through 17

Exposure Unit	SRCs/COCs/ROCs¹	Soil	Food²	Groundwater	Sediment	Surface Water⁵	Utilities³
EU 5	SRCs	Radionuclides VOCs PCBs	NA	None	Radionuclides ⁷	See Footnote 7	None
	COCs	None	None	None	See Footnote 7	See Footnote 7	None
	ROCs	Actinium-227 Cesium-137 Protactinium-231 Lead-210 Radium-226*, 228 Thorium-232	Actinium-227 Protactinium-231 Lead-210 Radium-226, 228 Thorium-232	None	See Footnote 7	See Footnote 7	None
EU 6	SRCs	Radionuclides VOCs PCBs Pesticides	NA	None	See Footnote 7	See Footnote 7	NA
	COCs	None	None	None	See Footnote 7	See Footnote 7	NA
	ROCs	Actinium-227 Cesium-137 Protactinium-231 Lead-210 Radium-226* Thorium-230 Uranium-234, 235, 238	Actinium-227 Protactinium-231 Lead-210 Radium-226 Thorium-230 Uranium-234, 238	None	See Footnote 7	See Footnote 7	NA
EU 7	SRCs	Radionuclides VOCs	NA	Radionuclides	See Footnote 7	Radionuclides ⁷	NA
	COCs	None	None	None	See Footnote 7	See Footnote 7	NA
	ROCs	Actinium-227 Cesium-137 Protactinium-231 Lead-210 Radium-226* Thorium -230	Actinium-227 Protactinium-231 Lead-210 Radium-226 Thorium -230	None	See Footnote 7	See Footnote 7	NA

Table ES-1. Summary of SRCs of Significance, COCs, and ROCs for Exposure Units 1 through 17

Exposure Unit	SRCs/COCs/ROCs ¹	Soil	Food ²	Groundwater	Sediment	Surface Water ⁵	Utilities ³
EU 8	SRCs	Radionuclides Metals VOCs SVOCs PAHs PCBs Pesticides	NA	Radionuclides	See Footnote 7	See Footnote 7	Radionuclides VOCs PAHs
	COCs	Benzo(a)anthracene* Benzo(a)pyrene Benzo(b)fluoranthene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene Total Uranium* ⁴	Aroclor-1260 Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Carbazole Dibenz(a,h)anthracene Heptachlor Epoxide Indeno(1,2,3-cd)pyrene	NA	See Footnote 7	See Footnote 7	None
	ROCs	Actinium-227 Cesium-137 Protactinium-231 Lead-210 Radium-226* Thorium -230 Uranium 234, 235, 238	Actinium-227 Protactinium-231 Lead-210 Radium-226 Thorium -230 Uranium 234, 238	NA	See Footnote 7	See Footnote 7	None
EU 9	SRCs	Radionuclides	NA	NA	See Footnote 7	Radionuclides ⁷	NA
	COCs	None	None	NA	See Footnote 7	See Footnote 7	NA
	ROCs	Lead-210 Radium-226*, 228 Thorium -230, 232	Lead-210 Radium-226 Thorium -232	NA	See Footnote 7	See Footnote 7	NA

Table ES-1. Summary of SRCs of Significance, COCs, and ROCs for Exposure Units 1 through 17

Exposure Unit	SRCs/COCs/ROCs¹	Soil	Food²	Groundwater	Sediment	Surface Water⁵	Utilities³
EU 10	SRCs	Radionuclides Metals VOCs PAHs Pesticides	NA	Radionuclides Metals SVOCs	See Footnote 7	See Footnote 7	Radionuclides
	COCs	None	None	None	See Footnote 7	See Footnote 7	None
	ROCs	None	None	None	See Footnote 7	See Footnote 7	None
EU 11	SRCs	Radionuclides SVOCs PAHs	NA	Radionuclides Metals	See Footnote 7	See Footnote 7	Radionuclides
	COCs	Total Uranium ^{*,4}	Benzo(a)pyrene* Benzo(b)fluoranthene Indeno(1,2,3-cd)pyrene	None	See Footnote 7	See Footnote 7	None
	ROCs	Actinium-227 Protactinium-231 Lead-210 Radium-226*, 228 Thorium-230, 232 Uranium-234, 235, 238	Actinium-227 Protactinium-231 Lead-210 Radium-226 Thorium-230, 232 Uranium-234, 235, 238	None	See Footnote 7	See Footnote 7	None

Table ES-1. Summary of SRCs of Significance, COCs, and ROCs for Exposure Units 1 through 17

Exposure Unit	SRCs/COCs/ROCs¹	Soil	Food²	Groundwater	Sediment	Surface Water⁵	Utilities³
EU 12	SRCs	Radionuclides Metals VOCs PAHs	NA	Radionuclides Metals	See Footnote 7	See Footnote 7	None
	COCs	Arsenic* Benzo(a)pyrene	Arsenic Benzo(a)pyrene Benzo(b)fluoranthene Indeno(1,2,3-cd)pyrene	None	See Footnote 7	See Footnote 7	None
	ROCs	Actinium-227 Cesium-137 Protactinium-231 Lead-210 Radium-226*, 228 Thorium-230, 232 Uranium-238	Actinium-227 Protactinium-231 Lead-210 Radium-226 Thorium-230, 232 Uranium-238	None	See Footnote 7	See Footnote 7	None

Table ES-1. Summary of SRCs of Significance, COCs, and ROCs for Exposure Units 1 through 17

Exposure Unit	SRCs/COCs/ROCs¹	Soil	Food²	Groundwater	Sediment	Surface Water⁵	Utilities³
EU 13	SRCs	Radionuclides Metals VOCs	NA	Radionuclides Metals SVOCs VOCs	See Footnote 7	See Footnote 7	Radionuclides Metals VOCs SVOCs Pesticides PCBs PAHs
	COCs	None	Aroclor-1254 Boron Copper Zinc	Arsenic* Boron Copper Manganese Lead Vanadium Bis(2-ethylhexyl)phthalate Cis-1,2-dichloroethene Trichloroethene	See Footnote 7	See Footnote 7	None
	ROCs	Actinium-227 Protactinium-231 Lead-210 Radium-226* Thorium-230 Uranium-238	Actinium-227 Protactinium-231 Lead-210 Radium-226 Thorium-230	Cesium-137 Lead-210 Radium-226 Uranium-234, 238	See Footnote 7	See Footnote 7	None

Table ES-1. Summary of SRCs of Significance, COCs, and ROCs for Exposure Units 1 through 17

Exposure Unit	SRCs/COCs/ROCs¹	Soil	Food²	Groundwater	Sediment	Surface Water⁵	Utilities³
EU 14	SRCs	Radionuclides Metals VOCs	NA	Radionuclides	See Footnote 7	See Footnote 7	None
	COCs	None	Di-n-octylphthalate Boron*	None	See Footnote 7	See Footnote 7	None
	ROCs	Actinium-227 Cesium-137 Protactinium-231 Lead-210 Radium-226*	Actinium-227 Protactinium-231 Lead-210 Radium-226	None	See Footnote 7	See Footnote 7	None
EU 15	SRCs	NA	NA	NA	See Footnote 7	Radionuclides ⁷ Metals VOCs	NA
	COCs	NA	NA	NA	See Footnote 7	See Footnote 7	NA
	ROCs	NA	NA	NA	See Footnote 7	See Footnote 7	NA
EU 16	SRCs	NA	NA	NA	NA	NA	<u>Sediment/Water</u> Radionuclides Metals VOCs PAHs <u>Sediment Only</u> PCBs Pesticides.
	COCs	NA	NA	NA	NA	NA	See Footnote 3.
	ROCs	NA	NA	NA	NA	NA	See Footnote 3.

Table ES-1. Summary of SRCs of Significance, COCs, and ROCs for Exposure Units 1 through 17

Exposure Unit	SRCs/COCs/ROCs ¹	Soil	Food ²	Groundwater	Sediment	Surface Water ⁵	Utilities ³
EU 17 Groundwater	SRCs	NA	NA	Radionuclides Metals SVOCs VOCs	NA	NA	NA
	COCs	NA	None	Arsenic Boron Manganese Vanadium Bis(2-ethylhexyl)phthalate Tetrachloroethene* Methylene Chloride	NA	NA	NA
	ROCs	NA	None	Lead-210 Radium-226*, 228 Uranium-234, 238	NA	NA	NA

NA – Not applicable

* - Constituent has been identified as a risk driver in the BRA. Total uranium identified as a risk driver applies to the child subsistence farmer only (see EUs 8 and 11).

1. The COCs and ROCs identified in the BRA represent the RME cancer risk for the conservative adult/child subsistence farmer scenario. The carcinogenic COCs are constituents that exceed the 10^{-5} risk level. For ROCs, if total cancer risk exceeds 10^{-4} , only the ROCs exceeding 10^{-5} risk levels are identified. ROCs included on this table are in secular equilibrium with other isotopes that may not exceed a risk level of 10^{-5} . For example, uranium-234, -235, and -238 are always present with one another, but there are occurrences where only one or two of these isotopes are identified as a ROC in any given EU medium. Similarly, thorium-228 will be present whenever radium-228 is present; however, thorium-228 may not exceed risk levels even when radium-228 has been identified as a ROC.

2. Food represents a risk pathway only and corresponds to a plant root depth of 0-0.5 feet in soil. No SRCs of significance were identified for the food pathway.

3. No COCs or ROCs were identified for individual physical EUs (1 through 14) or for EU 16 (pipelines and subsurface utilities) because the BRA assumes that the subsistence farmer will not be exposed to the subsurface utilities. However, the high concentrations of constituents found in both the sediment and water in these utilities could remain a potential source for soil and groundwater contamination due to cracks in the utility lines. Therefore, the presence of SRCs identified in sediment and water in subsurface utilities should be further addressed in the FS.

4. Total uranium is listed as a COC based on its chemical toxicity; however, for presentation purposes in this RI, total uranium is included as a radionuclide in the Section 4 figures and in the nature and extent discussions in Sections 5 and 7.

5. Surface water SRCs for interconnected Drainageways (Central Ditch, South 16 Ditch, South 31 Ditch, and Modern Ditch) are evaluated in EU 15, not in the individual physical EUs.

6. Lead was retained as a COC because the EPC exceeds the drinking water action level.

7. No human health COCs or ROCs were identified for sediment or surface water in any of the 14 physical EUs or in the interconnected Drainageways (EU 15) due to the short duration of exposure for individuals who may come in contact with surface water or sediment at NFSS.

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1.0 PROJECT INTRODUCTION

1.1 INTRODUCTION

The Niagara Falls Storage Site (NFSS), which is owned by the United States (U.S.) Government, is located at 1397 Pletcher Road, in the township of Lewiston, Niagara County, New York. The 191-acre parcel is part of the former Lake Ontario Ordinance Works (LOOW) that was used by the War Department beginning in 1942 for the production of trinitrotoluene (TNT). In 1944, the Manhattan Engineer District (MED) began using the site for storage of radioactive residues that resulted from the processing of uranium ores during the development of the atomic bomb. The site, consisting of open grassy areas and forested areas, is fenced and access is limited. Several man-made ditches, installed during the construction of the LOOW, drain the site. The site and vicinity are shown on Figures 1-1 and 1-2.

1.2 AUTHORITY, PURPOSE, AND CONTRIBUTORS TO THE REMEDIAL INVESTIGATION

Environmental investigation and remediation activities at the site are managed by the U.S. Army Corps of Engineers (USACE), Buffalo District, under the Formerly Utilized Sites Remedial Action Program (FUSRAP). The site previously passed through the governmental reorganizations of the MED to the Atomic Energy Commission (AEC), the Energy Research and Development Administration (ERDA) and the U.S. Department of Energy (DOE). In October 1997, the Energy and Water Development Appropriations Act for Fiscal Year 1998, PL 105-62, was signed into law, transferring responsibility for the administration and execution of FUSRAP from DOE to the USACE. The Energy and Water Development Appropriations Act for Fiscal Year 2000, Public Law 106-60, requires that USACE comply with the Comprehensive Environmental Response, Compensation, and Liability Act, 42 United States Code 9601 et seq., as amended (CERCLA), in conducting FUSRAP cleanup work. Therefore, USACE is conducting FUSRAP cleanups in accordance with CERCLA.

USACE conducted this Remedial Investigation (RI) to define the identity, amount, and location of chemicals of concern (COC) and radionuclides of concern (ROC) at the NFSS. COCs and ROCs are parameters that have been identified as posing risk to human health and the environment. The overall strategy for the site is to clean up radiological and chemical contamination to meet the requirements of the CERCLA, within the scope required by FUSRAP. The RI, and its associated documents, will provide primary data for the Feasibility Study (FS), which will be used to identify and evaluate various remedial action alternatives and assist in the development of a protective and cost-effective remedy for the site.

The long-term objective of this project is to clean up contamination resulting from work related to the Nation's early atomic energy program administered under MED/AEC in a manner that satisfies the requirements of the CERCLA. While chemical contamination is normally addressed only when collocated with radioactive contamination under FUSRAP, USACE will remediate both radioactive and chemical contamination because NFSS is a federally-owned property. The FS for NFSS shall also include the Niagara-Mohawk utility right-of-way, located to the west of the NFSS property.

RI planning and field activities were conducted by Maxim Technologies, Inc. (Maxim) under contract with the USACE. During the course of the RI, Maxim was acquired by Tetra Tech. Thus, this report contains references to both Maxim and Tetra Tech. Science Applications International Corporation, Inc. (SAIC) conducted radiological health physics activities during the RI. Maxim

and SAIC then shared responsibilities for completion of the RI report. In addition, this RI report is accompanied by the Baseline Risk Assessment (BRA) report (SAIC 2007), the Chemical Data Quality Assurance Report (USACE, 2006), and the Groundwater Flow and Contaminant Transport Modeling Report (HydroGeoLogic Inc. [HGL] 2007).

1.3 RI OBJECTIVES AND SCOPE

Through a series of scopes of work (SOW) which governed the RI tasks and the Technical Project Planning (TPP) process which guided the program, the following items were identified as project objectives:

- Conduct a historical records search;
- Describe site physical features and characteristics and determine the manner in which they may impact or govern the fate and transport of COCs and ROCs;
- Define the nature and extent of chemical and radiological site-related constituents (SRC) at the NFSS;
- Evaluate field and analytical data to verify or disprove USACE surveillance data that indicates there has been no release of chemical or radionuclide SRCs from the Interim Waste Containment Structure (IWCS) or other sources at the NFSS to groundwater or other media;
- Evaluate groundwater data and the construction details of the IWCS to determine the potential for groundwater to infiltrate into or out of the IWCS;
- Determine the presence or absence of radionuclide SRCs at the neighboring Niagara-Mohawk property;
- Conduct a gamma walk-over survey to evaluate surficial gamma-emitting radionuclides and a geophysical investigation using non-intrusive methods to evaluate subsurface features that could allow contaminant migration;
- Conduct a baseline human health risk assessment and a screening-level ecological risk assessment (SERA) to estimate potential human health, ecological, and environmental impacts of chemical and radiological constituents at NFSS;
- In support of the SERA, characterize the ecological setting of the NFSS through an ecological reconnaissance; and
- Predict the migration of SRCs of concern through solute transport modeling.

1.4 REPORT ORGANIZATION

The RI for the NFSS was conducted using a phased approach in order to refine the understanding of the nature and extent of contamination at the NFSS and the subsequent relationship to exposures, risks, and remedial alternatives. This RI report collectively presents the results of the three investigation phases and includes information from other studies conducted concurrently with the RI. The RI report is organized as follows:

- Section 1, Project Introduction, includes an overview of the RI project including a brief site description, responsible parties, project objectives, project organization, surrounding land use, operational history, and previous investigations and remedial activities.
- Section 2, Project Description, discusses the RI approach and provides site background information from record reviews including topography, physiography, surface water features, geology, hydrogeology, groundwater usage, and meteorology. The achievement of data quality objectives (DQO) are also addressed in this section.
- Section 3, Remedial Investigation Activities, includes a summary of the phases of investigation; site surveys (topographic, inspection and reconnaissance, gamma radiation, and landfill); characterization of surface soil, subsurface soil, surface water, sediment, groundwater, pipelines, railroad ballasts, and road/pad cores; and well and exploratory trench installation.
- Section 4, Results of Field Activities and Determination of SRCs, provides summaries of background sample analytical results and SRCs for soil, surface water, sediment, and groundwater.
- Section 5, Nature and Extent of SRCs, summarizes the operational history of each exposure unit (EU- a geographic area in which a receptor is assumed to work or live, and where a receptor may be exposed to SRCs detected during the RI); describes the occurrence of SRCs in soil, surface water, sediment, and groundwater within each EU; and provides observations of media interactions as well as sources and effects of past site use.
- Section 6, Fate and Transport, discusses the fate and transport of SRCs from a multi-media perspective. Contaminant transport routes, media interactions, and groundwater modeling results are discussed.
- Section 7, Conclusions and Recommendations, summarizes the overall impact of contaminants within each EU at the NFSS and provides recommendations as to which constituents within each EU should be addressed in the FS.

1.5 SITE HISTORY

During World War II (WWII), the USACE built several facilities across the U.S. to manufacture munitions for the military effort. To this end, the USACE acquired 7,500 acres of agricultural land in northwestern New York State which became the LOOW site, where a plant was constructed to produce TNT (Miscellaneous Property Information circa 1942-1981). Beginning in 1942, six TNT production lines, several storage facilities for raw materials and finished products, and several miscellaneous shops and support facilities were built on the 2,500-acre operations area located in the east-central portion of the LOOW. The LOOW produced TNT for only about eight months before the government determined that there was excess TNT production capacity in the U.S. TNT production ceased at the LOOW at the end of July 1943. During the eight months of operation, the LOOW produced approximately 41,656,000 pounds of TNT (NY State Assembly 1979).

In February 1944, the USACE's MED was granted use of a portion of the LOOW for the storage of radioactive residues generated through the processing of uranium ore (BNI 1990). With this

action, the NFSS was created. Figures 1-3 and 1-4 are aerial photos from 1944 showing the main features of the NFSS at that time. The first residues to be shipped to the site, designated as “L-50” and “R-10” (see Section 1.5.2 for residue descriptions), were from the Linde Air Products facility in Tonawanda, New York. The L-50 residue was transported to the site in bulk and was stored in buildings near the southwest corner of the NFSS. The R-10 residue was placed on the site in a pile on open ground north of the water treatment plant (Aerospace Corporation 1982). The MED and its successor agencies continued to periodically ship radioactive residues and materials to the NFSS for storage through the early 1950’s. The USACE MED transferred control of the radioactive residues at the NFSS to the AEC in 1946.

A 1970 investigation by AEC resulted in a 1972 action to remove impacted soil from the current NFSS site and adjacent properties. In 1975, the AEC was dissolved and the responsibility of the site was transferred to the ERDA. The ERDA was abolished in 1977 and the responsibility for the site was then transferred to the DOE. In 1979, the Battelle Columbus Laboratory performed a radiological characterization of the NFSS (Battelle 1980). The following year, in 1980, a geological investigation of the site was conducted. Beginning in 1981, a yearly monitoring program was initiated to assess the radon emissions from the NFSS and the potential for transport of the radiological contaminants to the surface water, sediment, and groundwater. Radioactively contaminated soil from a vicinity property was excavated and placed on the R-10 pile in 1981. Other remedial actions were performed through the 1980’s, culminating with the construction of the IWCS from 1982 to 1986.

The IWCS is the dominant site feature, occupying approximately 10 acres in the southwest portion of the site, and was built over the locations of the former water treatment plant and the R-10 pile. During the 1980’s, the DOE consolidated the radioactive wastes and contaminated materials at the NFSS into the IWCS, which was engineered to retard radon emissions, infiltration from precipitation, and migration of contamination to groundwater.

The base of the IWCS consists of naturally occurring clay. A clay dike, which is keyed 1.5 to 2 feet into the underlying gray clay, surrounds the stored radioactive materials. The IWCS is covered with an interim clay cap consisting of three layers. The bottom layer includes three feet of compacted clay keyed into the dike followed by a one foot layer of fill. The upper layer is a 6-inch topsoil vegetative cover. The residues containing low levels of radioisotopes (K-65, L-30, and F-32) were placed into the IWCS in the reinforced concrete basement of Building 411, which was designed to securely hold liquids as it was part of the original freshwater treatment plant. Before placing the materials in the basement of Building 411, drains, pipes, and openings in the basement were sealed (BNI 1990).

The cap is considered ‘interim’ because it does not include a barrier layer (typically a riprap layer at least three feet thick) and the side slopes of the structure, currently 3:1, were not constructed with a slope of 5:1. Also, the side slopes do not have a riprap covering, which is required for a long-term cap (BNI 1994a). In September 1986, DOE issued a Record of Decision (ROD) for remedial actions at NFSS that provided for the construction of a long-term cap over the IWCS; however, regulatory agencies expressed concerns over the DOE plan for long-term management of the residues so construction of the final cap did not occur.

In 1988, isolated areas of residual radioactivity from across the NFSS site were excavated and placed into temporary storage on the slab of former Building 430 and in 1990, a limited chemical characterization was performed at the NFSS. The materials placed in temporary storage were incorporated into the IWCS in 1991 (BNI 1994a). With the exception of annual monitoring and maintenance, no other activities took place at the NFSS until 1997, when the DOE transferred

control of the site back to the USACE. The USACE at that time instituted its own operations and maintenance plan for the site, which included continuation of the environmental surveillance program, for which data is collected and reported on an annual basis. From 1997 to 1999, USACE transitioned tasks from Bechtel and prepared a report to Congress that provided major scoping and costing of the program at the NFSS. In February of 1999, USACE issued the first SOW directing the performance of this RI, and from 1999 to 2000, characterization and removal of a portion of DOE legacy waste was completed. Building 403, originally a laboratory and office building, was decontaminated and demolished in 2000. Differences in documentation of position and amount of radiological contamination in Building 401, a building used for boron-10 manufacturing and radiological waste storage, was resolved and in 2003 the building underwent asbestos abatement in preparation for radiological decontamination and demolition. While demolition and disposal of Building 401 is not planned until post-2009, the asbestos was friable enough that its removal in 2003 was advisable. Additional work performed by the USACE includes continued maintenance of the IWCS and installation of fencing around the IWCS, an automatic front gate at the NFSS perimeter, and new power poles with upgraded electrical service.

The IWCS currently contains approximately 240,000 yd³ (183,000 m³) of residues, wastes, and debris. Material stored within the IWCS contains approximately 2,278 Ci of radium-226 and thorium-230. This material also contains several uranium isotopes and other radionuclides. Figure 1-5 shows the plan view of the IWCS and residue storage locations and Figure 1-6 shows a cross section of the IWCS.

Previous investigations and remedial activities at the NFSS are discussed in more detail in Section 1.5.3.

1.5.1 Historic Operational Areas

Former production facilities located on the portion of the LOOW that later became the NFSS (shown on Figure 1-2) included the following locations.

Acid Area

This area is located in the north central portion of the site, north of O Street and east of Campbell Street. Remnants of several above ground tank cradles are still evident. A separate area called the “T.N.T Mix Storage” was contained within the acid area (Reconstruction Finance Corporation circa 1945). Nitric acid is known to have been stored in this area, as was fuel oil. Anhydrous ammonia may also have been stored in this area (Industrial Research Corporation 1948).

Shops Area

The shops area is located south of O Street, between Campbell Street and Castle Garden Road, north of Building 401. Several building slabs and foundations are still present. During the operation of the LOOW, a supervisor’s office, several change houses, undefined storage buildings, a paint storage building, a garage and repair shop, a ‘combined’ shop, and a Millwright shop were also located in the area. An acetylene storage building, a fuel oil storage tank and a gasoline station building may also have been located in the area (Industrial Research Corporation 1948).

Baker-Smith Area

During the operation of the LOOW, administration buildings were located in the Baker-Smith area (Industrial Research Corporation 1948). Several foundations are still evident in the area.

Power Area

Building 401, located in the center of the NFSS, was the original steam plant for the LOOW. This building was modified and used for production of the nonradioactive isotope Boron-10 during 1953-1959 and 1965-1971. Boron-10 is a strong neutron absorber frequently used in control rods and boric acid to control the rate of nuclear fission in nuclear reactors. The raw materials used in the Boron-10 enrichment process were reported to be methanol, boron trifluoride, potassium fluoride, ethanol, potassium chloride and nitrogen. Mercury was not used as part of this Boron-10 production process (BNI 1994a). After 1971, the facility was gutted and the instrumentation and hardware were disposed of as surplus materials (Battelle 1981a). Building 401 still exists on the site, though it is currently slated for demolition. Building 403 (the Main Fire Headquarters), which formerly housed fire protection services, was also located in this area (Industrial Research Corporation 1948) but was demolished in 2000.

Freshwater Treatment Plant

The Freshwater Treatment Plant, included circular clarifiers and several water storage reservoirs, and was located approximately 800 feet west of Building 401, in the southern portion of the NFSS (Industrial Research Corporation 1948). Water from the Niagara River was pumped to the treatment plant. Water from this facility was used for fire protection, steam generation, process water for TNT production and process cooling. Three separate treatment trains were used at the plant. Fire protection water was subjected to primary settling prior to storage in the Fire Protection Storage Reservoir, located immediately south of the treatment plant. Process and cooling water was softened. Cooling water was routed through the recarbonation pit and stored in the 4,000,000-gallon reservoir north of the treatment plant. Water to be used in the boilers was further treated using Zeolite filters and then sent to Building 401.

Starting in 1944, the Freshwater Treatment Plant was used to store radioactive wastes and residues. The Freshwater Treatment Plant was shut down in 1944, prior to the start of storage of radioactive wastes and residues at the site. In the 1980's, the IWCS was built over these facilities (EA Engineering, Science, Technology [EA] 1999, BNI 1994a).

Subsurface Pipelines and Utilities

Subsurface pipelines and utilities were installed at the NFSS in association with many of the historical areas at the site, particularly the TNT production facility constructed by the War Department in the early 1940's. Pipelines and utilities were most likely associated with the boiler plant, freshwater treatment plant, acid concentration area, shops area, and the administrative buildings. Many of these pipelines and utility lines are still present at the NFSS, although those at the northern and southern site boundary have been sealed.

1.5.2 Storage of Radioactive Wastes and Residues

In 1944, the USACE-MED was granted use of Building 411, a large (200 feet long by 180 feet wide, 19 feet deep) fresh water storage reservoir that was part of the former LOOW freshwater treatment plant, located on the north side of Building 410 as shown in Figure 1-4. The USACE-MED request stated that the reservoir was to be used for storage of "semi-solid material" and that the material must be contained in a watertight structure for "security and health" reasons. In addition, the USACE-MED was granted use of 25 acres known as the Baker-Smith area in the northwest portion of what became the NFSS. This property was used for the storage of low-grade radioactive residues from the Linde Air Products facility in Tonawanda, New York. In December 1946, the responsibility for government activities related to the use and storage of radiological materials stored within the former LOOW was placed under the jurisdiction of the AEC. Due in part to the radioactive contamination at the site, AEC requested and was granted

ownership of 1,511 acres of the TNT production area within the original 7,500 acre LOOW site. All but approximately 212 acres of the 1511-acre site were determined to be in excess of needs beginning in 1955. Disposal of the excess acreage was effected at various times by the General Services Administration. In 1974, an additional area of approximately 22 acres, including the original sewage treatment plant facilities, was transferred to the Town of Lewiston. The NFSS consists of the remaining 191 acres (National Lead Company 1979, EA 1999). The one-acre discrepancy in the reported areas ($212 - 22 = 190$) is attributable to rounding errors in the reference documents. The current configuration of the NFSS, along with land use of nearby properties, is shown in Figure 1-7.

From 1949 through the early 1950's, several different types of radiologically contaminated wastes and residues were shipped to the NFSS. For security purposes, the residues were assigned a code name based on the place of origin, uranium content (U_3O_8) and extraction process. For example, the K-65 residues originated from Q-11 high-grade (35 – 60% uranium) pitchblende ores purchased under Contract TAB No. 2 (Rev.) originally obtained from the Katanga Province of the Congo (Aerospace Corporation 1982). The volumes of contaminated soil, rubble, and residues at the NFSS, shown in Table 1-1 and discussed in the following paragraphs, resulted from extensive document review. However, it is important to note that volumes given in other documents varied and that the volumes given here are estimates based on this review and site knowledge. Table 1-2 is an operational time line for the NFSS. The storage locations for wastes, after the remedial actions of the 1980's, are shown on Figure 1-5. The Ci inventories presented in the following descriptions are only for the isotopes measured and do not include contributions from decay products.

K-65

The K-65 residues currently located in the IWCS originated from the processing of Belgian Congo 'pitchblende' ores of very high uranium concentration (35-60% U_3O_8). The digestion of these high-grade uranium ores provided the feed material (uranium) required for the WWII Manhattan Project. After most of the uranium had been removed, the waste stream contained uranium progeny (thorium and radium) and was dubbed K-65

Prior to 1949, residues of these processes were returned to Africa. The material was considered a "resource" due to the radium and other metals in the residue. African Metals, Inc., the owner of the subject ore, ceased accepting the residues and it became necessary to locate storage sites in the U.S. Beginning in 1949, the NFSS was selected as a storage site based on its location near appropriate transportation routes, its situation in an area of low population density, and the availability of concrete structures for storage. Approximately 3,200 yd³ of K-65 residues (BNI 1986a) were transported to the site in drums. Some of these were stored outdoors along existing roads and rail lines. Others were stored in Building 410. From 1950 to 1952, the K-65 residues were transferred to Building 434 (a renovated concrete water tower) in the northeast corner of the NFSS (BNI 1986b). The K-65 residues account for only about two percent, by volume, of the wastes and residues stored at the NFSS; however, they contain 2,076 Ci of radium-226 and thorium-230 of the total of 2,278 Ci of those isotopes present in all the wastes and residues. This represents approximately 91% of radium-226 and thorium-230 activity, with these two constituents being the primary contributors of the radioactivity present at the site (DOE 1996). The volume of K-65 residues cited here (3,200 yd³) differs from the volume reported in the 1986 Environmental Impact Statement (EIS) (DOE 1986), but is based on internal Bechtel correspondence issued after the EIS was prepared (see Appendix A).

R-10

The R-10 residues resulted from the processing of ore containing approximately 3.5% U_3O_8 at the Linde Ceramics Plant, in Tonawanda, New York (Battelle 1981a). Approximately 9,400 yd³ of these residues and an iron cake associated with the same extraction process were shipped to the site sometime between 1944 and 1949 and were stored in a pile on open ground north of Building 411. This location is referred to as the “R-10 pile” (EA 1999, BNI 1986b). In 1964, the R-10 pile was covered with soil and seeded (BNI 1994a).

Later, soil resulting from off-site cleanups was added to the R-10 pile. It was estimated that prior to the incorporation of the R-10 materials into the IWCS, the R-10 pile contained approximately 59,500 yd³ of contaminated soils and residues. These soils and residues were estimated to contain five Ci of radium-226 and five Ci of thorium-230 (DOE 1996).

L-30

The L-30 residue resulted from the extraction of African pitchblende ore containing approximately ten percent U_3O_8 . The ore was extracted at the Linde Ceramics Plant in Tonawanda, New York, from December 1943 to October 1944 (Battelle 1981a). The L-30 residues were transported to the NFSS in 1944 and were stored in the east and west bays of Building 411 (Battelle 1981a, EA 1999). Approximately 7,960 yd³ of L-30 residues, containing an estimated 87 Ci of radium-226 and 87 Ci of thorium-230, were stored in Building 411. In addition to these radiological constituents, the L-30 residues also contained 10,000 mg/kg or more of lead, barium, iron, cobalt and nickel (Battelle 1981a).

F-32

This residue resulted from the Linde Ceramics’ extraction of Q-20 pitchblende ore from the Belgian Congo. Approximately 440 yd³ of material was stored in the recarbonation pit west of Building 411 (Battelle 1981a). This residue contained approximately 0.2 Ci of radium-226 and 0.2 Ci of thorium-230 (DOE 1996).

L-50

The L-50 residues resulted from uranium extraction of African pitchblende ores, containing approximately seven percent U_3O_8 , at the Linde Ceramics Plant in Tonawanda, New York (Battelle 1981a). Approximately 2,150 yd³ of these residues were transported to the NFSS starting in 1944 and stored in clarifier tanks at the water treatment plant (Buildings 413 and 414) (EA 1999, BNI 1994a). This residue contained approximately 6 Ci of radium-226 and 6 Ci of thorium-230 (DOE 1996).

Middlesex Sands

Inventory records show approximately 230 yd³ of sands resulting from sand blasting activities at the Middlesex Sampling Plant, located in New Jersey, were transported to the NFSS sometime prior to 1953 and were stored in a bin in Building 410. The sands were eroded from the bin by precipitation entering through holes in the roof and were spread through a significant portion of the lower floor of Building 410. The original concentration of uranium was reported to be three percent. Measurements made in 1979 showed that the sands contained less than 100 mg/kg of uranium and less than 0.01 µg/kg of radium-226 (Battelle 1981a).

Contaminated Rubble

In the late 1940’s, contaminated metal, concrete, lumber and reduction slag from other wartime plants were shipped to the NFSS and stored adjacent to Building 409. These materials were removed in the late 1950’s and transferred to the Y-12 Plant at Oak Ridge, Tennessee (National Lead Company 1979).

Other Wastes

In the period from 1952 to 1954, wastes generated at the Knolls Atomic Power Laboratory (KAPL) were shipped to the NFSS. Records indicate that the shipments consisted of approximately 700,000 pounds of contaminated wastes including 676 wooden boxes and 394 slurry drums. The contaminated materials included combustible and noncombustible solids stored in wooden crates and processing wastes stored in 55-gallon drums. The processing wastes contained some residual plutonium and fission product radioactivity (Ce-137, Sr-90) from a low-level processing plant at Schenectady. It is estimated that 408 Ci of mixed fission products and 0.63 Ci of plutonium were shipped to the site during this time period. The KAPL residues were originally stored near a railroad spur north of NFSS. Later, the wastes were moved to Buildings 443, 444, 445, 446, 447 and 448 in the Baker-Smith area. Some of the waste was also stored in Building 401. These materials were transferred to the Oak Ridge Burial grounds during the late 1950's and most of the storage buildings were later destroyed (EA 1998).

1.5.3 Previous Investigations and Remedial Activities

Several investigations and remedial actions have been performed at the NFSS and vicinity. These previous investigations and remedial activities are summarized in the following sections.

1.5.3.1 AEC Radiological Survey and Removal Action

In 1970, the AEC performed a radiological survey of the former LOOW site. Field screening was performed using hand-held survey meters and soil samples were collected at locations where radioactivity was detected at higher than "background" concentrations (defined to be 10 $\mu\text{R}/\text{Hr}$, measured with a sodium iodide (NaI) gamma detector at a height of one meter above the ground). These samples were analyzed for "radiological parameters". The available documentation does not specify the analytical parameters or sample locations. Based on this survey, offsite removal actions at vicinity properties (locations within the boundaries of the former LOOW but outside the boundaries of what is now the NFSS) began in 1972 to address radiologically impacted soil. Removal actions were performed in the Central Ditch, in Six Mile Creek, and several other parcels of the LOOW property. During these remedial actions, approximately 15,000 yd^3 of contaminated soils and sediments were removed and stored on the R-10 pile located north of the NFSS water treatment area (National Lead Company 1979).

1.5.3.2 DOE Investigations and Remedial Actions

Before 1979, no accurate records were maintained on waste characterization, inventories, or exact locations of stored wastes (BNI 1994a). To fill this data gap, Battelle Columbus Laboratory, under the direction of the DOE, performed a "radiological characterization" of the NFSS in 1979. This characterization was designed to 'provide the DOE with accurate information on which to base a cost-effective remedial action plan' (Battelle 1981a). Battelle reported "significant" radiological contamination in seven buildings and nine areas of the site. The locations of these buildings and areas are shown on Figure 1-8.

The report also contained the following statement about the subsurface piping at the NFSS:

"Manholes near the firehouse and in the southwest, northwest, and northeast quadrants showed no contamination in the interiors or on valves by smear or meter survey techniques. Sediment taken from these manholes showed no significant radionuclide contamination. "

In the 1980's the DOE and its contractor BNI performed remedial actions at the site and vicinity properties. NFSS vicinity properties are radioactively contaminated areas located adjacent to or near the NFSS that were once part of the former LOOW and were designated by the DOE as being radiologically impacted by past government activities. The cleanup criteria for DOE sites including the NFSS and the vicinity properties, as described in the DOE's Cleanup Criteria/Decision Document database (which is described at http://www.ead.anl.gov/project/images/pa/15_CleanupCriteriaDocDatabase.pdf), are as follows:

- Cesium-137: 33 pCi/g
- Radium-226: 5 pCi/g
- Uranium-natural: 90 pCi/g

It should be noted that only the Ra-226 criterion was used to guide cleanup decisions at the NFSS and vicinity properties prior to 1988, as the uranium and cesium-137 values were not developed until that time. Later remedial actions addressed the cleanup criteria for cesium-137 and natural uranium given above, which were developed in 1988 (Yu et al. 1988, Landis 1988). A chronology of the DOE remediation of the NFSS follows:

In 1981, 450 yd³ of radiologically impacted material were excavated from an adjacent offsite property located to the east of the NFSS. This material was brought to the NFSS and placed on the R-10 pile (BNI 1986b). This soil is included in the 59,500 yd³ of R-10 soils on Table 1-1. In order to 'protect the public from radon levels' the site perimeter fence was relocated approximately 500 feet to the west, creating an exclusion zone (BNI 1994a).

In 1982, two interim remedial actions were performed (Battelle 1981a; BNI 1990):

- The R-10 residue pile was stabilized as part of the initial construction of the IWCS. Stabilization included clearing and grubbing the surrounding area, moving approximately 15,700 yd³ of contaminated soil near the R-10 pile onto the cleared pile, and constructing a clay dike and cutoff wall around the R-10 pile. The clay cutoff wall was keyed into the underlying gray clay. The top of the pile was graded and covered with an ethylene propylene diene monomer (EPDM) liner which was removed during construction of the IWCS.
- Buildings 413 and 414 were sealed to reduce emissions of radon from L-50 residues stored in these buildings. Roof materials were removed and the troughs that encircled the inside of the buildings near the top of the residues were filled with concrete. The residues were covered with a multi-layered cap consisting of:
 - Sand,
 - Hypalon (a synthetic rubber),
 - Clay,
 - EPDM,
 - another clay layer,
 - another Hypalon layer, and
 - pea gravel.

In 1983, interim remedial actions included cleanup of 4,800 feet of the West Ditch and cleanup of 6,900 feet of the Central Ditch from where it entered the site to Balmer Road, generating 54,000 yd³ of contaminated soils and sediments. Also, 27,900 yd³ of contaminated soil were

excavated from vicinity properties and some onsite areas. These materials were stored north of Building 411 and later placed in the IWCS. Also in 1983, work was completed on the southward extension of the dike/cutoff wall, except for a portion of the west and south walls left open to allow for clean water drainage and access. The extended dike/cutoff wall was keyed into the underlying gray clay (BNI 1990).

In 1984, decontamination was completed on 11 vicinity properties and some on-site areas of localized contamination. These 11 vicinity properties were divided into discrete parcels and designated by letters as a means of tracking the identification and remediation of contamination. These vicinity properties included: A, L, M, N/N' North and N/N' South, Q, R, S, U, and V (DOE 1985). An additional 6,900 feet of the Central Ditch, from Balmer Road to 1,500 feet north of Lutts Road, was decontaminated. These cleanups generated approximately 29,385 yd³ of contaminated soil and rubble, which was placed in the IWCS (Berger 1990).

Also in 1984, the final section of the cutoff wall around the IWCS was completed. Building 410 and the upper portion of Building 415 were demolished, clearing the way for the final development and use of the southern portion of the IWCS. A three-foot thick clay layer was placed over the northern portion, about 40%, of the IWCS (BNI 1994a, BNI 1990).

Other major work in 1984 centered on the activities required to turn Building 411 into an interim storage area for the L-30, F-32, and K-65 residues. This work included residue transfer and dewatering activities within Building 411 and slurry transfer of the K-65 residues from Building 434 to Building 411. This work consisted of the following:

- The F-32 residues in Bay A, the F-32 residues in Bay B, and the L-30 residues in Bay C of Building 411 were transferred to Bay D.
- A 12-inch under-drain system consisting of slotted polyvinyl chloride (PVC) pipe covered with sand was installed in the bottom of Bays A, B, and C in Building 411. This under-drain system was put in by Bechtel to aid in dewatering of the residues. After the residues were dewatered the under-drain system remained in place and contaminated soils were placed above the residues.
- Workers began transferring the K-65 residues from Building 434 to Bay C of Building 411. Working first on top of Building 434, and later from scaffolding erected along the side, openings were cut into Building 434 to allow hydraulic mining equipment to be inserted. The residues were hydraulically mined and slurry-transferred to Building 411 through a four-inch above-ground steel pipeline. Through the end of 1984 and into early 1985, approximately 75% of the K-65 residues were transferred in this manner (BNI 1994a, BNI 1990).

In 1985, starting in May, the K-65 residues remaining in Building 434 (about 25%) were slurry transferred to Building 411. Figure 1-9 shows Building 411 during residue placement and construction activities taking place in 1985. The K-65 residues were hydraulically excavated from the building, mixed with water, and the resultant slurry was pumped through a pipe to the IWCS. Following the removal of the K-65 residue, Building 434 was demolished and the rubble was transferred to the IWCS (BNI 1990). Figures 1-10 and 1-11 show Building 434 before residue removal activities took place and after residue slurring was complete and the building was being demolished.

Water treatment ponds lined with impermeable membranes were constructed east of the IWCS along Campbell Street and in the area north of the IWCS. A water treatment system consisting of chemical treatment and sedimentation was installed east of the Central Ditch near the IWCS. The chemical treatment included pH adjustment to 2 using hydrochloric acid, followed by adding cationic polymer, coagulant, and calcium chloride. The pH was then adjusted to 11 using sodium hydroxide to precipitate the contaminants which were allowed to settle out. The treated water was tested and discharged in accordance with the New York State Pollution Discharge Elimination System permit. Both stormwater that had come in contact with waste materials in the IWCS and slurry water used to transport the K-65 residues were treated. Treating the slurry water allowed it to be re-circulated back through the K-65 transport system, thereby minimizing the amount of water required to move the K-65 residues from Building 434 to the IWCS. Water treatment proceeded slowly during the summer. The rate at which water could be treated limited the rate at which residues could be placed and dewatered in Building 411. In order to allow the placement and dewatering of residues to proceed without delay, Ponds 3 and 4 were constructed east of the IWCS. These ponds were designed to contain a total of 4.8 million gallons of water prior to treatment and release. After the water was treated and cleared for release, it was discharged to the Central Ditch. Ponds 1 and 2 immediately north of the IWCS were cleaned and restored to original grade (BNI 1990). A video tape made by the DOE provides limited details concerning the cleanup of Pond 3 in June and July of 1986. The pond was dewatered by pumping and bentonite was added to consolidate the sediment slurry. A track-mounted excavator then simultaneously removed the liner and accumulated solids. The materials were placed in dump trucks and placed in the IWCS. No specific information was found in the historical record concerning the cleanup of Ponds 1 and 2 in 1985.

After Building 434 was demolished, approximately 1,900 yd³ of soil, contaminated rubble and other materials were excavated and transported to the IWCS. Remedial actions were also performed on Buildings 409 and 401. The superstructure, basement walls and floor slab of Building 409 were decontaminated after treated water that had been stored in the building was pumped to a surface impoundment. Three beams in Building 401 were decontaminated and removed (BNI 1990).

Approximately 9,300 yd³ of contaminated materials were excavated from onsite and offsite areas and transferred to the IWCS (BNI 1986c).

In 1986, several off-site areas were decontaminated and contaminated materials resulting from these remedial actions were placed in the IWCS. Virtually all on-site contaminated areas were also cleaned up by the end of 1986; the contaminated materials were placed in the IWCS. Building 401 was used to store 32 drums of material removed from Vicinity Property G. These drums contained a mixture of polynuclear aromatics known to be contaminated with radium-226 (BNI 1990). Forty-five areas on the Vicinity Property G were remediated in 1986 (BNI 1989) and one drum was excavated from Vicinity Property G (Ahrends 1987). This drum was removed and "placed in the interim storage external to the encapsulation cell." Other drums were discovered on Vicinity Property G at this time but due to the unknown extent of the burial, the already committed cleanup budget and unknown nature of the contaminants, the drums were not excavated immediately.

During 1985 and 1986, ten other vicinity properties, several areas along Pletcher Road and three small off-site anomalies along the haul route between Tonawanda and the NFSS were the subject of remedial actions. Vicinity properties included in the remedial actions were: B, C', D, F, N/N' North, P, T, W, and parts of E and E' (Berger 1990).

The dike and cutoff wall forming the IWCS around Building 410 was completed. The K-65 and F-32 wastes were moved from their original onsite storage locations and placed in Building 411 in specific bays so that their storage location could be documented (BNI 1994a). Figure 1-5 shows the plan view of the IWCS and residue storage locations and Figure 1-6 shows a cross section view of the IWCS.

In August 1986, an exposed drum was excavated at Vicinity Property G. During further investigation of this area in 1987, additional drums were discovered including a drum labeled “K-65”. A total of 32 drums (including the one removed in 1986) containing a sludge-like material were excavated from this area. Radiological survey of these drums indicated that radiological residue was limited to the bottom of the drums and it was hypothesized that the drums were K-65 drums that had been reused following removal of the K-65 residues. Most of the drums were found without lids, some were ruptured and contents had been spilled. Forty-nine additional drums of soil contaminated with spilled “sludge” were removed. The 31 drums containing sludge were transported to the NFSS. Only 25 of the soil-filled drums were transported to the NFSS at this time. The remaining 24 soil-filled drums were left adjacent to the excavation awaiting analytical results (Ahrends 1987). Another historical record (BNI 1989) indicates that in 1987, 31 drums were removed from Vicinity Property G and placed in overpacks and that 90 drums of soil contaminated with material from the original drums were also removed and transported to the NFSS.

In 1988, offsite localized areas of elevated radioactivity, identified following the 1983 to 1986 offsite interim remedial actions, were excavated and removed (the locations of these hotspots were not identified in the available historical documents). The 3,200 yd³ of contaminated material thus generated were removed and placed on the foundation of the former Building 430. The material was encapsulated with an impermeable membrane (BNI 1990). No details of the type of membrane installed or how the encapsulation was constructed were reported. In 1991, this material was consolidated into the IWCS.

In 1990, BNI performed a limited chemical characterization of the site (BNI 1991). This characterization included soil, sediment, surface water, and groundwater sampling. The samples were analyzed for metals, volatile organic compounds (VOCs), and semi-volatile organic compounds (SVOCs). None of the samples were analyzed for radiological parameters. A soil gas survey was also performed. Because only summary tables of analytical results from this study are available, the data cannot be validated or evaluated and for this reason is not included in the RI analytical database. The data set was evaluated by the RI team and was used, to a limited extent, to plan sampling locations.

As part of the limited chemical characterization, Target Environmental Services, Inc. performed a soil gas survey (BNI 1991, Kapoor 1996a), which included 167 sampling locations over most of the NFSS exclusive of the IWCS area. All samples were collected at depths less than four feet below ground surface (bgs). The parameter list for the soil gas analysis was restricted to methylene chloride, trans-1,2-dichloroethene (DCE), cis-1,2-DCE, trichloroethene (TCE), tetrachloroethene (PCE), benzene, and toluene. The results of the soil gas survey are summarized below:

- TCE was detected in seven sampling locations surrounding Building 401 at concentrations ranging from 0.3 µg/L to 44.5 µg/L.

- Cis-1,2-DCE was detected in two sampling locations just north and south of Building 401 at concentrations of 2.52 µg/L and 9.0 µg/L respectively.
- PCE was detected at minimal concentrations (< 2.0 µg/L) in five sampling locations surrounding Building 401, in one location 200 feet north of O Street and another location 650 feet east of Campbell Street.
- Confirmatory soil samples were collected in one-foot increments to four feet bgs at the four locations that exhibited TCE or 1,2-DCE in the soil gas samples. TCE concentrations ranging from 7 to 440 µg/kg were found in all four sampling locations. One soil sample contained cis-1,2-DCE.
- Trans-1,2-DCE, methylene chloride, benzene, and toluene were not detected.

In 1991 and 1992, one localized onsite area approximately 100 m² was remediated. The location of this area was not definitively identified (BNI 1995), though the Preliminary Assessment for NFSS (BNI 1990) suggests that this area may have been located north of O Street. This material, the material generated in 1988-89, and 60 drums of radioactively contaminated materials (generated by remedial activities performed in 1987) were consolidated into the IWCS (BNI 1994a). The Failure Analysis Report, from which this information is excerpted, does not further identify the source of the material in the 60 drums. The source of these drums was not found in a review of the available historical documents.

In 1998, as part of the Defense Environmental Restoration Program – Formerly Used Defense Sites (DERP-FUDS), EA, on behalf of the USACE Baltimore District, conducted a Phase 1 RI of the entire former LOOW in 1998 (EA 1999).

For the LOOW RI, EA collected 121 soil, groundwater, surface water, and sediment samples from locations on the NFSS. Most of these samples were field screened for polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), TCE and nitroaromatics. No screening for radiological contamination was performed during this investigation. Thirty-two samples were submitted to a laboratory for metals, VOC, SVOC, PCB, and nitroaromatics analysis. The laboratory results for these 32 samples were incorporated into the NFSS analytical database

Figure 1-12 is a 2002 aerial photo of the site showing the current IWCS and Building 401.

2.0 PROJECT DESCRIPTION

This section discusses site history, previous investigations, and project objectives.

2.1 PROJECT APPROACH

This RI Report provides results of records review, visual site walkover inspections, radiation and topographic surveys, site investigations, sampling and analysis, data analysis and other activities performed to evaluate the nature and extent of radiological and chemical contamination at the NFSS. The RI began with a records review in order to gain an understanding of historic site operations and how these operations may have contributed to potential contamination. Following the records review, site reconnaissance was conducted to identify areas potentially impacted by site operations. Field activities then proceeded in a phased approach in order to refine the understanding of the nature and extent of contamination at the NFSS and their relationships to exposures, risks, and remedial alternatives.

Phase 1 fieldwork occurred from November 1999 until January 2000 and consisted of a wide investigation of the site, involving the collection of groundwater, surface water, sediment, and soil samples. These samples were analyzed for a broad range of radiological and chemical parameters. After the analytical results for this task were evaluated, a TPP meeting, attended by representatives from the USACE, SAIC, and Maxim, was convened and the Phase 1 data set was further assessed. This meeting resulted in general guidance for Phase 2 of the investigation, which focused on areas that appeared to be adversely impacted (both chemically and radiologically) by past activities at the site. The Phase 2 sampling period lasted from August 2000 until October 2000. Table 2-1 summarizes the samples used for evaluation during these two phases.

After the Phase 2 data set was evaluated, another TPP meeting was convened and several distinct data gaps and areas requiring further investigation were identified. Data generated by limited gamma walkover surveys of the site (see Appendix B), performed during the summer of 2000, were also included in this evaluation. It was determined that additional soil samples were needed to further characterize areas of elevated radioactivity found by the limited gamma walkover surveys. It was also determined that the various pipelines and sewers at the site could serve as sources of contamination and mechanisms of contaminant transport and warranted further investigation. Several other areas and media were also identified as meriting further investigation. These field efforts, along with the collection of radiological samples from the neighboring Niagara-Mohawk property, were performed in the summer and fall of 2001. Phase 3 included this and several other field efforts, shown on Table 2-1, occurring from May 2001 until October 2003.

During the summer of 2001, a sitewide gamma walkover survey was conducted to identify areas of surficial gamma-emitting radionuclides. In addition, a geophysical survey of the site was performed to locate buried debris, utilities, and geologic features, such as fractures/faults that could allow contaminant migration (SAIC 2003b). The results of this survey are presented in Appendix C. After the data set generated by the geophysical survey was evaluated, exploratory trenches were excavated to investigate the anomalies identified. Exploratory trenches were also excavated to further investigate elevated or suspected areas of radiological or chemical contamination and to identify potential underground storage tanks (UST), burial areas, and former pond areas. This field effort was performed during the summer of 2002.

A suitable background groundwater data set was necessary to fully evaluate the groundwater samples collected on the NFSS. A suitable data set, either in the public domain or in the site historical documentation, was not found. To fill that need, groundwater samples were collected in

March of 2003. Wells on the adjacent Modern Landfill site were selected for background groundwater sampling. All of the Modern Landfill wells that were designated as background wells are upgradient of the Modern Landfill disposal cell.

In late 2002, several additional soil samples required to support the BRA were identified. These samples were collected in the spring of 2003. As part of this field effort, background surface water and sediment samples were collected. Also as part of this effort, several abandoned drums on the NFSS, which had been discovered during previous field tasks, were sampled, placed in overpack drums and subsequently shipped off site for disposal.

In the summer of 2003, confirmatory samples were collected from several NFSS wells and manholes. Samples collected from these wells during previous sampling events had contained elevated concentrations of radionuclides and chemicals. Several wells near the IWCS that had not been previously sampled were also sampled at this time.

The final field effort for this RI was performed during the autumn of 2003. Soil and groundwater samples were collected to further delineate and characterize areas of suspect contamination found during earlier phases of the project. Also included in this final task was the collection of samples from the floor drains in Building 401, the collection of samples of the concrete floor slab in the building, and the collection of soil samples below the floor slab. Concurrent with this sampling effort were additional geophysical investigations of the IWCS. In September 2003, seismic refraction and electrical imaging/induced polarization investigative methods (SAIC 2004) were used to further support earlier seismic and resistivity surveys (SAIC 2003b) conducted on the IWCS.

Since the completion of Phase 3 activities of the RI in October 2003, project work has continued for review and presentation of the RI results. Continued RI activities include: quality review and electronic management of analytical data, preparation of figures and tables to visually summarize environmental sampling results, formulation of a computerized groundwater flow model, performance of human health risk calculations in development of the BRA, and multi-tiered reviews in preparation of final compilation of this RI report.

2.2 RECORDS REVIEW

The following sections describe the investigations and remedial actions performed at the NFSS as reported in available historical documents and records. This review was performed in accordance with Task 1 of the Statement of Work (USACE 1999).

2.2.1 Objective

Significant data exists on site history, geology, and the nature and quantities of radiological wastes stored at the NFSS. Historical and recent documents and records were reviewed and the results of that review are summarized in the subsequent sections.

2.2.2 Sources

Four hundred forty-four documents and records were reviewed during the performance of this task. Most of these documents were prepared by the DOE (or DOE contractors) and its predecessor agencies. Documents authored by the U.S. Environmental Protection Agency (EPA), USACE and other governmental entities were also reviewed. The documents reviewed are listed and summarized in Appendix D.

2.2.3 Significant Findings of Records Reviewed

The review of the historical record provided the information that is presented in Sections 1.5.3 and 2.3. Particularly germane documents are summarized in this section.

A Comprehensive Characterization and Hazard Assessment of the DOE-Niagara Falls Storage Site (Battelle 1981a)

This report provides a detailed characterization and hazard assessment of the NFSS prior to the construction of the IWCS and was prepared to provide the DOE with information to guide decisions concerning future remedial actions. Descriptions of the wastes and residues present at the site and a characterization of contaminated areas at the site are included in the report. Among the significant findings, it was reported that:

- The following ‘pitchblende-residue’ (a catch-all term for K-65, L-30, L-50, F-32, Middlesex sands, and R-10 wastes and residues) storage buildings were identified: Buildings 434 (a former water tower also known as the ‘Silo’), 411, 413, 414, and 410. Buildings 411, 413, and 414 were described as ‘highly contaminated’.
- Fifteen non-residue storage buildings were surface grid-surveyed for residual radioactivity. Buildings 403, 423, and 430 were described as ‘Contaminated’. The other twelve buildings surveyed were described as ‘Uncontaminated/Minimally Contaminated’.
- An extensive on-site environmental survey for radioactive contamination revealed that there were nine distinct contaminated areas on the site. The report concluded, “The R-10 residue storage and spoil pile area is the major contaminated area within the Site.”
- A total length of 19,650 feet of primary on-site and adjacent off-site drainage ditches were found to contain 28,600 yd³ of sediments in excess of the 5 pCi/g radium-226 action limit.

The contaminated areas identified in this report were subsequently remediated by the DOE. These remedial actions are described in Section 1.5.3.2. The value of this report to this project phase is in locating samples outside of the IWCS in areas that were previously identified as contaminated, to ensure that adequate remediation was completed.

Draft Chemical Characterization Report for the Niagara Falls Storage Site, Lewiston, New York, (BNI 1991)

In an effort to ready the NFSS for eventual land disposition, BNI performed a limited chemical characterization of the site for the DOE. The executive summary of the report states:

“The primary objective of the chemical characterization was to augment available information by identifying nonradioactive contaminants that are present on and potentially migrating from the site. Characterization activities included sampling and analysis of soil, sediment, surface water and groundwater and conducting a soil gas survey.”

The report concludes that:

Although results indicate that metals, volatile organics and base-neutral acids (BNA) are present in isolated areas, the average concentrations are low with metals only slightly above background levels. The levels at which these constituents are present are not indicative of onsite contamination with material managed under the Resource Conservation and Recovery Act (RCRA).

Preliminary Assessment for Niagara Falls Storage Site, Lewiston, New York (BNI 1990)

This document presents the findings of the preliminary assessment completed for the NFSS. Included as part of the assessment is a summary of all remedial actions performed at the site between 1972 and 1988. As a result of the preliminary assessment, the DOE concluded that the site was being addressed by the FUSRAP and “the vast majority of the hazards at the site have already been mitigated via extensive remedial actions conducted from 1981 through 1988”. From these conclusions, the DOE proposed to the EPA that “site inspection, hazard ranking scoring, and placement on the National Priorities List (NPL) are not necessary to protect human health and the environment surrounding NFSS.” The EPA response, which was appended to the document reviewed for this RI report, did not agree that the preliminary assessment supported the DOE recommendation. The EPA stated that “further evaluation of this site is warranted and therefore, a SI must be conducted.”

Failure Analysis Report (BNI 1994a)

The *Failure Analysis Report* was prepared to assess the impact that maximum credible natural phenomena could have on the proposed final waste containment structure and to determine whether an exposure pathway for the surrounding public would ensue. The following eight hypothetical failure scenarios were analyzed: erosions of the cap, earthquake, tornado, precipitation floods, floods from dam breaks, rising of Lake Ontario, glaciation, and intruder/exploratory drilling. The analysis overall showed that the proposed final waste containment structure would be protective for the 10,000 year period. However, some suggested modifications to the design are noted in the report and these modifications would enhance the margin of safety provided by the waste containment structure.

The proposed final waste containment structure design evaluated in this report consisted of the existing IWCS with additional materials augmenting the cap. The report addressed the following topics as part of the evaluation:

- Site history,
- An analysis of future land use and population trends in the vicinity of the site,
- A summary of the radiological and chemical composition of the residues and wastes stored in the IWCS, summarized in Table 1-1,
- A summary of the features of the NFSS that impact the life expectancy of the proposed final waste containment structure,
- A pathway analysis for contaminants of concern, and

- Eight scenarios (seven natural phenomena scenarios and one intruder scenario) and their impact on the proposed final waste containment structure.

This report contains a useful summary of the history of previous activities at the site and was used in part to prepare subsequent sections of this RI report. However, the report as a whole addresses several topics (such as the longevity of the IWCS and the potential impacts on the IWCS from several natural phenomena) which will be considered in the FS for the NFSS.

Chemical Data Gap Characterization at Niagara Falls Storage Site, Technical Memo (Kapoor 1996b)

As further confirmation of the results of the soil gas survey performed for the chemical characterization discussed above, Bechtel National Inc. (BNI) initiated a limited data gap characterization of the NFSS in 1995. The technical memorandum that presents the results of this characterization states:

“The purpose of this characterization activity was to: (1) define the presence and depth of organic and/or metal contamination in soil and groundwater in the vicinity of Building 401 and Building 407, (2) complete the sediment and surface water characterization downstream from Building 401 and former Building 407, (3) collect background soil samples, and (4) collect groundwater samples from background wells.”

The locations of roads and buildings at the NFSS are shown on Figures 1-1 and 1-2. The figures show both features that are present at the site and those features that were formerly present at the site which are relevant to this investigation.

Soil, surface water, sediment and groundwater samples were collected and analyzed for VOCs and metals (cadmium, copper, lead, magnesium, thallium, vanadium, and zinc).

The two background groundwater samples were collected from wells B02W20S and B02W20D, located on the NFSS, immediately south of O Street. The background soil samples were collected from the Lewiston Public School grounds. All soil samples were composited from zero to one foot below grade level.

The results of this characterization are described in Section 2.3.

History Search Report, Lake Ontario Ordinance Works, Niagara County New York (EA 1998)

The report contains a detailed operational history of the entire LOOW and the NFSS. It also includes a comprehensive description of past remedial actions at the NFSS. An operational time line for the NFSS, summarizing information from this report and from others, is presented in Table 1-2.

2.3 SITE DESCRIPTION

This section describes the physical site characteristics pertinent to the RI.

2.3.1 Site Physiography

With the exception of the IWCS, the site is generally level, with ground level elevations ranging from 315 feet above mean sea level (amsl) to 321 feet amsl.

2.3.2 Surface Water

Figure 2-1 shows surface water drainage to, through, and from the site. Surface water runs onto the site from the east from the Modern Landfill site along Castle Garden Road and along O Street and from the north and east from the adjacent CWM Chemical Services, LLC. site. In addition, surface water run-on to the NFSS occurs from the properties to the south of the site via ditches that are connected to the site by the Central and West Ditches, which flow through the site.

Several ditches on site collect surface water runoff. Over most of the site, surface water is conveyed through east-west ditches that empty into the Central Ditch. The Central Ditch flows north and joins Four Mile Creek about 1.5 miles north of the NFSS. Four Mile Creek, in turn, empties into Lake Ontario. Surface water runoff from the western periphery of the site and from the Baker-Smith area in the northwest corner of the site flows to the West Ditch. The West Ditch flows north and joins the Central Ditch approximately 0.5 miles north of the NFSS.

Drainage at the NFSS is poor because of the flat terrain and the relatively impermeable nature of surface soils. Much of the NFSS property has the potential to collect and hold standing water for lengthy periods, which is evident in several areas of the site (Figure 1-2).

2.3.3 Regional Geology and Geologic Units

A geologic column for the NFSS is shown in Figure 2-2. Six geologic units other than surficial soils and fill are present at the NFSS. These units, from shallowest to deepest, are:

- **Surficial Soils and Fill** - The surficial soil at the NFSS consists of a loose to medium dense, brown to yellowish silt with organic matter. Gravel and sands are generally encountered and are dispersed randomly throughout the unit. Thicknesses of surficial deposits vary from zero to five feet, with an average range of one to two feet (BNI 1994, Acres American, Inc. 1981a).
- **Brown Clay Unit** - The Brown Clay Unit, also known as the “Upper Clay Till” or the “Brown Clay Till”, is a brownish or reddish, poorly sorted, brown silty clay till deposit indicative of a ground moraine. The ground moraine occupies the low till plain in the area of the NFSS and extends west to east in a wide belt from Lockport to the Niagara River (USDA 1972). The till was deposited above sediments of glacio-lacustrine origin (Gray Clay Unit) described below. The thickness of the unit varies from 6 to 23 feet. The consistency of the upper clay till ranges from medium soft to hard with plasticity increasing with depth. Thin sand and silt seams, pockets and lenses are common in the basal portion of the unit.

The sand, gravel, and silt lenses in the basal portion of this unit average one to five feet in thickness and the lateral extent and thickness of these lenses vary abruptly. These intermittent sand lenses likely represent glaciofluvial deposits and are generally vertically and horizontally discontinuous. When saturated, these lenses, pockets and/or seams are most likely not hydraulically interconnected and do not represent a continuous water-bearing zone or aquifer. Geostatistical analyses indicate that the sand lenses cannot be correlated over distances greater than about 20 feet (HGL 2007). The sand and gravel in the lenses are usually moist to saturated and vary from loose to dense. Occasional extensive deposits of sand and gravel 17.5 to 20 feet in thickness occur within the Brown Clay Unit (BNI 1994b, Acres America 1981b).

Historical data and in-situ permeability testing conducted in 2001 and 2003 indicate that the horizontal permeability of the brown clay unit ranges from approximately 3×10^{-2} to 7×10^{-9} cm/sec. Typical values are between 1×10^{-5} to 1×10^{-7} cm/sec. Vertical permeability for this unit is reported as 7×10^{-7} cm/sec. (BNI 1994a).

- Gray Clay Unit - The Gray Clay Unit, also known as the “Glacio-Lacustrine Clay Unit”, is of lacustrine origin. Post depositional erosion is evident from channels (depressions) along the upper surface of this unit. These depressions are intermittently filled with the coarser-grained sand and gravel of the Brown Clay Unit. Based on boring logs, the fill deposits are not widespread and not representative of a contiguous lithologic unit. These channel deposits are also described above in the description of the Brown Clay Unit. The Gray Clay Unit occasionally grades vertically to a silt and sand mixture. Gravel is dispersed throughout the unit, as are lenses of fine to medium-grained sand. Sand and gravel become the primary constituents near the base of the unit. The overall consistency of the unit ranges from soft to medium soft, with clay portions being slightly to highly plastic. The clay is generally wet and sand lenses are wet to saturated.

The thickness of the Gray Clay Unit varies from less than 5 to 30 feet and it is the thickest unconsolidated unit on site (BNI 1994b, Acres America 1981b). Based on laboratory tests, the average permeability of the Gray Clay Unit is reported as 7.34×10^{-8} cm/sec (BNI 1982a).

- Middle Silt Till Unit - At some locations, a glacio-lacustrine Middle Silt Till Unit splits the Gray Clay Unit or where the lower portion of the Gray Clay Unit is absent, the Middle Silt Till overlies clastic sediments associated with the Sand and Gravel Unit of Wisconsinian age. This silt horizon was reported in the subsurface at the CWM landfill but was not found at the NFSS. The Middle Silt Till Unit may consist of zones of coarse to fine sand and traces of gravel, but dense gray silt is dominant. The horizontal permeability of the Middle Silt Till Unit was reported as 3×10^{-6} cm/sec and the vertical permeability was 1×10^{-7} cm/sec (BNI 1994b, Goldowitz and Greenholtz 1994).
- Sand and Gravel Unit - The Sand and Gravel Unit, also referred to as “Alluvial Sand and Gravel”, consists of clean sand to mixtures of sand, gravel, and silt. The unit is thought to be glaciofluvial in origin, is normally wet to saturated, and exhibits loose to medium relative density. In general, the thickest portions of the unit are present where depressions occur in the bedrock.

The Sand and Gravel Unit is approximately three to seven feet in thickness and occurs 15 to 28 feet bgs (BNI 1994b, Acres America 1981b). The horizontal permeability of the Sand and Gravel Unit ranges from 1.3×10^{-3} to 9×10^{-6} cm/sec (BNI 1994b, Acres America 1981b).

- Red Silt Unit - The Red Silt Unit, referred to as the “Basal Red Till” in some documents, consists of angular fragments of bedrock in a sandy silt matrix that suggests that this till was locally derived and emplaced as a basal lodgement till. The Red Silt Unit is composed of clayey gravelly silt with lesser amounts of sand. Gravel is dispersed throughout the unit and consists of both rounded and angular fragments of bedrock. This unit is generally dry to moist, over consolidated, and ranges from medium to very dense. The Red Silt Unit varies in thickness from zero to seven feet. The top of the Red Silt Unit varies across the site from a minimum of 17 feet bgs to a maximum of 45 feet bgs. The

base varies from 22 feet bgs to 48.73 feet bgs. (BNI 1994b, Acres America 1981b). The horizontal permeability of the Red Silt Unit is reported as 4×10^{-8} and the vertical permeability is 3×10^{-8} cm/sec (Goldowitz and Greenholtz 1994).

- Queenston Formation - The Queenston Formation forms the bedrock at the site and consists of brownish red shale, siltstone, and mudstone. Occasional lenses of green siltstone and shale occur within this formation. The Queenston Formation is over 1,200 feet thick. The top 6 to 12 feet of the Queenston Formation are moderately weathered, fractured and more permeable than lower portions of the formation. Calcite replacement and clays have been noted in some of the wider fractures. The Queenston Formation is typically encountered 32 to 49 feet bgs (BNI 1994b, Acres America 1981b). Based on information provided by Stratigrapher, Dr. Carlton Brett, the marine shales and sandstones of the Ordovician Georgian Bay Formation underlie the Queenston Formation (BNI 1994b, Acres America 1981b, Tisch 1979).

The horizontal permeability of the unweathered portion of the Queenston Formation ranges from 2.3×10^{-4} to 2×10^{-7} cm/sec (BNI 1994b, Acres America 1981b).

2.3.4 Regional Hydrogeology

Within 50 feet of the ground surface, there are two water-bearing zones at the NFSS and surrounding vicinity. The uppermost unit is present in the Brown Clay Unit (also identified as Unit 2) located above the Gray Clay Unit (also identified as Unit 3). The Gray Clay Unit acts as an aquitard for the second water zone that underlies the Gray Clay Unit. This second (lower) water-bearing zone is associated with the upper fractured portion of the Queenston Formation and the unconsolidated materials between the bedrock and the Gray Clay Unit (Red Silt and Sand and Gravel Units). A regional groundwater divide exists approximately two miles south of the NFSS. Regional groundwater flow north of the divide is toward the northwest, whereas groundwater flow south of the divide is toward to the southwest (BNI 1982b).

The two water-bearing zones identified at the NFSS are the upper water-bearing zone (UWBZ) and the lower water-bearing zone (LWBZ).

The UWBZ is typified by clayey silt and silty clay with occasional sand and gravel lenses. Coarse-grained, possibly channel fill deposits, are sporadically present in the basal portion of the zone on the undulating upper surface of the Gray Clay Unit. However, based on boring logs and recent statistical analysis (HydroGeoLogic Inc. [HGL] 2006), these sand seams, pockets, and lenses are intermittent and vertically and horizontally discontinuous.

HGL performed a geostatistical analysis to assess the continuity of sand lenses in the UWBZ at the NFSS to evaluate whether the sand lenses act as preferential migration pathways for contamination. Lithologic information from boring logs was spatially analyzed using semivariogram calculations and models. The results suggest the sand lenses in the UWBZ are not horizontally continuous over distances greater than 15 to 20 feet (HGL 2007).

Saturated conditions occur in the UWBZ in both the continuous, low permeability clays and in the discontinuous lenses of sand and gravel. Throughout the UWBZ, the coarse-grained lenses, pockets and seams vary considerably in thickness and extent and range from dry to saturated. As a result, the occurrence of groundwater varies across the site.

The horizontal hydraulic conductivity of the UWBZ, estimated from field (slug) tests and laboratory tests, ranges from 3×10^{-2} to 7×10^{-9} cm/sec with most values in the range of 1×10^{-5} to 1×10^{-7} cm/sec. Horizontal conductivity values for wells screened in the sand lenses, seams and pockets are typically higher than wells in the silt or clay (a range of 9.5×10^{-7} to 1.27×10^{-2} cm/s is evident).

Vertical hydraulic conductivity values for the clay within the Brown Clay Unit (Unit 2) were reported to be 6×10^{-7} cm/sec (BNI 1994a). However, preserved desiccation cracks (mud cracks), filled with clay, have been reported at 3 to 14 feet bgs at Modern Landfill and Model City (Wehran 1979, Goldowitz and Greenholtz 1994). Where open desiccation cracks occur, vertical hydraulic conductivity may be greater than reported. Mud cracks filled with clay may also increase vertical conductivity depending upon how efficiently the clay seals the cracks. Preserved desiccation cracks were not noted in the subsurface at the NFSS. Open desiccation cracks 0-1 foot deep were noted on a seasonal basis in surface soil during prolonged dry periods and were most prevalent in low-lying areas such as the ephemeral ditches throughout the NFSS and the low lying areas adjacent to N and O Streets. In the 1994 Failure Analysis Report, Bechtel reported that desiccation cracking had not been observed at the IWCS (BNI 1994a).

The Gray Clay Unit (Unit 3) acts as an aquitard separating the UWBZ from the LWBZ. For purposes of classification, wells that terminate in the Gray Clay Unit are considered to be representative of the UWBZ.

The LWBZ extends from bottom of the Gray Clay Unit (Unit 3) to the bottom of the weathered zone of the Queenston Formation (Unit 7) and consists of the stratified sands and gravels of the Sand and Gravel Unit (Unit 5), the dense silt and sands of the Red Silt Unit (Unit 6) and the weathered and fractured upper portions of the Queenston Formation (Unit 7). The presence of Middle Silt Till (Unit 4) was not noted in NFSS boring logs. The thickness of the LWBZ varies from about 10 feet to about 38.5 feet. The LWBZ has significantly higher permeability and more lateral continuity than the UWBZ.

In the Sand and Gravel Unit (Unit 5), the horizontal hydraulic conductivity ranges from 1.3×10^{-3} to 9×10^{-6} cm/sec (BNI 1994b, Acres American, Inc. 1981a). Well yields in the LWBZ are less than seven gpm in the fractured portion of the Queenston Formation (Acres American, Inc. 1981a).

The potential for contamination of this zone is limited due to the presence of the confining Gray Clay Unit and Red Silt Unit (where present) and the relatively low permeability of the Queenston Shale. In addition, documents suggest an upward vertical gradient at locations where the Red Silt Unit is absent (BNI 1994b and Acres American, Inc. 1981a). Based on NFSS boring logs, the Red Silt Unit is absent from at least 6 boreholes at scattered locations suggesting this limiting factor may be of only local significance at NFSS.

The general direction of groundwater flow in the LWBZ is to the northwest. The highest gradients occur south of the NFSS and the Modern Landfill property.

2.3.5 Groundwater Usage

A public water supply from the upper Niagara River has been utilized by almost all county residents for several decades (Niagara County Department of Health [DOH] 2006). Prior to installation of the public water supply, groundwater from private wells was the primary source of drinking water near the LOOW property. The highest yields and quality of potable groundwater

are found in the fractured dolomite associated with the Lockport Dolomite. However, this formation is absent in the subsurface of the Ontario Plain where the NFSS is located. In the Ontario Plain, the Queenston Shale and thin sandy deposits of glacial origin provide a very limited supply of potable groundwater that is reportedly poor in yield and water quality (Johnston 1964, DOE 1986). Groundwater yields are generally less than seven gallons per minute. Based on early U.S. Geological Survey (USGS) documents and current information, groundwater usage in the vicinity of the NFSS is restricted to limited domestic use and farm applications. Current use of private wells near the NFSS for drinking water is uncommon (Johnston 1964, DOE 1991).

During compilation of this report, the towns of Lewiston and Porter, the Niagara County Water District, and the Niagara County Health Department were contacted. These agencies reported that the Niagara County Water District supplies water to the residents of nearby Lewiston and Porter. Everyone within the region has access to District water. The District obtains water from the west branch of the Niagara River.

In 1988, a well survey was performed by BNI and six wells were identified within three miles of the site. Four of the wells were used for domestic purposes and the use of the remaining two wells was unknown. The locations of the six private wells were not provided (BNI 1994a).

In 1990, Wehran EnviroTech performed a water well survey for Modern Landfill. The survey encompassed one mile downgradient and one-quarter mile upgradient of the landfill. One water well user was identified along Porter Center Road, upgradient of the Modern Landfill facility. The well was 28 feet deep and produced less than two to three gallons per minute. This well is located east and upgradient of the NFSS (Wehran Engineering 1990) and was regularly sampled in 1982 by DOE along with three other wells within four miles of the NFSS. Three of the four wells sampled by DOE in 1982 were approximately 25 feet deep and were used for domestic purposes and the fourth well was identified as the industrial Service Corporation of America (SCA) Services, Inc. (a subsidiary of Chemical Waste Management) well.

In 1994, BNI updated their 1988 well survey information. Eight wells were identified within a 3.5-mile radius of the NFSS as shown on the map in Appendix E. One existing private well was downgradient (northwest) of the NFSS, four were northeast and three wells were southeast (BNI 1994a, BNI 1982a). No public water-supply wells were found within 3.5 miles of the NFSS. Current use of the eight wells was not reported, but the document stated that “None of the wells are known to have been used for drinking water.” The maximum depth of the eight wells was 60 feet and the well yields ranged from 2 to 10 gallons per minute (BNI 1994a).

A 2002 list of wells in the vicinity of the NFSS, obtained from the USGS, indicated 138 wells were located within a four-mile radius of the NFSS. Sixteen wells were located potentially downgradient (northwest) of the site. The depths of the wells ranged from 16 to 22 feet bgs. Seven of the 16 wells were completed in bedrock (frequently specified as the Queenston Formation), but the aquifer penetrated in the remaining nine wells was not identified. Based on reported well depths, these wells likely draw groundwater from glacial sediments. The use of these wells was specified as follows: ten used for domestic purposes, one used for stock, one used for irrigation, and three wells unused. The use of one well was unknown. The 2002 USGS list of wells is most likely not verified frequently and the current status of the wells listed is not known.

In March 2006, the Niagara County DOH issued the results of a private well study (Niagara County DOH 2006), which is included in Appendix E. One-hundred seventeen private wells were identified near the LOOW property. Of the 117 wells identified, 11 were reported as potable, 8 were reported as non-potable, 20 were reported as not accessible, and 78 were reported as not in

use. Of the 11 private wells reported as potable, six were identified as secondary groundwater sources (i.e. public water was the primary drinking water source). This study concluded that only a small number of private wells in the study area were active (19 of 117). Thirteen wells were sampled for temperature, turbidity, pH, total coliform, heterotrophic plate count, E coli, chloride, nitrate/nitrite, phenol, fluoride, lithium, drinking water metals (arsenic, boron, copper, manganese, nickel, lead, and vanadium), nuclear chemistry parameters, pesticides, PCBs, VOCs, and SVOCs. Five wells exceeded the regulatory maximum contaminant levels (MCL) for a single parameter, and in each case the parameter was different (chloride, phenol, arsenic, manganese, and lead). All wells that were sampled met safe drinking water standards with respect to radiological quality. The New York State DOH issued advisories to well owners whose wells exceeded the regulatory MCL for the five other parameters noted above.

2.3.6 Regional Meteorology

Weather data for Niagara Falls, NY was obtained from the Air Force Combat Climatology Center in Asheville, NC. The data is the result of observations at the Niagara Falls Air Force Base, located off Route 62, about seven miles southeast of NFSS and four miles east of Niagara Falls. The period of record is from 1973 through 1995.

Figure 2-3 demonstrates mean daily maximum and minimum temperatures, as well as extreme maximum and minimum monthly temperatures observed at Niagara Falls during the period from 1973-1995. As shown, extremes at Niagara Falls have ranged from a maximum of 99 °F to a minimum of -17 °F.

Annual precipitation (rain and equivalent snow and ice) is approximately 38.0 inches per year. Average monthly precipitation at Niagara Falls is relatively consistent throughout the year. August and November are the wettest months (mean 3.9 inches) and February is the driest month (2.5 inches). Mean and extreme monthly precipitation data are presented in Figure 2-4. The maximum 24-hour rain event in Niagara Falls was 4.4 inches. Thunderstorms occur on an average of 33 days per year, primarily during June through August.

Average annual snowfall at Niagara Falls is 89 inches, and the record maximum snowfall in one year was 176 inches. Monthly average snowfall peaks during January, which averages 24 inches. Maximum monthly snowfall recorded at Niagara Falls was 68 inches, which has occurred during both of the months of December and January. The record 24-hour snowfall event at Niagara Falls is 19 inches.

Average afternoon relative humidity ranges from a minimum of 54% during May, June, and July to a maximum of 71% during the months of January and November. Average morning relative humidity ranges from a minimum of 78% during the month of November to a maximum of 87% during the month of August.

The winter months are typically mostly cloudy, averaging 75% of maximum possible cloud cover. Low ceilings (less than 3,000 feet) and/or reduced visibility (less than three miles) are most likely to occur during the month of January (54% occurrence) and are least likely during July (15% occurrence). During the summer months (June through August) cloud cover averages 50% of maximum. Fog is observed at Niagara Falls on an average of 164 days per year, and occurs on an average of 12 or more days each month.

Prevailing winds at Niagara Falls are from the west during most of the winter months and from the southwest during spring and summer months. Southeast winds are least prevalent. Mean wind

speed ranges from a maximum of 11 knots during January to a low of seven knots during August. An annual wind rose for Niagara Falls is presented in Figure 2-5 and wind summaries are presented in Figures 2-6 and 2-7. The wind rose (Figure 2-5) represents data collected from over 20 years ago and is the only available information obtained for on-site wind direction and speed. The information presented in Figures 2-6 and 2-7 are generally consistent with this wind rose although these two figures indicate a somewhat higher percentage of calm conditions.

2.3.7 Surrounding Land Use

The NFSS is bordered on the north and northeast by the CWM Chemical Services, LLC. hazardous waste disposal facility, on the east and south by the Modern Landfill, Inc. solid waste disposal facility, on the west by a transmission corridor owned by Niagara-Mohawk Power Corporation, and on the northwest by the village of Lewiston (the former LOOW wastewater treatment plant) (BNI 1994a). All of the aforementioned properties were once part of the original LOOW.

The surrounding area land use consists primarily of row-crops and orchards, abandoned agricultural fields, and second-growth forests. The Lewiston-Porter public school property is approximately 1.5 miles northwest of the site and a public campground is approximately 0.5 miles west of the site. A hydroponic greenhouse has been constructed immediately south of the NFSS (south of Pletcher Road) where a farm field used to be. Many residences are also in the area with the nearest residences located on Pletcher Road approximately 0.5 miles west-southwest of the site.

Land use in the vicinity of the NFSS is shown on Figure 1-7.

2.4 DATA QUALITY OBJECTIVES

DQOs are qualitative and quantitative statements that are used to develop a scientific and resource-effective sample collection plan. They serve as formal documentation of the data quality requirements. Effective use of DQOs yields data of known quality, documents the planning process, and provides benchmarks to determine if data meet project objectives. DQO #1 is a general DQO that was developed during the June 1999 TPP meeting. During the May 2000 TPP meeting, two more DQOs were developed to meet the needs of the BRA (DQOs #2 and #3).

DQO #1

Obtain information of sufficient quantity and quality to meet the requirements for an RI as described in the directive *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988). Requirements of the directive *Guidance for Performing Site Inspections Under CERCLA* (EPA 1992a) were also used, where appropriate. The information obtained also had to be of sufficient quantity and quality to identify sources of contamination and migration pathways in order to adequately characterize potential contamination at areas included in this investigation. DQO #1 includes the elements listed below.

- Intended Data Uses:
 - Satisfy project objectives,
- Data Need Requirements:
 - Satisfy data user perspective(s),
 - Determine contaminants or characteristics of interest,
 - Determine media of interest,

- Determine required sampling areas/locations and depths,
 - Determine the number of samples required,
 - Determine the reference concentration of interest or other performance criteria,
- Appropriate Sampling and Analysis Methods:
 - Determine the sampling method, and
 - Determine the analytical method.

DQO #2

Obtain information of sufficient quantity and quality to meet the requirements described in the EPA document, *Guidance for Data Usability in Risk Assessment*, (EPA 1992b).

DQO #3

Obtain information of sufficient quantity and quality to meet the requirements for development of a BRA based on EPA Risk Assessment Guidance for Superfund (RAGS), 1989 and subsequent guidance documents.

In order to achieve these three DQOs, the Quality Assurance Project Plan (QAPP) and addenda and the Field Sampling and Analysis Plan and addenda guided all sampling and analysis. Methods used to demonstrate the achievement of the DQOs are discussed in the sections that follow. Section 2.4.4 contains a summary discussion of the DQOs.

2.4.1 Data Collection

Samples from all the types of collected media were used to generate definitive data. These media included water, soil, sediment, debris, concrete, rock, and both solid and liquid waste materials. The samples were analyzed for the following parameters:

- VOCs,
- SVOCs,
- Organochlorine Pesticides,
- PCBs,
- Target analyte list metals plus Boron and Lithium,
- Cation exchange capacity,
- Total Organic Carbon,
- Nitroaromatic compounds,
- Geotechnical analyses,
- Asbestos,
- Radiological parameters, and
- PAHs, a subcategory of SVOCs.

General Engineering Laboratories (GEL), a USACE-certified lab in Charleston, SC, performed all primary radiological and chemical analyses. Maxim's geotechnical laboratory in St. Louis, MO performed all geotechnical analyses. Data Chem, in Cincinnati, OH, performed all asbestos testing. Tables 2-2 through 2-5 list analytical methods for analyses performed during the RI.

To assess the primary laboratory's performance, several laboratories were designated by the USACE for the analysis of Quality Assurance (QA) samples during the progress of the RI. The analysis of QA samples is an element of the QA management system that measures the degree of excellence of environmental data. Initially, Argonne National Laboratory (ANL), Chicago, IL,

was utilized for the analysis of QA samples for both chemical and radiological parameters. Responsibility for the testing of QA samples for radiological parameters was later transferred to Nuclear Technology Services (NTS), Roswell, GA and then again, to Severn-Trent Laboratories (STL), St. Louis, MO.

2.4.2 Quality Control Protocols

Appendix F describes the Quality Control (QC) procedures employed during the RI. These procedures, which address key QA elements (e.g. the level of QC effort; accuracy, precision, and sensitivity of analysis; method blanks; LCSs; MS/MSDs; blind field duplicates; laboratory duplicates; QA samples; completeness; representativeness; comparability; and presentation of data), ensure the correct level and extent of sampling and analysis was conducted to produce sufficient data for evaluating remedial alternatives at NFSS.

2.4.3 Data Review

The data review process applied to data received from the laboratory is described in greater detail in Appendix F and consisted of three phases of review.

- The first phase involved the review of the hardcopy analytical data reports and was conducted to monitor completeness, correctness, consistency and compliance of the primary data with the QAPP and the Subcontract Services Agreement with the primary laboratory. The first phase of the review was also conducted with respect to the electronic data deliverables (EDDs) and verified the accuracy, completeness and compliance of the spreadsheet formatted data with the format specified in the QAPP.
- The second phase included a further review of the data for accuracy by SAIC to ensure the data met EPA national functional guidelines where appropriate, specifically the 5x and 10x rule for organics and the uncertainty rules for radiological parameters, and that assigned data qualifiers were appropriate.
- The final phase included a detailed validation of the data packages by U.S. Army Engineer Research and Development Center Environmental Laboratory (Omaha, NE), Integrated, Inc. (Baton Rouge, LA), and Nuclear Technologies Services, Inc (NTS) (Roswell, GA). This was done to comply with USACE Engineer Regulation 1110-1-263 *Chemical Data Quality Management for Hazardous, Toxic, Radioactive Waste Remedial Activities*. The results of this validation are presented in a Chemical Data Quality Assessment Report (CDQAR). In the NFSS CDQAR, primary and QA split sample results from chemical quality assurance reports (CQAR) resulting from RI Fieldwork Phases 1, 2, and 3 were evaluated. Additionally, the data verification/validation processes and findings regarding data usability were documented. The NFSS RI CDQAR can be found in Appendix G.

2.4.4 Achievement of DQOs

The information generated in this report was evaluated by using the QA parameters discussed briefly in the previous sections and guidance documents cited below. This evaluation is used, along with reference to relevant guidance documents, to demonstrate the achievement of the three DQOs presented in Section 2.4.

2.4.4.1 DQO #1

All applicable sections of the EPA guidance documents were followed during the performance of this investigation. Three phases of environmental samples were collected from soil, surface water, sediment, groundwater and subsurface utilities at the site. A review of historical documents helped identify contaminants and media of interest for each EU identified in Figure 1-2. Section 3 tables provide the sampling rationale for each media of interest and document the number of samples collected, their depth, location, and contaminants of interest. Sampling rationale was dynamic and biased in nature, i.e., sample collection was guided by field instrumentation (PID, radiation detections meters). In addition, the second two phases of field investigation used results from the previous sampling round to further guide sample collection to ensure that all data need requirements were met. The environmental sampling data was supplemented with information from a site gamma walkover survey, non-invasive geophysical methods, and trenching activities. The rationale and requirements for all sampling and analytical methods are discussed in the RI QAPP and Field Sampling and Analysis Plan and addenda. Appendix F discusses the sampling and analytical methods used. Sections 3 through 6 of this report discuss the data collected, the nature and extent of contamination, and the fate and transport of constituents at NFSS. The quality and quantity of information collected has proved to be adequate to address all of the elements listed for DQO #1 in Section 2.4.

2.4.4.2 DQO #2

The objective of DQO #2 was to obtain information of sufficient quantity and quality to meet the requirements described in the *Guidance for Data Usability in Risk Assessment* (EPA 1992b). Information from this RI was provided to the risk assessors, so that they could evaluate the site, sampling locations and media types, and analyte lists. Documentation of the sampling is sufficient so that samples are traceable to a specific location. Historical data and information, as well as three phases of recent sampling and newly discovered historical information, were evaluated along with analytical methods to ensure that a broad spectrum of analytes evaluated the entire site and all its media. In addition the physical characteristics of the media were documented. This ensures that the information obtained represents appropriate data sources for a risk assessment. The analytical methods with appropriate detection limits were reviewed and determined to meet guidance requirements. Data Quality Indicators (DQI) (precision, accuracy, representativeness, completeness and comparability) have been evaluated and found to meet guidance requirements. Documentation of the review and other QA/QC evaluations is found in Appendix F. Therefore all six criteria used to evaluate the achievement of this DQO have been satisfied.

2.4.4.3 DQO #3

The objective of DQO #3 was to obtain information of sufficient quantity and quality to meet the requirements for development of a BRA based on RAGS (EPA 1989) and subsequent guidance documents. This DQO is, in part, based on DQO #2. Table 2-1 includes a summary of the numbers of samples by EU and by media. As documented in Appendix F, the quality of data was assessed. As a result, the quality and quantity of information collected has proved adequate to produce the BRA included with this report.

2.4.4.4 DQO #4

The objective of DQO #4 was to obtain information of sufficient quantity and quality to identify sources of contamination and migration pathways to adequately characterize potential contamination at areas included in this investigation. To meet this objective, three phases of environmental samples were collected from soil, surface water, sediment, groundwater and subsurface utilities at the site. This data was supplemented with information from a site gamma walkover survey, non-invasive geophysical methods and trenching activities. Sections 3 through 6 of this report discuss the data collected, the nature and extent of contamination and the fate, and transport of constituents at NFSS. The quality and quantity of information collected has proved to be adequate for this purpose.

3.0 REMEDIAL INVESTIGATION ACTIVITIES

3.1 INTRODUCTION

The NFSS RI was performed using a phased approach. The strategy employed was to begin with a single field sampling phase and to add additional phases to further refine site knowledge and to more accurately characterize the site. A total of three phases were performed. A brief summary of these phases follows:

- Phase 1 fieldwork started in November 1999 and concluded in January 2000. Surface water and sediment samples were collected from ditches across the site. Groundwater samples, collected from both previously existing wells and from temporary well points (TWP), subsurface soil samples, and surface soil samples were collected from locations at which historical information suggested the potential presence of contamination.
- Phase 2 fieldwork started in August 2000 and concluded in October 2000. Analytical data from Phase 1 suggested potential contamination in thirteen TWPs. Permanent monitoring wells were installed and sampled at these locations in Phase 2. Surface soil, subsurface soil, railroad ballast, and pavement core samples were collected in and around Phase 1 sample locations that exhibited elevated concentrations of parameters of concern. Samples were also collected from areas that were previously uninvestigated. Surface soil and subsurface soil background samples were collected. Five surface water and sediment samples were collected from locations that were dry during the Phase 1 fieldwork.
- Phase 3 fieldwork started in May 2001 and continued on an intermittent basis until October 2003. After a site-wide gamma walkover survey was performed at the site, surface and subsurface soil samples were collected in and around locations that exhibited elevated gamma readings. Geophysical investigations, consisting of ground penetrating radar (GPR), seismic reflection and refraction, electromagnetic frequency domain and time domain, and electrical imaging/induced polarization were conducted at the site. Exploratory trenches were excavated at the locations of geophysical anomalies. Exploratory trenches were also excavated at locations where the historical record indicated contamination might be present. A detailed reconnaissance of the pipelines and sewers at the site was performed and samples were collected from manholes, pipes, and sumps. Confirmation samples were later collected from several manholes that exhibited elevated concentrations of parameters of concern. Because the need for a suitable background groundwater data set was identified, and no suitable data set existed for the site, background groundwater samples were collected. During the previous phases of fieldwork at the site, several abandoned drums were found. These drums were sampled in Phase 3. Additional surface soil, subsurface soil and groundwater samples were collected to fill data gaps identified in the preparation of the BRA work plan. Confirmation samples were collected from several wells that previously exhibited elevated concentrations of parameters of concern. Additional monitoring wells were also installed in Phase 3 to further investigate and characterize the groundwater at the NFSS.

Because this is a federally-owned site, USACE investigated potential chemical contamination at the NFSS. Therefore, many of the samples collected for this RI were analyzed for chemical parameters, as well as radiological parameters.

In order to facilitate the accurate estimation of exposure and dose in the BRA, the site was divided into 18 EUs. These EUs provided the geographical framework within which the determination of SRCs was performed. SRCs are defined as those compounds that exceed background in their respective EUs. The determination of SRCs is further discussed in Section 4 of this RI report.

Because the site data are to a large degree organized around the concept of EUs, they are briefly presented here in the RI report. A more detailed discussion of EUs is presented in the BRA. The BRA evaluates risks to human and ecological receptors. An EU is the geographical area in which a receptor is assumed to work or live. In other words, it is the area in which the receptor may be exposed to SRCs detected during the RI. As explained in the BRA, the EUs were defined based on specific administrative and data considerations such as:

- Adequate representation of potential site exposures in terms of receptor behavior,
- The potential for future release of specific properties for re-use (e.g., sale of property),
- Consistency with previous divisions of the site as identified in prior site investigations,
- Consistency with historical use of specific areas at NFSS,
- Consistency with operable unit (OU) definitions for the FS,
- Quantity and spacing of samples,
- Distribution of contamination,
- Conformity for use in both the human health and ERAs, and
- Relative size of each EU.

Figure 1-2 shows the geographical boundaries of the various EUs. The descriptions of the individual EUs are presented in Table 3-1. The area of investigation considered by this RI, consisting of the NFSS and the neighboring Niagara-Mohawk property, was divided into 14 distinct EUs, numbered 1 through 14, as seen in Table 3-1. These EUs formed the basis for the evaluation of surface soils, subsurface soils, and some of the sediment and surface water samples. The separate determinations of SRCs for these media were made in each of these 14 EUs.

EUs 15 through 18 were created to accommodate special circumstances of the site or needs of the BRA. These EUs are described below:

- EU 15 consists of ditches that are inundated at least 50% of the year including the Central Ditch, South 16 Ditch, South 31 Ditch, and Modern Ditch. All sediment and surface water samples collected from these ditches were evaluated in EU 15. Sediment and surface water samples collected from ditches other than those in EU 15 were evaluated in the EUs from which they were collected.
- EU 16 contains on-site subsurface pipelines used in former site operations. These pipelines include acid lines, water lines, sanitary sewers, and storm sewers. All sediment and water samples collected from these pipelines were evaluated in EU 16.
- EU 17 is a site-wide EU and includes all areas and media within the property boundary of NFSS. This includes all soil, sediment, surface water, and pipeline material in EUs 1 through 16. In addition it contains site-wide groundwater, including both the upper and lower water bearing zones. EU 17 is approximately 191 acres.
- EU 18 consists of all background samples that were used for the determination of SRCs in EUs 1 through 17.

Hereinafter, the RI report may refer to 14 physical EUs or 18 risk EUs, depending on the topic being discussed. The 14 physical EUs represent the distinct EUs into which the site was divided. The 18 risk EUs includes the 14 physical EUs and the EUs discussed in the bullets above.

Section 3 is organized by RI tasks and site media (groundwater, surface soil, etc.) sampled for this RI. Each medium is presented in its own subsection. Each site media subsection presents the following information:

- Sample locations and rationale for their selection,
- Analytical parameters for each sample and the rationale for the selection of the parameters, and
- A description of the methods of sample collection.

Table 3-2 summarizes the sample naming conventions.

In addition to sampling performed during the RI at NFSS, regular sampling of air, surface water, groundwater, and streambed sediment is conducted to support the ongoing environmental surveillance program. Environmental surveillance results are compared to local background conditions and regulatory criteria to determine if radioactive waste stored on-site poses a threat to human health and the environment.

Since 1981, an annual technical memorandum has been issued to document surveillance results. Based on the FUSRAP NFSS 2004 Environmental Surveillance Technical Memorandum (USACE 2004), the nearest off-site worker receives an annual radiation dose of approximately 0.0046 mrem/yr from radioactive materials stored at the NFSS. The nearest resident receives an annual radiation dose of approximately 0.001 mrem/yr. To put these values into perspective, the U.S. average annual background dose is 360 mrem/yr and the annual dose limit above background to the public is 100 mrem/yr. By further defining the nature and extend of SRCs at the NFSS during the RI, goals and objectives of the environmental surveillance program will be better directed to ensure continued safety to human health and the environment.

The sample collection methods are briefly summarized in the sections that follow. For detailed descriptions of sample collection methods and decontamination procedures, the reader is directed to the FSP (Maxim 1999) and subsequent addenda.

3.2 TOPOGRAPHIC SURVEY

A topographic survey, described in detail in the sections that follow, was performed for the RI. The topographic survey performed at the NFSS determined the locations of sample points and other features of interest, relative to horizontal and vertical datums. A horizontal datum is a reference point for a grid system across the earth's surface and vertical datum is an elevation reference point, relative to distance amsl.

3.2.1 Objectives

There were two objectives for the topographic survey; the first objective was specified in the original project SOW and consisted of a detailed civil survey of the IWCS. This survey was performed to investigate if settlement of the IWCS cap had occurred and to provide a baseline for

such determinations in the future. The civil survey of the IWCS was performed on December 21, 1999 at grid nodes originally established by the DOE. The 1999 elevations were compared to measurements taken by the DOE on April 10, 1996. Both sets of elevation measurements are shown on Table 3-3. An examination of the data shows that some minor settling has occurred, primarily in the area of the original R-10 pile. Most locations that experienced settling only reduced in elevation by an inch or less. Localized areas of settling greater than one inch occurred around the area where approximately 60 drums containing contaminated soils and resin, 4 steel tanks, approximately 900 boxes of soil samples, tarps, geotextiles, and other miscellaneous debris were added to trenches cut into the IWCS in 1991. The maximum difference in elevation between the 1996 and 1999 surveys was 1.9 inches.

The second objective was to provide an accurate record of all samples and exploratory trench locations. The horizontal coordinates for all survey points were determined relative to the New York State Plane Coordinates, 1983, West Zone. The basis of these coordinates was derived from a global positioning system (GPS) static survey with reference to the National Geodetic Survey (NGS) control monuments “Youn USCG B: Upper” and “Youn USCG B: Power”. The vertical datum for all survey points was the National Geodetic Vertical Datum (NGVD) 1929. The source benchmark used for the site was the top of the west bonnet bolt of a fire hydrant located at the southwest corner of Building 429. The elevation of this benchmark, relative to NGVD 1929, was 321.50 feet. Relative to the vertical datum NGVD 1988, the elevation of the benchmark was 320.94 feet.

3.2.2 Methods

Except as noted below, all horizontal coordinates were determined using a two-receiver differential GPS. A stationary receiver was set up on a known benchmark located in O Street north of the IWCS and a roving receiver was used to determine the coordinates of each surveyed point. The stationary receiver determined the necessary corrections that were applied to the coordinate data collected with the roving receiver. Elevations determined by this method are accurate to within 0.13 feet and horizontal coordinates are accurate to within 0.01 feet.

The elevations of ground level survey points (exclusive of the IWCS and exploratory trenches) were also determined using a two-receiver differential GPS. The elevation of survey points located on the IWCS and survey points located above the ground surface (e.g. the top of well casings) were determined by closed-loop differential leveling. Elevations determined by closed-loop differential leveling are accurate to within 0.01 feet.

The horizontal coordinates of exploratory trenches were determined with a single receiver resource-grade differential GPS. The accuracy of the coordinates determined with this unit was one meter.

3.2.3 Activities

The civil survey of the IWCS was performed in 1999 and sample locations were surveyed at the conclusion of each field task. The coordinates for all sample locations are shown in Appendix H.

3.3 SITE WALKOVER INSPECTIONS AND RECONNAISSANCE SURVEYS

As part of this RI, several visual site walkover inspections and reconnaissance surveys were performed at the site to gather information on site features, physical characteristics, and potential waste sources and migration pathways.

3.3.1 Objectives

In general, the objectives of these visual site walkover inspections and reconnaissance surveys were to obtain information to guide the development of sampling strategies and to acquire information necessary for the preparation of the FSP and subsequent addenda.

3.3.2 Activities

The specific visual site walkover inspections are discussed in detail in the following sections.

3.3.2.1 Initial Visual Site Walkover Inspection

Prior to the preparation of work plans for the RI, a project kickoff meeting was held in April 1999. This meeting included a visual inspection during a site walkover of the NFSS. Building 401 was the focus of the inspection and included a tour of the interior of Building 401. The inspection also included a brief ‘windshield’ tour of the site to familiarize project personnel with the site geography. The project team acquired familiarity with Building 401 and general site features through this inspection. A civil survey of the cap of the IWCS was also performed as part of the initial visual site walkover inspection.

3.3.2.2 FSP Support Reconnaissance

In July 1999, a detailed reconnaissance of the site was performed in support of the preparation of the FSP. The reconnaissance consisted of:

- Mapping previously uncharted site features, including ruins (structures in poor condition), slabs and unimproved roads.
- Evaluation of potential sample locations.
- Evaluation and resolution of issues regarding access and logistics.

3.3.2.3 Pipeline Reconnaissance

Reconnaissance of the pipelines at the NFSS was performed in 2000 in support of the preparation of the FSP that described the sampling of the pipelines. The bulk of the reconnaissance was performed in May of that year, though knowledge of the pipeline system was refined during subsequent inspections performed in later months. As-built drawings were used as a guide. The reconnaissance consisted of:

- Locating all known manholes and sumps at the NFSS.
- Measuring the depth to the invert in each manhole and sump.
- Evaluating the presence or absence of water and sediment in the pipelines at each manhole.
- Evaluating the general condition of the various sewers, sumps and pipelines at the site.

The following bullets summarize the NFSS pipeline reconnaissance.

- A review of as-built drawings showed that 46 manholes were located on the sanitary, storm and acid process sewer lines. The field reconnaissance found 40 of these manholes. Six manholes, three on the storm sewer system, one on the sanitary sewer system, and two on the acid lines were not found.
- The as-built drawings showed two storm sewer outfalls (Outfall 1 and Outfall 2) on the Central Ditch. Outfall 2 was found and consisted of an exposed wooden pipe banded with steel. Outfall 1 could not be located. For purposes of sampling, its location was approximated based on site drawings.
- Seventy-two exposed pipes, most of which were vitrified clay pipes (VCP), were found. Most of these pipes are in the acid area.
- A four-inch steel pipe was found near Building 401. This pipe may have been either a sewer cleanout or a fill tube for an UST.
- A 10-inch VCP was found in the shops area, on the remnant floor slab of the Garage and Repair Shop. This pipe may be connected to a sump also found in the floor slab.
- A review of as-built drawings showed 36 sumps associated with the on-site pipe network. The field reconnaissance found 26 of these sumps.

The results of this reconnaissance were used to develop the Pipeline FSP. The sampling of the pipelines and associated sumps is described in Section 3.12.

Field notes made during the pipeline reconnaissance and tables summarizing the findings are shown in Appendix I. The pipeline reconnaissance discussed above was supplemented with non-intrusive geophysical survey techniques (SAIC 2003b), which were used to further delineate the subsurface piping extent.

3.3.2.4 Niagara-Mohawk Reconnaissance

A reconnaissance of the Niagara-Mohawk property was performed in August 2001 in support of the preparation of the FSP that described the sampling of soil, sediment and surface water at the Niagara-Mohawk property. The reconnaissance consisted of:

- Mapping previously uncharted site features,
- Evaluating potential sample locations, and
- Performing a limited gamma walkover survey of the site.

3.3.2.5 Ecological Reconnaissance

Maxim performed an Ecological Reconnaissance of the NFSS from August 21 through August 25, 2001. The purpose of the reconnaissance was to develop an ecological understanding and description of the site sufficient for the preparation of a site conceptual model for use in an ecological risk assessment. The results of this reconnaissance were presented in *Technical Memorandum #1, Niagara Falls Storage Site, Ecological Reconnaissance Report* (Maxim 2002a). This document is included in Appendix J.

3.4 FIELD SCREENING METHODS

3.4.1 Objectives

Field screening of environmental media was conducted in order to select sampling locations and depths, ensure worker safety, and comply with the Department of Transportation (DOT) shipping regulations. Field screening tools used during the RI field activities included gamma and geophysical surveys, photo-ionization detectors (PID), TNT kits, and magnetometers.

3.4.2 Methods

A PID was used to screen environmental samples for the presence of organic compounds, mainly VOCs. Similarly, samples were screened using TNT kits when historical data indicated the possible presence of TNT (i.e. areas known or suspected to have been used for explosives manufacturing or handling). Magnetometers (i.e. Schonstedt magnetic locators) were used to locate underground pipes and other magnetic objects prior to trenching or drilling activities to appropriately determine sampling locations and ensure safety of field personnel.

Portable gamma radiation meters were used by health physics technicians to evaluate the presence of gamma emitting radionuclides in soil, sediments, and other solid materials present at NFSS. Surface soil, subsurface exploration, and sediment and surface water sampling locations were screened to investigate the nature, presence, and horizontal and vertical extent of radiological compounds. Screening was performed to identify locations and depths at which radiation levels exhibited localized maximum values. Monitoring was performed to screen sample containers against background values, and at these depths samples were collected.

3.4.3 Activities

Sample locations and rationale for their selection were specified in the FSPs. The tentative locations were based on factors such as:

- results of previous site investigations,
- site history,
- site topography,
- locations of former buildings and slabs,
- results of gamma walk-over surveys,
- PID and TNT screening results,
- site drawings,
- knowledge of former site activities and processes ,
- presence of evidence of potential contamination, and
- need to provide representative sampling throughout each EU of the site.

Unbiased samples were also collected to ensure adequate data coverage for each constituent and media in each EU for risk assessment purposes. The tentative locations and composition of samples in all environmental media were screened with a gamma meter and modified if necessary, based on gamma survey results, as described in the following sections.

3.4.3.1 Selection of Sampling Locations

Sediment and Surface Water

Prior to sample collection, each planned sediment and surface water sampling location was surveyed by a health physics technician, using a NaI gamma 2 inch by 2 inch detector (60 second static count). The survey at each location was conducted along a 50 foot line that extended from the tentative sample point in both the upstream and downstream directions. The width of the gamma survey extended from about ten feet beyond the top of the bank to the centerline of the ditch (if dry), or to the edge of the water (if present). After the point with the highest gamma radiation measurement was identified, the location was staked and the sediment sample was collected from within the ditch as close as possible to the stake. In general, surface water samples were collocated with the sediment samples, though if surface water was not present at the sediment sample location, the surface water sample location was moved downgradient to the first location at which water was present.

Surface Soil, Subsurface Exploration, and Railroad Ballast Locations

Each planned soil sampling location, TWP, and groundwater monitoring well, was staked or otherwise marked, and the surrounding ten meter by ten meter area (33 feet by 33 feet) was surveyed by a health physics technician using a NaI gamma 2 inch by 2 inch detector. The planned surface soil and/or boring location was re-located, if necessary, so that it coincided with the location with the highest surface gamma measurements.

3.4.3.2 Borehole Radiological Logging

All soil borings installed with a drill rig were continuously logged by a health physics technician using a NaI gamma 2 inch by 2 inch detector. The health physics technician surveyed the entire length of each sample core after the sampler (either a 24-inch split spoon or a five-foot continuous sampler) was opened and the soil core was presented to the sample team for logging. The supervising geologist recorded gamma radiation measurements and other observations on the borehole log sheet. This information was used, in part, to select the depth interval for subsurface sample collection.

During Phase 1 of the RI, a downhole gamma survey was performed on each boring. These downhole surveys were performed to evaluate the vertical distribution of gamma-emitting radionuclides and to confirm the results of the gamma survey performed on the corresponding soil core. Downhole logging was performed using a one cm by one cm (3/8 inch by 3/8 inch) NaI gamma detector with a portable logging device. The one cm by one cm detector was equipped with a collimator to ensure that the photons detected originated from the nearest boring wall. Testing was performed through the PVC casing that was placed along one side of the boring. The NaI one cm by one cm detector was attached to a cable and initially lowered to the bottom of the casing. The instrument was then withdrawn to the surface and the boring was continuously logged. Each instrument was checked daily against the cesium-137 source provided by the equipment vendor and instrument responses were verified against calculated values. The real time data generated during the downhole logging was found to be consistent with the continuous core gamma logging performed during the installation of each borehole. Information from both gamma scans was used to determine where samples were collected along the soil core (i.e., the zone with elevated gamma readings). The results of the downhole logging are presented in Appendix K for informational purposes only.

3.4.3.3 Gamma Scanning of Soil and Sediment Sample Media

Sample material was removed from the bucket auger, split spoon or other sampling device, and placed in a stainless steel bowl. Materials such as grass, twigs, and pebbles were removed to the extent practical. After the volatile organic sample was collected, the contents of the sample bowl were screened with a NaI 2 inch by 2 inch detector. The health physics technician used the NaI 2 inch by 2 inch detector probe to investigate whether radioactivity was uniformly spread throughout the sample material. In some cases, it was found that radioactivity was not uniformly distributed, and that elevated radioactivity was due to presence of a single small “rock” of radioactive material. In individual cases, these rocks were submitted for analysis.

3.4.3.4 Gamma Scanning of Sample Containers

In order to ensure that sample shipments conformed to DOT shipping requirements, each sample container was scanned with a NaI 2 inch by 2 inch gamma detector prior to shipment. The results of this scan, reported relative to background, were recorded on the sample chain of custody. A background gamma radiation measurement for the sample shipment area (i.e. near the field trailer) was determined using the NaI detector prior to bringing sample containers into the shipment area. Each soil sample container was scanned and gamma radiation measurements were compared to the background measurement. Samples that exhibited gamma radiation levels 1.5 times background, or more, were labeled as radioactive samples.

3.5 SITE-WIDE GAMMA RADIATION SURVEY

A gamma walkover survey covering the NFSS and the adjoining Niagara-Mohawk property was performed from May 12 to August 27, 2001.

3.5.1 Objectives

The objective of this survey was to identify areas at NFSS where gamma radiation exceeded the site-specific background level. Lewiston-Porter School property was selected as the site for gathering the site-specific background levels due to its proximity to the NFSS site and based on historical records, no DOD or MED activities occurred on this property. The Lewiston-Porter School background gamma radiation measurement was determined to be approximately 8,000 counts per minute (cpm). A comparison background study was conducted at the Army National Guard Weekend Training Site on Balmer Road, also an area identified as having no documented MED activities. The Weekend Training Site background measurement was determined to be approximately 9,000 cpm. Gamma radiation surveys for both the background sites and NFSS were performed with a Ludlum rate meter coupled with a 2 inch by 2 inch NaI gamma detector in units of cpm while GPS instruments provided coordinate and time information for each radiation measurement. The product of the survey was a data set, stored in the field in a data logger, and then mapped to display relative levels of gamma radiation measurements across the site.

The survey was performed over the entire site, though it was designed to focus on areas most likely to contain radiological contamination. The areas identified as more likely to contain residual contamination were surveyed in one-meter transects. The remaining areas were surveyed in five-meter transects.

Details of procedures used to perform the gamma walkover survey are presented in *Final Gamma Walkover Survey and Geophysical Survey for the NFSS* (SAIC 2003b). The results of the gamma walkover survey are shown on Figures 3-1 through 3-6.

3.5.2 Summary Results and Conclusions

For purposes of the gamma walkover survey, the site was divided into six sectors.

Sector 1 consisted of the northwest corner of the site. Two areas of elevated activity were identified. Gamma readings of up to 25,000 cpm were noted at the western end of Sector 1. This area contained a slag/soil mixture at the surface. The second area of elevated activity was along the banks of the West Ditch, where gamma readings up to 66,000 cpm were identified.

Sector 2 consisted of the north-central portion of the site. Four localized areas of elevated activity (up to 26,000 cpm) were identified in the southeast corner of the Sector. Eight areas of up to 65,000 cpm were identified in the west-central portion of the sector. Numerous other localized areas of elevated activity up to 21,000 cpm were detected in slag/soil areas.

Sector 3 consisted of the northeast portion of the site. Activity up to 18,000 cpm was detected intermittently in slag/soil areas. A concrete foundation had up to 17,000 cpm. Two isolated areas north of N Street had activity of 50,000 and 20,000 cpm. Localized areas in the southeast portion of the Sector exhibited up to 82,000 cpm.

Sector 4 consisted of the southwest portion of the site and included the IWCS and the majority of the Central Ditch. Two localized areas of elevated activity up to 47,000 cpm were detected in the bottom of the O Street Ditch. Twenty-six localized areas of up to 107,000 cpm were detected in the field south of the O Street South Ditch and north of the IWCS. Nine areas up to 53,000 cpm were noted at the north edge of the IWCS. A 4-meter x 4-meter area of 120,000 cpm was detected on the northeast slope of the IWCS. Numerous other localized areas of elevated activity up to 40,000 cpm were noted in this Sector.

Sector 5 consisted of the southeast portion of the site and includes Building 401. Twenty-three locations of elevated activity up to 53,000 cpm were identified east of Campbell Street. Elevated activity as high as 17,000 cpm was detected on concrete pads in the area. Between X Street and Building 401 there were 45 isolated areas up to 40,000 cpm. In the fenced area of Building 401 there were eight areas up to 107,000 cpm. The area south of Building 401 had eight areas of elevated activity up to 93,000 cpm.

Sector 6 contained the West Ditch. Most of the West Ditch is on Niagara-Mohawk property. It crosses Sector 1 before intersecting the CWM property line. Five areas of elevated activity were identified. It was suspected that in four of the areas, the elevated activity was attributable to presence of granite rocks (glacial erratics) found during the survey.

The background level for the Site-Wide Gamma Walkover Survey was established at the beginning of the field activities by taking ten gamma survey counts of soil and pavement surfaces at the National Guard facility located north of the NFSS on the former LOOW. These ten survey counts were then averaged to establish the background value. The background value used for the Site-Wide Gamma Walkover Survey was 9,000 cpm.

The results from the gamma walkover survey are shown in Appendix B.

Results of the gamma walkover survey were used to guide subsequent soil, road/pad coring, sediment, and groundwater sampling efforts.

3.6 SURFACE SOIL CHARACTERIZATION

Surface soil characterization at the NFSS was performed using a phased-approach. Characterization activities included a review of historical site operations and previous investigations. This review was used to select the surface soil sample locations collected in Phase 1. Additional activities were performed in Phase 2 and 3 to fill data gaps, confirm previous results and provide sufficient and representative data to characterize the surface soil at NFSS. The information obtained from this characterization was used to support the RI and the BRA for the NFSS.

3.6.1 Objectives

The objectives for the surface soil characterization that supported the overall objectives included the following:

- Evaluate the distribution of potential chemical and radiological parameters of interest in the surface soil and investigate whether these potential SRCs exceed background levels.
- Confirm and investigate areas previously sampled and found to contain detectable concentrations of chemical or radiological constituents which may exceed background.
- Provide a basis for evaluation of the horizontal and vertical migration of SRCs and the estimation of source terms for use in the BRA.

3.6.1.1 NFSS Samples

During Phase 1 of this RI, over 60 surface soil samples were collected from the Building 401 Area, former shops area, former acid area, former Baker-Smith area, former radioactive residue storage areas and uninvestigated areas. These areas were sampled to investigate the presence or absence of chemical and/or radiological compounds associated with operation of the LOOW or AEC/DOE activities.

Approximately 140 surface soil samples collected during Phase 2 of the RI were located in the Building 401 Area, former shops area, former acid area, former Baker-Smith area, IWCS Area and uninvestigated areas. Samples were collected to:

- Further evaluate the presence and extent of chemical and/or radiological compounds found during Phase 1.
- Evaluate the presence or absence of chemical and/or radiological compounds in areas of the NFSS not investigated during Phase 1.

Over 250 surface soil samples were collected from locations throughout the NFSS during Phase 3 of the RI. Samples were collected in Phase 3 to:

- Further evaluate the presence and horizontal extent of chemical and radiological compounds found during previous phases.

- Further evaluate the presence or absence of chemical and radiological compounds in previously uninvestigated areas.
- Evaluate the presence or absence of chemical and radiological compounds at selected trench locations where visual observations or field monitoring indicated the potential presence of chemical compounds or the presence of radiological compounds at concentrations above background.
- Evaluate the horizontal extent of radiological parameters at areas with elevated gamma radiation, as investigated by the Gamma Walkover Survey of the NFSS described in Section 3.5.
- Evaluate the presence or absence of chemical and radiological compounds at the locations of abandoned drums.
- Fill data gaps identified during the preparation of the BRA Work Plan, including the collection of a sufficient number of samples in each EU to provide an adequate database for statistical analysis, comparison to background, and the development of an exposure source term.

Table 3-4 shows the surface soil samples collected from the NFSS, the parameter list for each sample, and a brief description of the rationale for the selection of each sample location. The locations of the surface soil samples are depicted by a gray triangle on Figures 3-7 through 3-13.

3.6.1.2 Background Samples

Background soil samples collected by EA for chemical analysis during the LOOW RI were also used for this RI. Tetra Tech collected additional background samples for radiological analysis. Background sampling locations were located in the buffer area of the former LOOW. These areas were considered to be representative background sampling locations, since they are close to NFSS, and are presumably un-impacted by LOOW or NFSS site-related activities. Background sample locations are shown on Figure 3-14. EA provided geological logging of all the test holes and all labor in the collection of the samples. EA also performed a topographic survey of the background sampling locations [*Final Report from Phase II Remedial Investigation at the Former LOOW in Niagara County, NY*, (EA 2002)]. Boring logs for background samples are presented in Appendix L.

Table 3-5 provides a summary of background surface soil samples, the approximate distance of the background locations to the closest NFSS border, and the rationale for sample location and analysis.

3.6.2 Surface Soil Sample Collection

Surface soils were defined as the interval from zero to six inches bgs. Samples were collected with clean, stainless steel hand augers, spoons and bowls. For each sample, soil was placed in a stainless steel bowl and surveyed with a PID for organic vapors and a gamma meter for radioactivity. These values and a description of the soil were noted on field data sheets, shown in Appendix M. Materials such as roots, rocks and sticks were removed from the six inch soil core and were not included in the samples. Only the most contaminated depth interval below the root zone was collect for analysis based on field screening results. Therefore, the sample volume sent

to the laboratory for analysis would not have included the entire 0 to 6 inch interval. If the root zone encompassed approximately 2 to 3 inches, the portion of the sample that was analyzed was from the top 3 to 4 inches of soil.

Samples for VOC analysis were collected prior to homogenizing the sample, to prevent loss of volatiles. The remainder of the sample was then homogenized and the remaining sample containers were filled. Sample containers were then placed on ice, documented on chain-of-custody forms and shipped to GEL for analysis.

3.7 SUBSURFACE SOIL CHARACTERIZATION AND BORING INSTALLATION

Subsurface soil characterization for this investigation was performed in three phases. Phase 1 sample locations were selected using information gained from a review of historical site information and previous studies performed by other contractors. Phase 2 and 3 sampling was performed to fill data gaps, confirm previous results and provide sufficient and representative data to characterize the subsurface soil at NFSS. Data collected during the subsurface soil characterization was used to support the RI and the BRA for the NFSS.

3.7.1 Objectives

The objectives for the subsurface soil characterization that support the RI objectives include:

- Evaluate the horizontal and vertical distribution of the chemical and radiological parameters of interest and investigate whether these compounds exceed background concentrations.
- Evaluate and confirm previous detections of chemical and radiological compounds.
- Provide sufficient and representative soil data for use in the BRA.

3.7.1.1 NFSS Samples

Over seventy subsurface soil samples were collected during Phase 1 of the RI from the Building-401 Area, former shops area, former acid area, former Baker-Smith area, former radioactive residue storage areas and previously uninvestigated portions of the site. Samples were collected to investigate the presence or absence of chemical and radiological compounds associated with operation of the LOOW or AEC/DOE activities.

Approximately fifty subsurface soil samples were collected during Phase 2 from the Building 401 Area, former shops area, former acid area, former Baker-Smith area, IWCS Area and previously uninvestigated portions of the site. Samples were collected to:

- Investigate the horizontal and vertical extent of chemical and/or radiological compounds found during the Phase 1 investigation.
- Investigate the presence or absence of chemical and/or radiological compounds in areas not investigated during the Phase 1 investigation.

Phase 3 of the RI consisted of several activities performed from May 2001 through October 2003. Almost 300 subsurface soil samples were collected during this phase from all areas of the NFSS. Samples were collected to:

- Further evaluate the horizontal and vertical extent of chemical and radiological compounds found in previous phases.
- Evaluate the presence or absence of chemical and radiological compounds at trenching locations selected based on the geophysical survey or the appearance of disturbed areas.
- Evaluate the horizontal and vertical extent of radiological parameters at locations where gamma radiation was found above background levels during the Gamma Walkover Survey.
- Investigate the presence or absence of chemical and radiological compounds at locations where abandoned drums were found.
- Fill data gaps identified during preparation of the BRA Work Plan, including collection of a sufficient number of samples in each EU to provide a suitable database for statistical analysis, comparison to background and the development of an exposure source term.

Subsurface soil samples are listed in Tables 3-6 and 3-7. The locations of the surface soil samples are depicted by a small red dot on Figures 3-7 through 3-13.

3.7.1.2 Background Samples

Background subsurface soil samples were collected from the buffer area of the former LOOW. This area was chosen because it was close to the NFSS and assumed to be unaffected by activities related to the LOOW or NFSS. Samples were collected for the LOOW RI and a topographic survey of the sample locations was performed as part of that RI (EA 1999). Figure 3-14 shows the sample locations. Table 3-8 lists the sample numbers and a brief rationale for their collection.

3.7.2 Subsurface Soil Sample Collection

The majority of subsurface soil samples were collected using either a truck- or all terrain vehicle (ATV)-mounted drill rig advancing a two-foot split spoon sampler or a five-foot continuous sampler. All borings were continuously sampled and logged from the surface to the termination depth. Copies of the boring logs are presented in Appendix N. The sampler was advanced ahead of the augers to obtain a relatively undisturbed sample. After the sampler was advanced (two feet for the split spoon and five feet for the continuous sampler) it was brought to the surface and opened. The exposed sample was then logged and scanned for gamma radiation and organic vapors. This process was repeated until the prescribed depth was reached.

Shallow (0.5 foot – 2.0 foot) subsurface soil samples, collected in areas identified as a result of the Gamma Walkover Survey, were collected with a stainless steel bucket auger. The bucket auger was advanced in approximately six-inch intervals. Each soil interval was then placed in a stainless steel bowl and scanned for gamma radiation and organic vapors.

Samples were collected from intervals exhibiting signs of contamination (staining, odors, elevated PID or gamma readings). If no signs of contamination were observed, samples were

collected at sand lenses, the soil-water interface, changes in lithology or the bottom of the borehole. Samples for VOC analysis were collected prior to homogenizing to prevent the loss of volatiles. The remainder of the sample was then homogenized and the remaining sample containers were filled. Sample containers were then placed on ice, documented on a chain-of-custody form and shipped to the laboratory for analysis.

3.8 SURFACE WATER CHARACTERIZATION

Initial surface water characterization activities were performed in Phase 1. Additional samples were collected in Phase 2 and Phase 3 to fill data gaps, confirm previous results, obtain background surface water data and provide sufficient and representative data for use in the risk assessment.

3.8.1 Objectives

The overall project objectives associated with surface water at the NFSS were to define the nature and extent of chemical and radiological contamination.

The objectives for the surface water characterization that support the overall objectives included the following:

- Provide a basis for the determination of the presence, absence and extent of SRCs in surface water associated with the network of ditches and low-lying wetland areas within the NFSS boundaries.
- Evaluate the potential for migration of parameters of interest onto off-site adjacent properties.
- Provide sufficient and representative surface water data for use in the BRA.

In order to achieve these objectives, characterization activities included a review of historical surface water monitoring results and collection of over 50 surface water samples from onsite and upstream locations within ditches and low-lying areas.

3.8.1.1 Selection of Sampling Locations

An extensive network of man-made ditches is present at the NFSS. Five east-west-trending ditches empty into two primary north-south ditches that direct the surface water drainage off-site to Four Mile Creek. Numerous low-lying areas are present that collect and retain standing water during wet portions of the year. Approximately 40 surface water samples were collected from ditches and low-lying areas located within the NFSS. The majority of the samples were collected from ditches and low-lying areas that drain portions of the NFSS formerly used to handle, store, treat, transport or dispose of chemical and/or radiological materials and waste. The majority of surface water sampling locations coincided with sediment sampling locations.

In addition, surface water samples were collected near the NFSS property boundary in order to evaluate the presence, absence and/or migration of site-related compounds in these areas.

Surface water sampling locations were selected based on the activities previously performed near or within the area, analytical results of previous site investigations, current RI results, and the need for sufficient and representative analytical data in specific areas. The locations of the surface

water samples are depicted by a blue triangle on Figures 3-7 through 3-13. A summary of the surface water sample locations, rationale for selection, sample designations, and analytical parameters are presented in Table 3-9 and 3-10.

3.8.1.2 Selection of Background Sampling Locations

Surface water enters the site via ditches as shown in Figure 2-1. To characterize background conditions, ten samples were collected in March and May 2003 at locations where surface water flows onto the NFSS. Background surface water sampling locations, shown in Figure 3-14, are prefaced with the label SWBKGD. With one exception, background surface water samples were collected on NFSS property immediately adjacent to and within a few feet of the site boundary. One background sample (SWBKGD-02) was collected on Niagara-Mohawk property a short distance off site, because right-of-entry was available.

A summary of the background surface water sample locations, rationale for selection, sample designations and analysis parameters are presented in Table 3-11.

3.8.1.3 Selection of Analytical Parameters

The analytical parameters at each surface water location were selected to detect a wide range of chemical compounds and radiological parameters based on the activities previously performed throughout the NFSS, previous results presented in the LOOW RI, and current RI sampling results. Rationale for the selection of analytical parameters for each surface water sampling location is provided in Tables 3-9 through 3-11.

3.8.2 Surface Water Sample Collection

Because many of the sample locations were in ephemeral streams, sampling activities were conducted during or after significant rain events or snowmelt event. Sampling activities were recorded on Field Boring Logs or specially designed sampling logs (see Appendix O). Information recorded on the forms during surface water sampling included the following:

- Location and sample number,
- Depth, flow direction and flow rate of the surface water,
- Collection date and time,
- Water quality parameters, and
- Evidence of contamination, i.e., odors, sheens, turbidity.

To minimize turbidity, surface water samples were collected prior to the collection of collocated sediment samples. Sampling equipment was either disposable or decontaminated prior to use. Before collection of the sample, the depth of the water was measured with a tape measure. The surface water was collected by submerging a precleaned sample container or dedicated disposable bailer into the water. When the water level was not sufficient for submersion, a peristaltic pump with disposable Teflon tubing was used to collect the sample. Filtered samples were collected using the peristaltic pump, disposable tubing and a 0.45-micron disposable filter prior to preserving the sample. After collection, samples were placed in an iced cooler for overnight shipment.

Following sample collection, water quality parameters and the flow rate of the water were monitored and noted. The pH, temperature, conductivity, oxidation-reduction potential (ORP),

and dissolved oxygen (DO) were recorded by placing the water quality meter probe into the surface water. When insufficient water was available to place the probe into the water, a small plastic cup was dipped into the water and attached to the probe. The direction of flow was noted and the velocity of flow was estimated by floating sticks or other small items in the water and noting the time it took for the item to travel a given length of the stream.

3.9 SEDIMENT CHARACTERIZATION

Sediment characterization at the NFSS was performed using a phased approach. Characterization activities included a review of historical site operations and previous investigations. This review was used to select the sediment sample locations collected in Phase 1. Additional activities were performed in Phase 2 and 3 to fill data gaps and provide sufficient and representative site data. The information obtained from this characterization was used to support the RI and the BRA for the NFSS. For this RI, over seventy sediment samples were collected from ditches and low-lying areas on the NFSS.

3.9.1 Objectives

The overall project objectives associated with sediment at the NFSS were to define the nature and extent of chemical and radiological contamination.

The objectives for the sediment characterization that supported the overall objectives included the following:

- Investigate the presence, absence and extent of chemical and radiological parameters of interest in sediment associated with the network of ditches and low-lying areas within the NFSS boundaries.
- Characterize background concentrations of parameters of interest at locations along the perimeter of the NFSS.
- Evaluate the potential for migration of parameters of interest onto off-site adjacent properties.
- Provide sufficient and representative sediment data for use in the BRA.

The network of ditches and the flow of surface water at the NFSS is described in Section 2. The majority of the sediment samples were collected from these ditches and low-lying areas. Approximately forty samples were collocated with surface water samples. The majority of the sediment samples were collected from areas that drain portions of the NFSS formerly used to handle, store, treat, transport or dispose of chemical and/or radiological materials and waste. These areas include the IWCS, the IWCS stormwater ponds, the former Shop Area, Building 401, the acid area, the Baker-Smith area and the area around former Building 434. The sediment samples were collected to characterize the presence or absence of the parameters of interest in the ditches and low-lying areas that may have originated from activities that occurred in these areas during operation of the LOOW or NFSS. Sediment samples were also collected near the NFSS property boundary in order to evaluate the migration of potential SRCs at the perimeter of the site.

The locations of the sediment samples are depicted by a large black dot on Figures 3-7 through 3-13. A summary of the sediment sample locations, rationale for selection, sample designations and analysis parameters are presented in Table 3-12 and 3-13.

To characterize sediment background conditions, ten samples were collected along the NFSS perimeter at locations where surface water flows onto the NFSS. The locations are outside the known zone of impacted sediment associated with the NFSS. Each background sediment sample was collocated with a background surface water sample. Background sediment sampling locations, shown in Figure 3-14, are prefaced with the label SDBKGD. A summary of the background sediment sample locations, rationale for selection, sample designations and analysis parameters are presented in Table 3-14.

The analytical parameters were selected to detect a wide range of chemical compounds and radiological parameters based on the activities previously performed throughout the NFSS, previous results presented in the LOOW RI, current RI sampling results, and the need for sufficient and representative data to characterize the sediments at the NFSS. Analytical parameters included: VOCs, SVOCs, pesticides, PCBs, metals, radionuclides and nitroaromatics, though not all samples were analyzed for all these parameters. Samples collected in 2003 were also analyzed for PAHs. Rationale for the selection of analytical parameters for each sediment sampling location is provided in Tables 3-12 through 3-14.

Analytical methods and required QC are described in Appendix F.

3.9.2 Sediment Sample Collection

Sampling activities were documented in field notebooks or project-specific sample logs and are included in Appendix P. Information recorded on the forms during sediment sampling included the following:

- Location and sample number;
- Collection date and time;
- Evidence of contamination, i.e., staining, odors, gamma readings, PID measurements;
- Sample depth; and
- Description of the sediment.

Sampling equipment was decontaminated prior to use at each sampling location.

Most sediment samples were collected to a maximum depth of 0.5 feet bgs with a steel shovel, stainless steel Ekman dredge, stainless steel bucket auger, or stainless steel spoon. Vegetation, rock and other debris were removed from the sediment sample. The sediment was placed in a stainless steel bowl and free water was decanted from the sample and organic vapor and gamma radiation were measured using hand-held field meters. VOCs were collected first prior to homogenizing the sample. The sample was then thoroughly homogenized and the remaining sample containers were filled. The containers were then placed on ice in a cooler and prepared for overnight shipment.

To evaluate the vertical extent of potential SRCs, some sediment samples were collected from specific depths. These samples are described in the following sections.

3.9.2.1 Sediment Samples Collected From Locations Based on Gamma Screening

Twelve samples were collected at specific depths from seven locations based on gamma screening results. The initial locations were surface samples (0 to 0.5' bgs) selected based upon the gamma walkover survey. A bucket auger was used to collect the sample. Additional sediment was collected from depths of 0.5-1.0 feet bgs, 1.0-1.5 feet bgs and 1.5-2.0 feet bgs. Each 0.5-foot interval was screened for gamma radiation during sample collection. A sediment sample was collected at the surface, at the interval with the highest gamma reading and, where possible, from the depth that exhibited a background gamma reading. Sample locations collected in this manner included SD746 through SD752.

3.9.2.2 Sediment Core Samples

Ten continuous sediment core samples were collected from six locations. The samples were collected using a 24-inch long thin-walled steel tube. At each sample location, the tube was manually pushed through the sediment, advanced approximately two inches into the native soil and manually removed. The entire core was extracted and placed in an aluminum pan. The sediment core was then scanned using a gamma radiation survey meter, measured and the native soil plug was removed. The sediment texture, color, odor and field screening results were recorded in a field notebook. Sediment core sample locations included SEDC01 through SEDC06. Samples of the soft sediment were collected from specific depths to vertically characterize the sediment. Core samples for VOCs were recollected several months after initial sample collection due to problems encountered concerning sample preservation.

3.10 GROUNDWATER CHARACTERIZATION, WELL INSTALLATION AND SAMPLE COLLECTION

Groundwater at the NFSS was characterized using a phased approach. Initial characterization activities were performed in Phase 1. Additional activities were performed in Phase 2 and 3 to fill data gaps, confirm previous results and provide sufficient and representative data to characterize the groundwater at NFSS. The information obtained from this characterization was used to support the RI and the BRA for the NFSS.

3.10.1 Sampling Objectives and Selection Criteria

The overall project objectives associated with groundwater at the NFSS were to define the nature and extent of chemical and radiological contamination, evaluate the potential release of contamination from the IWCS to the groundwater and investigate the potential for groundwater to infiltrate into the IWCS.

The objectives for the groundwater characterization that supported the overall objectives included the following:

- Investigate the presence, absence and extent of chemical and radiological parameters of interest in the UWBZ and LWBZ.
- Evaluate the distribution of parameters of interest in the UWBZ and LWBZ and identify locations where these constituents may exceed background levels.

- Confirm and investigate areas previously sampled and found to contain detectable concentrations of chemical or radiological constituents which may exceed background.
- Evaluate the dissolved nature of metals and radionuclides in groundwater to aid in determining their potential for migration.
- Provide a basis for evaluation of the horizontal and vertical migration of parameters of interest in the UWBZ and LWBZ.
- Investigate the direction of groundwater flow.
- Describe the physical characteristics of the water-bearing zones.
- Evaluate the potential for natural attenuation at locations where parameters of interest were found in the groundwater.
- Provide sufficient and representative groundwater data for use in the BRA.

In order to achieve these objectives, characterization activities included a review of historical groundwater monitoring results and boring logs, installation and sampling of temporary and permanent groundwater monitoring wells, collection of samples from previously installed monitoring wells, collection of water level monitoring data, performance of permeability testing and establishment of horizontal and vertical coordinates for each well point.

Filtered and unfiltered groundwater samples were collected as part of the groundwater evaluation process. For comparison purposes, background groundwater results were also obtained for filtered and unfiltered groundwater samples.

3.10.1.1 Selection of Groundwater Sampling Locations

Over two hundred samples were collected from groundwater monitoring wells installed prior to this RI (“previously installed wells”), newly installed monitoring wells (“new wells”), and TWPs installed during this RI. The majority of the wells was located near or within areas that were formerly used to handle, store, treat, transport or dispose of chemical and/or radiological materials and waste. These areas included the IWCS and vicinity, the former Shop Area, Building 401, the acid area, the Baker-Smith area and the former LOOW water tower (or “silo”) used to store K-65 residues.

In addition, groundwater samples were collected near the NFSS property boundary and areas where no LOOW, AEC or DOE operations were known to have occurred in order to evaluate the presence, absence or migration of parameters of interest in these areas.

Specific well locations were selected based on the activities previously performed near or within the area, analytical results of previous site investigations, current RI results, and the need for sufficient and representative analytical data in specific areas. The locations of the new and previously installed groundwater monitoring wells and TWPs are shown in Figures 3-7 through 3-13, and background wells and piezometers are shown in Figure 3-14. A summary of the permanent, temporary and background well networks including sample locations, well depths, rationale for selection, sample designations and analysis parameters are presented in Tables 3-15 through 3-18. In order to ensure adequate coverage of the entire site, some sampling locations

were selected to fill data gaps even if there was no historical evidence to suspect presence of contamination.

Previously Installed Wells

Approximately 80 groundwater samples were collected from 62 previously installed DOE monitoring wells prior to the initiation of this RI. Thirty-six of the 62 wells were screened in the LWBZ and the remaining 26 wells monitored the UWBZ. Most of these wells were located adjacent to or near the IWCS. Locations were selected to provide adequate information to characterize the UWBZ and LWBZs at the NFSS. During the course of the RI, some of the previously installed wells were re-sampled to confirm previous results, to provide additional information and/or as a part of the environmental surveillance program.

New Wells

Over 30 groundwater samples were collected from 25 new wells installed as a part of this RI. Twenty-two of the 25 new wells were screened in the UWBZ and the remaining three wells monitored the LWBZ. Well locations were generally selected to confirm the presence and extent of parameters of interest found in nearby TWPs and to provide sufficient data to develop a representative picture of the constituents present in the groundwater. Several of the new wells were re-sampled to confirm previous results and provide additional information for the RI and BRA.

TWPs

One hundred and twelve TWPs were installed in the UWBZ to characterize the shallow groundwater quality and depth. Locations were selected based on historical activities at the NFSS, results presented in the LOOW RI, current RI results and the need for sufficient and representative data for use in the RI and BRA.

Background Wells and Piezometers

Twenty-six wells and piezometers, located within the Modern Landfill property boundaries, were sampled to characterize background groundwater quality. The wells were located off-site and upgradient from the NFSS. Eight background wells monitor the UWBZ and 18 monitor the LWBZ. Four additional wells, MW7A, MW8B, MW9A and MW18, sampled in July 1998 during the LOOW RI, were not included in Table 3-18 but were included in the database for background groundwater. These wells monitor the UWBZ and were analyzed for metals only. The locations of the background wells are shown in Figure 3-14. Field observations recorded during the sampling of background groundwater are presented in Appendix Q.

3.10.1.2 Selection of Analytical Parameters

The analytes were selected to detect a wide range of compounds based on the activities previously performed near or within the areas, previous results presented in the LOOW RI, current RI sampling results, and the need for sufficient and representative data to characterize the groundwater at the NFSS. Rationale for the selection of analytes for each well is provided in Tables 3-15 through 3-17. Some of the samples collected were analyzed for the “full suite” of analytical parameters in order to cover potential lapses in site history.

3.10.1.3 Analytical Methods and QC Samples

Analytical methods and required QC are described in Appendix F of this document.

3.10.2 Permanent Well and TWP

Twenty-five permanent monitoring wells and 112 TWPs were installed during the RI. The following sections describe the procedures, materials, and testing performed during the installation of permanent and temporary monitoring wells.

3.10.2.1 Permanent Well Installation

Twenty-five permanent wells were installed with truck-mounted or ATV-mounted drill rigs using 4-1/4 ID hollow stem augers in accordance with EM 1110-1-4000. Borings were continuously logged for soil classification using either two-foot split spoons or five-foot Central Mining Equipment (CME) continuous samplers. Boring logs are presented in Appendix R.

3.10.2.2 Permanent Well Depths

Twenty-two wells were installed and screened in the UWBZ at depths ranging from ten feet to top of casing (TOC) to 25.5 feet to TOC (top of screened interval ranging from 4.7 to 12.75 feet bgs and bottom of screened interval ranging from 9.7 to 24.7 feet bgs). Three wells were installed and screened in the LWBZ at depths ranging from 42.15 feet to 44.50 feet to TOC (top of screened interval ranging from 30 to 32.25 feet bgs and bottom of screened interval ranging from 40 to 42.25 feet bgs). The depth of each well sampled is provided in Table 3-15 and 3-16.

3.10.2.3 Permanent Well Construction

Wells were constructed using the materials described below. Well construction logs are presented in Appendix S.

Casing (Riser):

The well riser consisted of new, threaded, flush joint, PVC pipe with a two-inch ID. The riser conformed to the ASTM-D 1785 Schedule 40 requirements, as well as National Sanitation Foundation potable water grade requirements.

Screen:

The well screen did not exceed ten feet in length and was constructed of factory-slotted, two-inch ID, Schedule 40 PVC pipe. The slot size was 0.010 inches. Screens were placed to intercept the water table.

Centralizers:

No centralizers were used.

Filter Pack:

A filter pack, consisting of clean 0.6 to 0.7 mm silica sand was placed in the annulus of each well from the bottom of the borehole to a level three to five feet above the top of the screen.

Bentonite Seal:

A three to five-foot seal, consisting of tamped 0.25-inch bentonite pellets or chips, was placed in the annular space immediately above the gravel pack. The thickness of the gravel pack and bentonite seal was measured through use of a weighted measuring tape. The bentonite pellets were hydrated using clean, nonchlorinated water. The thickness of the bentonite seal was adjusted in the field if the well was shallow.

Grout Mix:

A non-shrink, neat, cement grout was used as a surface seal. The grout consisted of not more than seven gallons of clean, approved water per bag (one ft³ or 94 pounds) of Portland cement (ASTM-C 150), plus 7% by weight of bentonite powder. The grout was placed from the top of the bentonite seal to the ground surface using a tremmie pipe. The surface seal extended to one foot below the frost line. After a minimum of 24 hours, the borehole was checked for grout settlement and more grout was added when necessary.

Well Protection:

Upon completion of the well, a suitable vented cap was installed to prevent material from entering the well. The PVC riser was surrounded by a large diameter protective steel casing, which stood 24 to 36 inches above ground level and set into concrete. The steel casing had a 0.25 inch diameter drainage port drilled immediately above the concrete collar and was provided with a lock and cap. A two-foot radius, six-inch thick concrete pad was constructed around the well casing above the final ground level elevation. Round steel bumper posts (two-inch diameter or larger), filled with concrete, were spaced equally around the well and embedded in concrete. The steel protective casing and posts were painted with permanent high visibility paint.

Survey Marker:

A permanent aluminum tag was attached to the protective casing of each well. Each aluminum tag was stamped with 0.125 inch tall letters with the following information:

- USACE Buffalo District,
- Well ID,
- Month and year of installation,
- Elevation: TOC PVC (top of PVC casing), and
- Ground surface elevation.

3.10.2.4 Permanent Well Development

New and previously installed wells were developed by pumping and surging after installation or, for the previously installed wells, prior to sampling. The development of the wells was performed in accordance with USACE guidance manuals, Preparation of Sampling and Analysis Plans, and Monitor Well Design and Installation (USACE 1994, USACE 1998), and modified as necessary during the RI to address specific problems encountered in the field.

Water purged from each well was pumped into truck-mounted tanks, transported to the investigative derived waste (IDW) storage area and transferred to 1,500-gallon storage tanks.

Phase 1 and Phase 2 (1999 – 2000) Development Protocol

After each well was constructed, but not sooner than 48 hours after grouting was completed, each well was developed by pumping and surging or bailing and surging using a submersible pump or a disposable bailer. The water level and depth of each well were measured and recorded prior to

initiation of well development. A portable water quality meter was used to monitor turbidity, pH, conductivity, temperature, DO, and ORP of the well water initially, three to five times throughout purging, and after development was finished. The wells were surged and pumped until a maximum of five times the standing volume of water present in the well casing and annulus was removed or until the turbidity of the water was less than or equal to 20 nephelometric turbidity units (NTU). Development time did not exceed six hours. The volume of water purged and any odor, color, turbidity, or elevated PID readings were noted on well development logs (Appendix T). Development continued until all the following criteria were met:

- The water was clear (<20 NTUs);
- There was less than 0.1 foot of sediment in the well; and
- Five times the standing borehole volume was removed, along with five times the volume of any water lost to the well during drilling or construction.

In the fall of 2000, the development criteria were revised to maximize the clarity of the groundwater in wells with limited recharge while minimizing the development time. For wells developed after September 2000, development continued until all the following criteria was met:

- Stabilization of pH (± 0.2 units), conductivity (<10% variation), and temperature (± 0.5 °C) for three consecutive readings (measured for each well volume);
- Removal of a maximum of three well volumes (standing water in the well casing and the saturated portion of the annulus), regardless of whether the stabilization criteria were met; and
- Pumping a well dry on three separate days.

Phase 3 (2003) Development Protocol

Wells were developed using procedures similar to those described above. Well development was considered complete when less than 0.1 foot of sediment remained in the well and three successive water quality measurements met all the following criteria:

- ± 0.2 units for pH,
- Relative percent difference (RPD) <3% for conductivity,
- ± 10 mv for ORP,
- ± 1 °C for temperature,
- RPD <10% for DO,
- RPD <10% for turbidity, and
- Turbidity <50 NTU.

3.10.2.5 Permanent Well In-situ Permeability Testing

In-situ permeability testing of the screened portion of the water-bearing zone of 50 groundwater monitoring wells was performed in 2001 (35 wells) and 2003 (16 wells) to estimate the hydraulic conductivity of the aquifer materials and investigate the aquifer characteristics of the UWBZ. Slug tests were performed according to ASTM D-4044-96 using a data logger and pressure transducer or an electronic water level indicator. The data set was analyzed using the software Aqtesolve and Single Well Solutions 3.1 in accordance with either the Bouwer and Rice Method

for unconfined aquifers (Bouwer and Rice 1976) or the Hvorslev Method for confined aquifers (Hvorslev 1951).

The in-situ permeability testing was conducted using the following method. The depth of water was measured with an electronic pressure transducer and electronic water level indicator. A PVC slug of known volume, which was filled with sand and sealed at both ends, was lowered into the water column (a slug-in or falling head test). Immediately after the bailer was lowered, the water levels were monitored by hand or were recorded using a Hermit 3000C Data Logger. If an electronic water level indicator was used, the water level was measured every five to ten seconds during the first two minutes and then every 30 seconds until the well stabilized. After the water level had stabilized, the slug was removed and the test was repeated as a slug-out (rising head) test. No water or other liquid was introduced into the well other than formation water from that well. If the well stabilized in 15 minutes or less, the slug test was performed at least three times. If the well was slow to recharge (15 minutes or more) fewer than three tests were conducted. Results are presented in Appendix U.

3.10.2.6 Permanent Well Water Level Measurements

In order to investigate the direction of groundwater flow, water levels were recorded during two separate water level monitoring events. The water levels in 69 TWP were measured on December 7, 1999, and water levels were recorded for 66 permanent monitoring wells on August 24, 2000. This was accomplished by recording water-levels within a 24-hour period using an electronic water level indicator.

3.10.2.7 TWP Installation

One hundred-twelve TWP were installed as described above using a truck or ATV-mounted drill rig and 4¼-inch ID hollow stem augers. Borings were continuously logged for soil classification using either two-foot split spoons or five-foot CME continuous samplers. Boring logs are presented in Appendix R.

Two-inch, Schedule 40 PVC, screens and risers were placed in each boring to facilitate collection of a groundwater sample. After the groundwater sample was collected, the screen and riser were removed and the borehole was sealed to grade with bentonite grout.

3.10.2.8 TWP Depths

TWP were installed and screened exclusively in the UWBZ. Depths ranged from 10.00 feet bgs to 25.00 feet bgs. The depth of each TWP is provided in Table 3-17.

3.10.2.9 TWP Construction

Each TWP was constructed using two-inch, Schedule 40 PVC, screens and risers. Screens were factory-slotted (0.010 inch) and were five or ten feet in length. Filter pack, bentonite seal and grout were not used in the construction of the TWP.

3.10.2.10 TWP Well Development

TWP were not developed after installation or before sample collection.

3.10.3 Groundwater Sample Collection Procedures

Throughout the course of the RI, groundwater-sampling procedures were continuously updated and revised to address problems encountered in the field. The groundwater sample collection methods used during this RI are described in the following section.

3.10.3.1 Groundwater Sampling Procedures for Permanent Monitoring Wells

Permanent monitoring wells were developed and/or purged either after installation or prior to sampling according to Section 3.10.2.4.

Phases 1 and 2

Prior to sample collection, water levels and well depths were measured to TOC. All monitoring and sampling were performed using a modified low-flow method. Low flow procedures are outlined in *USEPA Ground Water Issue for Low-Flow (Minimal Drawdown) Ground Water Sampling Procedures* (EPA 1996). Using a submersible pump and tubing each well was purged of a minimum of three and a maximum of five standing volumes of water present in the well casing and annulus. The pump was placed in the middle of the wetted screened interval and the water level and water quality meter were placed above the pump intake. To the extent possible, the purge rate was adjusted to match the well recharge rate (i.e. establish an equilibrated or near zero drawdown) and did not exceed 0.5 liters per minute.

Water quality parameters of pH, temperature, conductivity, ORP, and DO were measured prior to purging, throughout purging and when purging was complete. These measurements were collected in-situ with a YSI 600XL water quality meter while simultaneously purging the wells.

Purging ceased when:

- The turbidity was less than or equal to 20 NTU.
- Temperature, pH, and conductivity readings stabilized for three successive measurements to within ± 0.5 °C, ± 0.2 pH units, and less than 10% variation in conductivity.
- A volume equivalent to five times the standing volume of water present in the well casing and annulus was removed.

If a well was pumped dry before purging was complete, well purging ceased and the well was sampled after the well recharged. The length of time purged, volume of water removed, odors, color, turbidity, and PID readings were noted on a Well Monitoring Data Log (Appendix V). All purge water was pumped into plastic carboys, transported to the IDW storage area and transferred to 1,500 gallon storage tanks.

After purging, samples were collected using a disposable submersible pump, a Masterflex peristaltic pump or a disposable Teflon® bailer. Water was pumped through disposable tubing or bailed from the well and placed directly into the appropriate sample containers. The VOC samples were collected first with a disposable Teflon® bailer to minimize the loss of volatile organics. The remaining samples were collected using peristaltic/submersible pumps.

The hierarchy of analytes collected from the wells was typically: VOCs, SVOCs, nitroaromatics, pesticides/PCBs, and inorganic compounds (metals, radiological parameters). Samples collected for analysis for dissolved parameters were filtered using a peristaltic pump and dedicated

disposable 0.45-micron filter prior to sample preservation. After collection, groundwater samples were placed in iced coolers for overnight shipment.

Phase 3

Samples were collected as described above in Section 3.10.3.1, except the low-flow sampling technique used during this phase more closely followed the 1998 EPA low-flow sampling guidance document.

The wells were purged using submersible pumps and tubing equipped with rheostats or valves to accommodate low pump rates and enable adjustment of the rate to less than 0.5 L/minute. The pump was placed in the middle of the wetted screened interval and an in-line flow-through cell was attached to the tubing and the water quality meter. A water level indicator was lowered into the well and the water level was recorded. The pumping rate of the well did not exceed 0.5 L/minute and was adjusted to cause little or no drawdown in the well. If the well was pumped dry, pumping was suspended until the well recovered. Water quality parameters (temperature, pH, conductivity, ORP, oxygen concentration, and turbidity) were continuously monitored and were recorded every three to five minutes. Stabilization was defined as three successive readings for all parameters within the following ranges:

- pH: difference of less than 0.1 units between the high and low readings;
- Conductivity: RPD between the high and low readings of no more than 3%;
- ORP: difference of less than 10 mV between high and low readings;
- DO: RPD between the high and low readings of no more than 10%; and
- Turbidity: all readings less than 50 NTU and RPD between the high and low readings of no more than 10%.

In 2003, the hierarchy of analytes collected from wells was typically as follows: VOCs, unfiltered radiological parameters, unfiltered uranium, unfiltered metals, PAHs, filtered radiological parameters, filtered uranium, filtered metals, filtered gross alpha/beta, SVOCs, PCBs, pesticides, nitroaromatics, total gross alpha/beta and miscellaneous parameters.

3.10.3.2 Groundwater Sampling Procedures for TWPs

No development or purging was performed on TWPs prior to sampling.

Phases 1 and 2

Water levels and TWP depths were measured prior to sample collection. Samples were collected using a disposable submersible pump, a Masterflex peristaltic pump or a disposable Teflon® bailer. The VOC samples were collected first with a disposable Teflon® bailer to minimize the loss of volatile organics. The remaining samples were collected using peristaltic/submersible pumps. The sample rate, to the extent possible, was adjusted to match the well recharge rate.

The hierarchy of analytes collected from the wells was typically: VOCs, SVOCs, nitroaromatics, pesticides/PCBs, and inorganic compounds (metals, radiological parameters).

Samples collected for analysis of dissolved parameters were filtered using a peristaltic pump and dedicated disposable 0.45-micron filter prior to sample preservation. After collection, groundwater samples were placed in an iced cooler for overnight shipment.

When sufficient volume of water was available in the well, a portable water quality meter was used to monitor pH, conductivity, temperature, DO, ORP, and turbidity of the groundwater immediately preceding sampling. Water levels, well depths, odors, color, turbidity, water quality parameters, and PID readings were noted in a field notebook or on a Well Monitoring Data Log (Appendix V).

Phase 3

Samples were collected as described above except the sampling sequence of the analytes was amended. The hierarchy of analytes collected during 2003 was typically as follows: VOCs, unfiltered radiological parameters, unfiltered uranium, unfiltered metals, PAHs, filtered radiological parameters, filtered uranium, filtered metals, filtered gross alpha/beta, SVOCs, PCBs, pesticides and total gross alpha/beta.

3.11 INSTALLATION OF EXPLORATORY TRENCHES

As part of the RI performed at the NFSS, 27 exploratory trenches were excavated in May and June 2002 to characterize potential USTs, potential burial areas and anomalies found during the 2001 geophysical study conducted by SAIC. The trench lengths varied from 30 feet to 150 feet and the maximum excavated depth was ten feet.

The activities described in this section were based on the February 2002 SOW for *On-Site Trenching and Associated Sampling* (USACE 2002) issued by the Buffalo District of USACE and subsequent discussions.

3.11.1 Exploratory Trench Objectives

The objectives of the trenching task that supported the overall project objectives included the following:

- Confirm the presence or absence of suspected anomalies based on historical information and previous phases of the RI and visual inspection during a site walkover. Anomalies confirmed to be present were characterized (e.g. anomaly size, depth, condition, and type).
- Investigate anomalies disclosed as a result of the historical review and the geophysical survey of the site.
- Investigate the potential nature and extent for contamination, collect samples of subsurface soil from near identified anomalies, and analyze those samples for site-related compounds.

3.11.2 Trench Installation and Sample Collection

Trench locations and samples are shown on Figure 3-15 and the location justifications are described on Table 3-19. Figures 3-16 through 3-44 show cross-sections of the individual trenches.

Prior to the arrival of the excavating equipment on-site, the boundaries of each trench were staked and flagged and, for trenches designed to investigate geophysical anomalies, the presence of the anomaly within the footprint of the proposed trench was confirmed and flagged. The known locations of sewers and other subsurface anomalies in the vicinity of each trench were also staked and flagged. A limited gamma survey of the area was performed. The purpose of the survey was to accurately locate the trench in an area of interest to prevent mixing of potentially contaminated soils with uncontaminated soils.

All trenches were excavated with a track-mounted hydraulic excavator. Depth of the trenches ranged from one to ten feet bgs. The final trench depth was specified in the *Trenching Plan and Addendum to the FSP* (Maxim 2002b), and was specified after evaluating the known features of the items being investigated by the trenches, along with depth estimates furnished by the geophysical survey. In some cases, the trenches were terminated short of the planned depth if field evidence showed that the trench had been advanced two feet into uncontaminated, undisturbed native soil and magnetometer survey of the bottom of the trench did not indicate the presence of a geophysical anomaly. Because of this modification, the planned trenching activities were completed ahead of schedule and allowed for the excavation of several additional trenches.

A geologist directly supervised each trenching activity. The geologist directed the equipment operator to remove no more than one foot of soil from the bottom of the trench with each bucket and each bucket of excavated material was monitored with a PID and gamma survey meter and inspected for evidence of nitroaromatic contamination. After each one foot of excavation the bottom of the trench was surveyed with a magnetometer and gamma survey meter.

Specific sample locations within each trench were chosen in the field based on trench monitoring results and field observations. In general, sample locations were selected according to the following priorities:

- Samples were collected from areas exhibiting elevated PID or gamma meter readings;
- Samples were collected from locations near buried debris, subsurface utilities or stained areas;
- Samples were collected from hydraulically conductive zones such as sand lenses or gravel seams; and
- Samples were collected from the bottom of the trench. Surface soil samples collected from the exploratory trenches are described in Table 3-4. The over 70 subsurface soil samples that were also collected from the trenches are summarized in Tables 3-6 and 3-7.

The selection of analytes for the soil samples collected from the trench was based on previous phases of the NFSS RI. Sample collection methods and analysis parameters for surface and subsurface soil samples collected from the trenches are presented in Sections 3.6 and 3.7, respectively.

Each trench was backfilled with soil from the trench and compacted with the bucket of the excavator. Locations were then seeded with annual rye.

3.12 PIPELINE CHARACTERIZATION

The sewer systems and associated piping (collectively, “the pipelines”) serving the NFSS were constructed as a part of the former LOOW and supported the normal plant operations and TNT-manufacturing processes carried out at the LOOW prior to the creation of the NFSS. Constituents of interest potentially present in the pipelines included compounds related both to TNT manufacturing and to the handling and storage processes of radioactive materials later carried out at the NFSS.

3.12.1 Objectives

The objective of the subsurface piping network characterization at the NFSS was to define the nature and extent of chemical and radiological contamination and to obtain sufficient and representative data to:

- Evaluate the presence or absence of parameters of interest in the subsurface piping system;
- Investigate the migration and extent of potential SRCs in the piping network; and
- Evaluate direct, indirect and potential contaminant migration pathways associated with the subsurface piping system.

In order to achieve these objectives, characterization activities included the review of historical information concerning the LOOW and collection of sediment and water samples from the piping network.

3.12.2 Historical Background of the Subsurface Piping Network at the NFSS

The subsurface piping network constructed to serve the LOOW was also present during operation of the NFSS. The type of lines present at the NFSS included lines for water (for drinking, plant processes, and fire protection), sanitary sewer lines, storm water lines, and acid/process sewer lines.

With the exception of pipelines located in the vicinity of the IWCS, the original piping network installed during the construction of the LOOW exists relatively unchanged today. Some of the subsurface piping located in vicinity of the IWCS was sealed and/or excavated prior to construction of the IWCS.

Historical documents and as-built construction drawings indicate subsurface piping within the planned confines of the IWCS was excavated from building perimeters to an area immediately outside of the planned cut-off wall. The piping outside of the cut-off wall was sealed with concrete or grout. The piping was removed and/or sealed to eliminate “pathways for possible migration of radionuclides and to prevent future subsidence of compacted wastes.” (BNI 1984a, BNI 1995)

The configuration of the subsurface piping network is shown in Figure 1-2. Copies of the as-built drawings of the water and sewer lines are presented in Appendix W.

3.12.2.1 Fresh Water Lines

As-built facility drawings showed that approximately 1,360 linear feet of fresh water lines (drinking, process and fire protection) were located in the subsurface at the NFSS. The main trunk lines ran north-south along Campbell Street. Additional water lines for fire protection, cooling and drinking water were located along the eastern perimeter of the NFSS. The fresh water lines were located approximately eight feet below grade. East-west oriented lateral lines were present in the Acidification Area and at the northern and southern ends of the Shop Area (EA 1999). Remnants of a large network of waterlines were located in the southwest quadrant of the site south and east of the IWCS near the former location of the water treatment plant (Ordnance Department circa 1942, Acres American, Inc. 1981b, BNI 1984a, EA 1999).

The diameter of the pipes ranged from two inches up to 36 inches in diameter.

Drinking water was obtained from the City of Niagara Falls and was not processed through the water treatment plant. Drinking water lines entered the property from the chlorination station located south of Pletcher road. Drinking water lines were constructed of two-inch to ten-inch diameter cast iron pipe (Ordnance Department circa 1942, EA 1999).

3.12.2.2 Storm Water Lines

As-built facility drawings showed approximately 4,340 linear feet of stormwater sewer lines within the NFSS. Two separate east-west oriented lines were located south of N Street and north of O Street. Acidic storm water runoff from leakage of acid storage tanks, spills and housekeeping practices was directed into the stormwater sewer system and discharged at two outfalls located in the Central Ditch. The lines consisted of 24-inch VCP (Ordnance Department circa 1942).

3.12.2.3 Sanitary Sewer Lines

As-built facility drawings showed approximately 11,875 linear feet of the LOOW sanitary sewer system were present at the NFSS. The main sanitary sewer line on the NFSS ran to the north and was located along the west side of Campbell Street. Lateral lines extended into Building 401, Fresh Water Treatment Plant, shop area and the acid area. Wastes were directed northward to the LOOW waste water treatment plant (WWTP). At the WWTP, the sanitary sewer water was combined with the TNT and acid process wastewaters after pH neutralization. The combined wastewaters were discharged to the Niagara River through two outfalls. The sanitary lines located on the NFSS were constructed of 24-inch diameter VCP. (EA 1999, Ordnance Department circa 1942).

3.12.2.4 Acid/Process Sewer Lines

As-built facility drawings showed approximately 3,830 linear feet of acid/process sewer lines were present in the northeastern portion of the NFSS. These lines were associated with the acid area. Acidic wastewater from the production, concentration and storage of acids were discharged to the acid/process sewers. Acidic wastewater collected in this system was directed northwest toward the LOOW WWTP. Outside the NFSS boundary, the acid/process line combined with process lines from the TNT Manufacturing Area and discharged acidic and TNT-contaminated wastewater at the LOOW WWTP. At the LOOW WWTP, the acidic wastewater was neutralized and the TNT-contaminated water was diluted with the sanitary and acid process waters. The

combined wastewater was discharged from the LOOW WWTP to two outfalls located in the Niagara River. The acid/process lines were constructed of ten to 30-inch diameter VCP (EA 1999).

3.12.3 Selection of Sampling Locations

Approximately 45 sewer sediment/soil and 30 water samples were collected from 31 manholes, 11 exposed pipes, 8 sumps and 1 outfall. The sample locations were in EUs 2, 3, 4, 5, 8, 10, 11, and 13. An additional 6 water, 2 oil, and 14 sediment samples were collected from drains and sumps located inside Building 401 (EU 13).

Specific sampling locations were selected based on the presence of sufficient volume of sewer sediment and/or water for sampling purposes, the activities previously performed near or within the area, and historical and current analytical results. The locations of the manholes, pipes and sewers that were sampled are shown on Figures 3-7 through 3-13. A summary of the visual examination of the piping network, sample locations selected, rationale for selection, sample designations and analysis parameters are presented in Tables 3-20 and 3-21. The locations of samples collected inside Building 401 are shown in Figure 3-45 and sample designations, locations and analysis parameters are summarized in Table 3-22. Field notes for sediment and surface water sampling are presented in Appendix X.

All manholes found on the NFSS were sampled, except those that did not contain either sediment or water. In 2003, manholes MH06, MH07, MH08, MH41, MH43 and MH45 were re-sampled to confirm previous results and obtain additional information to characterize the extent of potential SRCs in the piping network. Approximately 30 water and 30 sediment samples were collected from the 31 manholes sampled during the RI.

Most exposed pipes and sumps identified during the reconnaissance of the sewer lines were connected to the acid/process sewer system or with acid storage tanks. Eleven of the 74 exposed pipes and eight of the 35 sumps were sampled. Pipes and sumps were selected for sampling based on:

- Accessibility of the pipe or sump,
- The presence of a sufficient volume of sediment and/or water,
- The position of the drain or sump within the buildings drainage network,
- Historical activities in the area,
- Past and current analytical results, and
- Geographical distribution of samples to provide a representative picture of the potential SRCs present in the piping system.

With the exception of PIPE28, PIPE74, and SUMP35, the pipe/sump locations were associated with the acid processing lines or acid storage tanks. PIPE28, PIPE74, and SUMP35 were located in isolated areas that are not thought to be directly or indirectly connected to the sewer network.

In 2003, one exposed pipe (PIPE74) was resampled to confirm previous results and obtain additional information to characterize the extent of SRCs in the piping network.

A total of four water (three from exposed pipes and one from a sump) and 20 sediment samples (12 from exposed pipes and eight from sumps) were collected from the 11 exposed pipes and eight sumps sampled.

Surface water, sediment and soil samples were collected near the two outfalls associated with the storm sewers. These outfalls discharge directly to the Central Ditch. The samples were collected in Phase 1 and Phase 2 of the RI, prior to the pipeline characterization.

In 2003, Outfall 2 was resampled to confirm previous results and obtain additional information to characterize the extent of SRCs in the piping network.

Fourteen drains and sumps located within Building 401 were selected based on the following:

- Accessibility of the drain or sump,
- The presence of a sufficient volume of sediment and/or water,
- Geographical distribution of samples to provide a representative picture of the potential SRCs present in the indoor piping system associated with the structure, and
- Historical activities that took place within specific rooms.

3.12.4 Sample Analysis and Rationale for Selection

Due to the widespread handling and storage of radiological wastes and the widespread dispersion of fly ash and coal residuum from power generation, sewer water and sediment samples were typically analyzed for radionuclides and SVOC. VOCs were included as analytes when visual evidence of contamination such as a sheen or odor was observed during the visual examination of the piping network. In addition, selected samples were analyzed for metals, PCBs, pesticide, VOCs and nitroaromatics based on historical use and previous analytical results. Rationale for the selection of the analytes for each sample location is provided in Tables 3-20 and 3-21. Sample locations are shown in Figures 3-7 through 3-13.

When sufficient sample volume was available, drain water, oil, and sediment from inside Building 401 was analyzed for the entire suite of parameters (VOC, metals, radionuclides, SVOCs, PAHs, pesticides and PCBs) in order to detect a wide range of compounds. When sample volume was minimal, the parameters were selected based on the historical use of the room/building. Analytes for each drain sample are summarized in Table 3-22. Sample locations are shown in Figure 3-45.

Analytical methods and required QC are described in Appendix F of this document.

3.12.5 Sampling Procedures

Prior to collection of each water and sediment sample, the depth to water, depth to sediment, height of the water column, and thickness of the sediment layer were recorded. When both water

and sediment samples were collected from the same location, the water sample was collected first to minimize turbidity.

Water samples were collected using dedicated low-voltage submersible pumps and disposable Teflon[®] tubing. If the depth of water at a given sample location was not deep enough to allow the use of submersible pumps, a peristaltic pump with disposable Teflon tubing or a disposable bailer was used. Drain samples within Building 401 were collected using a peristaltic pump or disposable Teflon[®] bailer. The sample was pumped directly into the appropriate sample containers. Samples for dissolved metals were filtered using a 0.45-micron disposable filter in the field prior to the addition of preservative. If sufficient water was available after sample collection, the probe of the water quality meter was placed in the water in the manhole, pipe or sump and the temperature, conductivity, DO, pH and ORP were recorded.

A light, non-aqueous phase liquid referred to as “oil” was present above the drain water inside Building 401 at two locations. The oil was collected first using a peristaltic pump, prior to collection of water or sediment.

When water was present at the outdoor manhole or pipe sample location, sediment samples were collected using a clean Ekman Dredge. A stainless steel hand auger with extensions was used to collect dry sediment. A stainless steel spoon or bucket auger was used to collect sediment from drains located inside Building 401.

It was not possible to collect sediment samples from several of the pipes because the pipes had 90-degree elbows located one or two feet below grade. At these locations, a soil sample was collected adjacent to the bottom of the elbow using a bucket auger.

Soil/sediment from the dredge or hand-auger was placed in a clean stainless steel bowl, free water was decanted from the sample material and the sample was scanned for gamma radiation. A portion of the sample was also placed in a plastic bag for subsequent headspace monitoring for organic vapors using a PID. VOC samples were collected (where applicable) and the sample was then thoroughly mixed and placed in the appropriate sample containers.

3.13 RAILROAD BALLAST CHARACTERIZATION

Several rail lines served the site. These lines were operational both during the operational period of the LOOW and the period during which radioactive materials were transported to the NFSS. During Phase 1 of the RI, soil samples were collected near these lines and analyzed for chemical and radiological parameters. While performing the field gamma survey prior to collecting these soil samples, it was discovered that the ballast material exhibited higher gamma readings than the surrounding soil. In order to further evaluate these elevated field readings, five railroad ballast samples were collected during Phase 2 of the RI.

3.13.1 Objectives

The objective of the railroad ballast characterization at the NFSS was to define the nature of the elevated field gamma readings observed in the railroad ballast at three locations during Phase 1 of the RI. Two additional samples were also collected from rail lines near Building 401.

The ballast samples were analyzed for the following:

- Actinium-227, americium-241, cobalt-60, protactinium-231, radium-226, radium-228, thorium-228, uranium-238, thorium-230, thorium-232, uranium-234, and uranium-235;

- Gross alpha/beta; and
- Total uranium.

Table 3-23 shows the list of ballast samples collected, collection dates, and rationale for sample locations. The sample locations are depicted by a yellow square with a “B” in the center on Figures 3-7 through 3-13.

3.13.2 Sample Collection

The railroad ballast samples were collected in a manner similar to surface soil samples. A limited gamma survey was performed in the vicinity of the proposed sample locations and the location with the highest gamma reading was selected for collection. Approximately one kilogram of railroad ballast material was then containerized and shipped to Maxim’s geotechnical laboratory, where the sample was crushed to pass a number 20 sieve. The crushed samples were then submitted to GEL for radiological analysis.

3.14 ROAD/BUILDING 401 CORE CHARACTERIZATION

3.14.1 Objectives

Gamma survey activities detected gamma readings above background at several locations on asphalt roads. Fourteen core samples were collected during Phase 2 of the RI. Five additional roadway cores were collected during Phase 3. The cores were submitted for radiological analysis to investigate the presence of radionuclides associated with the roadways.

Also during Phase 3, ten cores were collected from the floor slab inside Building 401. The Building 401 cores were collected from stained areas and locations near floor sumps and drains. In order to investigate whether any of the previous activities that occurred inside Building 401 had resulted in the release of chemical or radiological compounds, the cores collected from inside Building 401 were submitted for total metals, pesticides, PCBs, VOC, SVOC, and radiological analysis.

3.14.2 Sample Collection

Core samples were collected with a concrete coring machine. The following paragraphs summarize the road/pad core sample collection procedure that was originally presented in Appendix F of the FSP Addendum, Phase 2 edition.

- A limited gamma survey was performed with a NaI gamma 2 inch by 2 inch detector on the paved area within 30 feet of the proposed core sample location. The point with the highest gamma reading was cored.
- A core of the pavement was collected. The coring machine and bit were decontaminated before each use.
- The sample was removed from the bit and examined and surveyed with a NaI detector. Due to the way the concrete was poured, occasionally the core samples inhibited distinct layers. If the sample contained distinct layers, each layer was surveyed separately. The

portion of the core with the highest gamma reading was submitted for sample preparation and analysis.

- The sample was prepared for analysis by crushing the sample to pass a number 20 sieve and was submitted to GEL for analysis.

The locations of the core samples are depicted by yellow squares with a “C” in the center in Figures 3-7 through 3-13. Table 3-24 shows the samples collected, collection dates, and rationale for sample locations organized by EU. The analytes selected at each sample location, and the rationales for selection of analytes and locations, are also shown on Table 3-24.

For the Building 401 cores, the method by which sample locations were selected was modified. Because of the varied past uses of Building 401, there was a broad range of chemicals and radiological compounds that were potentially present. Also, the purpose of the coring, in addition to allow the collection of a sample of the concrete floor, was to facilitate the collection of subsurface soil samples below the floor slab. Locations were first selected based on presence of staining on the floor. Other locations were selected based on cracks in the concrete, which could serve as migration routes to the subsurface. Lastly, some locations were selected based on the apparent former use of a particular room or area. The core samples were collected in accordance with steps two through four, described above. The justifications for each core location are given in Table 3-24. The locations of the core samples inside Building 401 are shown on Figure 3-46.

3.15 NIAGARA-MOHAWK INVESTIGATION

Property owned by the Niagara-Mohawk Power Company is adjacent to the NFSS along its western border. This strip of land was not identified as a vicinity property.

This property was once part of the LOOW. The West Ditch transects the property north to south. The West Ditch had been documented as being radiologically contaminated and later remediated (BNI 1990). No analytical data documenting remediation was available.

Gamma walkover survey results on NFSS property near the border with Niagara-Mohawk property were nearly two times background.

3.15.1 Objectives

The objective of work at the Niagara-Mohawk property was to perform a CERCLA investigation of the presence and extent of FUSRAP-related radiological and/or chemical contamination on the Niagara-Mohawk Power Company property. As this property is privately owned, the government only has the authority to address contamination that is related to the adjacent FUSRAP site (i.e. NFSS).

For this investigation, surface soil and subsurface soil, sediment, and surface water samples were collected.

Sampling locations were chosen based on observations made during the reconnaissance of the property and on the results from a limited gamma walkover survey. In order to facilitate the gamma walkover survey, a 200-foot wide lane, centered on the West Ditch, was cleared of trees and shrubs prior to the survey.

Both chemical and radiological analyses were performed on the samples collected from the Niagara-Mohawk property. The chemical analyses were performed solely for waste characterization purposes because of limits in the authority of FUSRAP.

Figure 3-11 shows the sample locations. Tables 3-25 and 3-26 list the samples collected and include rationale for sample location and analytes.

3.15.2 Sample Collection Methods

Surface soil, subsurface soil, sediment and surface water samples were collected using the same methods prescribed for the NFSS. These methods are described in Section 3.6.2 (Surface Soil), Section 3.7.2 (Subsurface Soil), Section 3.8.2 (Surface Water) and Section 3.9.2 (Sediment).

Further information concerning collection of soil, sediment, and surface water samples is presented in Appendix Y.

3.16 INVESTIGATIVE DERIVED WASTE GENERATION AND DISPOSAL

Field activities conducted during the completion of this RI resulted in the generation of both solid and liquid IDW. This IDW included:

- Soil cuttings,
- Decontamination pad solids,
- Personal protective equipment (PPE),
- PVC piping,
- Plastic tarps,
- Canvas,
- Well casings and screens,
- Deteriorated drums/scrap metal,
- Concrete core samples,
- Decontamination water,
- Purge water,
- Well development water,
- Abandoned drums and their contents,
- Wood and Styrofoam used at the IDW liquid storage pad,
- Vegetative growth removed from the IDW liquid storage tanks, and
- IDW liquid sludge cake.

3.16.1 Solid IDW

Solid IDW generated during field activities was containerized in 55-gallon drums. Deteriorated drums, including their contents and adjacent soils, scrap metal, and decontamination pad solids were placed in 85-gallon polyethylene overpack drums. All drums were initially stored outdoors on a former building pad in the northern portion of the NFSS. Drums were palletized and covered with tarps to prevent water from accumulating on the drum tops thereby reducing infiltration of water into the drums and reducing drum corrosion. Drums remaining on-site after conclusion of the RI field investigations were transferred to Building 401 to protect them from the elements until shipment.

3.16.1.1 Solid IDW Characterization

Soil cuttings generated during installation of boreholes were containerized in the 55-gallon drums and analyses of representative samples from each borehole were used to characterize the content of each of these drums. The abandoned drums and drums containing the concrete cores from Building 401 were also sampled and analyzed to characterize the waste. Drums containing contact wastes (PPE, well casings, tarps, canvas, decontamination pad solids, debris, etc.) were characterized by using an algorithm to estimate radionuclide activity in each container. NFSS mean radionuclide concentrations (pCi/g) were multiplied by estimated soil/media weight (g) to characterize container activity. By subtracting the tare weight of the container from the container's gross weight, a "net" content weight was calculated. The estimated soil weights for each waste type modeled in the algorithm included conservative assumptions concerning the amount of soil present in each drum. Based on the waste type (PPE, well casings, soil, etc.), a fraction of the weight was estimated as soil (1%-100%). By multiplying the estimated amount of soil by the mean concentration of each radionuclide in the appropriate waste stream, an overall container radionuclide inventory was calculated.

3.16.1.2 Shipment and Disposal

Two shipments of IDW drums were made to the contracted disposal facility, Waste Control Specialists in Andrews, Texas. For the first shipment, the drums remained on pallets in the outdoor IDW storage area until shipment arrangements were made. The drums were then prepared for pickup by trimming plastic from under the lids and removing rust and debris from the drum lids. As mentioned above, the second shipment of drums was transferred to Building 401 to protect them from the elements prior to shipment.

The hauler contracted to transport the drums, T.A.G Transport, began loading the first shipment of drums on the first of three trucks on September 18, 2002 with 22 pallets containing 64 drums being loaded this day. On September 19, 2002 two more trucks from T.A.G. Transport were loaded carrying 22 pallets containing 64 drums and 20 pallets containing 61 drums, respectively. Before leaving the site, both the drums and the trucks were scanned for radiological characteristics. All three trucks arrived at Waste Control Specialists on September 23, 2002 with a total of 189 55-gallon drums.

The second shipment consisting of approximately 160 drums was transported by T.A.G. Transport to Waste Control Specialists in September 2006. Approximately ten drums that did not meet the definition of Naturally Occurring Radioactive Material (NORM) due to low levels of Pu-239/240 and Sr-90 could not be disposed of at Waste Control Specialists. These drums were brokered to Energy Solutions in Utah for disposal.

3.16.2 Liquid IDW

Liquid IDW generated during field activities was containerized in temporary storage containers located near Building 429. In January of 2000, 10,000 gallons of liquid IDW was transported from the site and disposed of at the City of Niagara Falls Waste Water Treatment Plant. Another 3,500 gallons was disposed of at the same facility in November of 2001. After these initial disposal efforts, seven 1,500 gallon polyethylene tanks containing approximately 5,050 gallons of liquid IDW including NFSS purge, decontamination, and well development water, Vicinity Property G decontamination water, and Modern Landfill purge water remained onsite.

3.16.2.1 Liquid IDW Characterization

Before the remaining liquid IDW could be disposed, the New York Department of Environmental Conservation (NYSDEC) requested that the wastes be characterized to ensure it met the receiving POTW's discharge regulations. The remaining liquid IDW in six of the tanks (Tanks 1, 2, 3, 5, 6, and 8) was sampled as part of Tetra Tech's original RI field effort in 2000 and 2001. In order to further characterize the IDW in these tanks, as well as the IDW in Tank 4, a sampling effort was performed in October of 2004.

During the field sampling effort, the sediment in the bottom of each tank was agitated in order to mix the tank contents. Water samples were then taken by pumping the IDW through a 10-micron filter bag attached to the end of a pump discharge hose. An unfiltered sample was also taken from Tank 4. The samples were analyzed at General Engineering Laboratories (GEL), Charleston, SC by alpha spectroscopy and gamma spectroscopy for a parameter list approved by NYSDEC. The 10-micron filtered sample was also filtered through a 0.45-micron filter in the lab and the resulting effluent was analyzed by alpha spectroscopy and gamma spectroscopy.

The analytical results from the 2004 IDW sampling event as well as the 2000 and 2001 IDW liquid sampling events were reviewed by both NYSDEC and the City of Lockport, NY. Both entities approved the disposal of the liquid IDW at the City of Lockport, contingent on filtering the liquid in Tanks 1, 4, 5, and 8.

3.16.2.2 Shipment and Disposal

As mentioned previously, 13,500 gallons of liquid IDW were disposed of at the City of Niagara Falls Waste Water Treatment Plant in January of 2000 and November of 2001. For the remaining 5,050 gallons, USACE performed the requested liquid IDW filtration for Tanks 1, 4, 5, and 8 prior to disposal. The liquid in Tank 1 was filtered through a 5-micron filter bag and the liquid in Tanks 4, 5, and 8 was filtered using a 10-micron filter bag. Tanks 2, 3, and 6 did not require filtration. All of the liquid was then consolidated before being released to the contracted septic hauler, Western New York Septic Tank Cleaning Service. The approximately 5,650 gallons of liquid, including 5,050 gallons of filtered IDW and 600 gallons of rinse water, was transported in two loads to the Lockport Waste Water Treatment Plant in Lockport, New York for disposal in May 2005.

3.16.3 Hydraulic Oil

One additional 55 gallon drum left onsite containing hydraulic oil was shipped to Safety-Kleen Systems, Inc. for reprocessing.

3.17 LANDFILL SURVEY

In order to support the evaluation of future potential remedial actions, a landfill survey was conducted early in the RI/FS process. The survey investigated disposal locations outside of the state of New York through telephone and written contact. Since that time, changes in legislation and associated changes in regulatory status of potential disposal sites have occurred. These changes may affect the disposition options for residues and wastes at NFSS. Section 3.17.1 and 3.17.2 present the results of the early landfill survey. Section 3.17.3 discusses pertinent activities that occurred since August 2004.

3.17.1 Objectives

In 1999-2000, a nationwide landfill survey was performed to identify alternative disposal alternatives for residues and related wastes. The objectives of the landfill survey were to answer the following questions:

- Is off-site disposal legally feasible? If landfill disposal is feasible, is pretreatment required to render the chemical and radiological characteristics of the NFSS residues and wastes suitable to comply with landfill waste acceptance criteria (WAC)?
- Do appropriate resource recovery or recycling technologies exist for application to residues and waste?
- Will existing DOE facilities accept NFSS residues and wastes?

3.17.2 Results

The findings of the landfill survey were presented in a report to the USACE titled *Task 3- Landfill Survey: A Survey of Facilities with Potential to Accept K-65 Residues from the Niagara Falls Storage Site*; (Maxim 2000). Key findings presented in that report are summarized in the following sections.

3.17.2.1 Off-Site Disposal

None of the 19 off-site waste treatment/disposal and three resource recovery firms contacted indicated a capability to accept untreated residues and waste. Three firms (Energy Solutions [formerly Envirocare], Envirosafe, and Waste Control Specialists) have USACE contracts in place to receive FUSRAP wastes. However, the specific activity of the residues and wastes is significantly higher than these firms' existing WAC. Energy Solutions and Waste Control Specialists stated that they could potentially accept the residues and wastes after treatment at their facilities or pretreatment at the NFSS, or after receipt of a special one-time exemption from their permit requirements.

3.17.2.2 Recovery or Recycling

Constituents of residues and wastes with potential resource recovery value include uranium and vanadium. The only firm contacted during the survey that indicated a potential interest in recovery of these constituents was International Uranium Corporation (IUC). Without preliminary extraction studies, it is not known if a recovery process is feasible. However, if such a process were determined to be feasible, IUC would reconfigure existing equipment at its White Mesa Mill in Utah to implement the recovery process of the NFSS residues and wastes. After completion of the extraction process, the remaining tailings would be stored in an on-site mill tailings impoundment for disposal.

Issues related to transportation of the residues and wastes, and potential radon exposures, limit the feasibility of this option. In addition, the State of Utah might not approve of this option.

3.17.2.3 Disposal at Other DOE Facilities

Three DOE facilities (Hanford, Nevada Test Site, and the Savannah River Site) will accept some types of radioactive materials from off-site government generators, though a DOE directive (*DOE Preferred Alternatives for Disposal of LLW and MLLW –12/10/99* [see Appendix Z]) allows only Hanford and the Nevada Test Site to accept waste from off-site DOE generators. A memorandum of understanding between the USACE and DOE, dated 3/17/99, potentially allows the disposal of the NFSS residues and wastes at either Hanford or the Nevada Test Site, but only after it was determined that no commercial disposal sites will accept the residues.

3.17.3 Disposition of NFSS Residues and Wastes Since August 2004

The ultimate disposition of the residues and wastes in the IWCS will be evaluated in the FS. A primary consideration in disposing radioactive material is its classification. At the end of 2004, language included in the Energy and Water Development Appropriations Act designated the NFSS wastes as "byproduct material" as defined by Section 11e(2) of the Atomic Energy Act of 1954, as amended. This legislation allows for the disposition of the NFSS wastes in a Nuclear Regulatory Commission (NRC) regulated or Agreement State regulated facility. It also eliminates uncertainties regarding waste classification of the NFSS residues.

In August 2004 Waste Control Specialists LLC filed an application with the Texas Commission on Environmental Quality to modify its license to allow for disposal of radioactive waste that is the responsibility of the federal government, among other requested modifications. If the application is approved, the Waste Control Specialists' facility in Andrews County, Texas appears to be the most promising disposal site for the residue material, if it is determined during the FS that the wastes should be excavated and disposed offsite. An alternate disposal facility is Energy Solutions, LLC in Clive, Utah, although an amendment to the current WAC may be required.

The exact language from Section 312 of the Energy and Water Development Appropriations Act (Fiscal Year 2004) which outlines the framework for disposal of NFSS residues and wastes at Waste Control Specialists or Energy Solutions is presented as follows:

“Section 312. Notwithstanding any other provision of law, the material in the concrete silos at the Fernald uranium processing facility currently managed by the DOE and the ore processing residual materials in the NFSS subsurface waste containment structure managed by the USACE under the FUSRAP shall be considered “byproduct material” as defined by section 11e.(2) of the Atomic Energy Act of 1954, as amended (42 U.S.C. 2014(e)(2)). The NRC or an Agreement State, as appropriate, shall regulate the material as “11e.(2) by-product material” for the purpose of disposition of the material in an NRC-regulated or Agreement State-regulated facility.”

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4.0 RESULTS OF FIELD ACTIVITIES AND DETERMINATION OF SRCs

4.1 INTRODUCTION

This section presents the results and findings from the field activities performed for this RI. Section 4.4.2 presents the statistical method by which SRCs were identified.

4.2 TRENCH FINDINGS

In general, trenches were excavated to a depth of one to ten feet below grade and were terminated when undisturbed native soil was encountered. Sections of trenches T301, T304, T404, and T413 were terminated before native soil was encountered due to the influx of water from gravel deposits (principally railroad ballast) at the surface.

Analytical results from surface and subsurface soil samples are discussed in Sections 4.5 and 4.6.

Significant findings resulting from the installation of the trenches are:

- Buried debris, sample containers (apparently unused), paper and other solid wastes were found in trenches T802 and T808, located north of the IWCS. Numerous small chips of radioactive waste residue with elevated gamma readings were found near the ground surface in the vicinity of these trenches.
- Soil in trenches T202 and T205 had an organic or 'pesticide-like' odor, though no staining or elevated PID readings were observed to provide a further basis for identification of the chemical nature of this odor.
- Unidentified concrete structures were found in trench T201 on the west side of Building 401. It is thought that these structures may be the remnants of above ground or USTs. Historical photographs show an UST pool south of Building 401 as well as concrete tank cradles that were unearthed (and potentially reburied). No evidence of contamination was observed during the excavation of this trench.
- Except as noted for trench T201, no evidence of USTs was found. Anomalies identified by a geophysical survey of the site were attributed to buried utilities, debris or saturated clays.
- A surface soil sample (TS812-2928-062), collected from trench T812 near the south gate, contained concentrations of several radiological parameters above background.

A summary of field observations from each trench is contained in Table 4-1 and shown on Figures 3-16 through 3-44.

4.3 SUMMARY OF DRUM SAMPLES, ROAD/PAD CORES, RAILROAD BALLAST, AND GENERAL CHEMISTRY SAMPLES

Field activities included the collection of drum samples, road/pad core samples, and railroad ballast as discussed in the following sections; however, the analytical results were not used for the determination of SRCs.

4.3.1 Road/Building 401 Cores and Railroad Ballast Samples

Sample designations, location and analysis parameters are discussed in Section 3.13 and 3.14 and are summarized in Tables 3-23 and 3-24. Analytical results are presented in Appendix AA.

4.3.1.1 Background Sample Analytical Results

No suitable background data set was available for these matrices.

4.3.1.2 Road/Building 401 Cores and Railroad Ballast Analytical Results

Because no suitable background data sets for the cores or railroad ballast media were available, it was not possible to determine if any parameter found in these samples exceeded background. For this reason, SRCs were not determined for these media. Table 4-2 summarizes all analytical results above the laboratory reporting limits for the road/Building 401 cores and railroad ballast samples.

4.3.2 Drum Samples

Two abandoned and deteriorated drums were found on the ground surface in EUs 2 and 4. Samples were taken from the two drums as well as from the soil beneath the drums. The deteriorated drums were subsequently re-drummed for disposal. Analysis results from the samples collected from these drums are presented in Appendix AA. Table 4-3 summarizes all analytical results above the laboratory reporting limits for the drum samples.

No suitable background data set was available for these matrices; however, the analytical results were used to determine the appropriate disposition of the drums.

4.3.3 General Chemistry Samples

Samples for general chemistry parameters were collected for use in groundwater modeling efforts, as a supplement for evaluating natural attenuation of constituents in the RI, and for evaluating technologies in the FS. Table 4-4 summarizes all analytical results for the general chemistry samples.

4.4 DATA EVALUATION METHODS

4.4.1 Determination of Background

Background concentrations were used in the identification of SRCs presented in this RI and in the evaluation of human health risk presented in the BRA. The determination of background involved the establishment of a background data set for each medium and the calculation of a background value for each analyte within each medium. Background was determined for the following media during the NFSS RI: groundwater, sediment, soil (0-10 feet), surface soil (0-0.5 feet), and surface water.

Background samples for the NFSS were collected along the inside perimeter of the boundary of the former LOOW DERP-FUDS site. Because the potential for impact to these sample locations could not be absolutely eliminated, an outlier test was used in conjunction with a review of the historical use of these properties. The presence of all of the constituents that were identified as

being outliers in the background data sets could be explained based on previous site use, as further explained in this section.

Prior to performing calculations using the medium-specific background data sets, outliers within the data set were identified using a simple inter-quartile test (Iglewicz and Hoaglin, 1993) that determined a limit above which a sample value may be considered a potential outlier. The equation used to determine this limit is as follows:

$$L=Q3+3(Q3-Q1)$$

where:

Q1= first quartile of the data

Q3= third quartile of the data

L= the limit above which a sample value may be considered a potential outlier.

A factor of three was applied to the difference between the third quartile and the first quartile in the above equation for conservatism so that only the most extreme outliers would be rejected.

Any background sample value that exceeded this calculated limit was considered to be a potential outlier. Potential outliers were further reviewed to determine if there were any technical reason(s) for removing the data from the background data set (e.g. impacts from site activities, or laboratory and transcription errors). The evaluation of potential outliers in the NFSS background data resulted in the following conclusions.

- Some of the background sample values in the NFSS RI medium-specific background data sets are only slightly greater than the upper limit specified by the outlier test. A sufficient number of samples were available to determine that the data were simply high values in the medium-specific background data sets and not outliers.
- Because the detection limits for an analyte within a given medium vary, many of the potential outliers represent detection limits that are relatively greater in value than other analytical results for that parameter. However, the presence of a significant number of non-detected results for non-radiological parameters in the medium-specific background data sets tends to skew the quartile values, resulting in low values for the outlier limits. This is due to the fact that non-detected results are evaluated using $\frac{1}{2}$ the detection limit, while detected results are evaluated using the value at which they are reported. In such cases, a greater possibility exists for the identification of potential outliers.
- The NFSS RI background data set was reviewed to determine if any background values exceeded the acceptable risk screening values. Background values that exceeded risk screening values may be identified as potential outliers. However, no background values in the NFSS RI medium-specific background data sets exceeded the risk screening values. Potential outliers in the medium-specific background data sets that are less than risk screening levels do not affect evaluation of site risk. However, potential outliers in the medium-specific background data sets can affect the identification of SRCs because SRCs are determined using background values, not risk screening values. The presence of potential outliers in the medium-specific background data sets can result in fewer SRCs being identified for any given medium because the background concentrations used to screen SRCs may be biased high.

- Manganese oxides and hydroxides naturally occur in the mineral (solid) phase under oxidizing conditions. Manganese minerals are commonly associated with iron oxides and hydroxides, which are also solids under oxidizing conditions. Under anaerobic (reducing) conditions, such as in low lying swampy areas, both manganese and iron are reduced to more soluble forms, resulting in higher dissolved phase concentrations. Once in the dissolved phase, iron and manganese may precipitate as new oxygenated water mixes with the soluble metals. The precipitation of these metals under aerobic conditions to form concretions high in iron and manganese is a common occurrence in soils. The soil conditions at NFSS are conducive for generating such concretions.

The background UTL for manganese in soils at the NFSS is 6,650 mg/kg, which represents the maximum value of manganese detected in NFSS background soil samples. This sample was not considered to be an outlier because it is believed to represent the presence of iron/manganese concretions that are typically found in soils at the NFSS. As a result, all other detections of manganese in soil were found to be below the background UTL and were not further investigated as SRCs, even though manganese concentrations in NFSS soils are observed to be up to thousands of parts per million. Total and dissolved concentrations of manganese in sitewide groundwater are less than 80 ppm. The concentrations of manganese and iron in groundwater are most likely related to the naturally occurring concentrations of these metals in NFSS soils and not from operations conducted at the NFSS. However, to conservatively evaluate human health risk, manganese was identified as a COC in sitewide groundwater (EU 17), and in groundwater in EUs 4 and 13.

- An outlier for selenium was identified in the surface soil sample collected from background location BKGD-12. BKGD-12 is on property owned by a hunting and gaming club. Selenium dioxide is used to “blue” gun metal, and selenium is used in various copper alloys that could be associated with ammunition (NLM, 2002). Selenium is a common contaminant at ammunition facilities. Because selenium could be a result of the current land use, the selenium concentration reported in the surface soil sample collected at BKGD-12 was considered to be an outlier and was not included in the surface soil background data set.
- Lead and arsenic were identified as outliers in the surface soil sample collected at background location BKGD-17 because these metals are likely to be a result of historical land use. Lead arsenate, used historically as a pesticide and herbicide, was employed extensively on apple orchards to control the codling moth (NLM, 2002; NJDEP, 1999). Lead arsenate was also used for control of agricultural pests in vegetable fields and other fruit orchards, as well as golf courses and turf farms (NJDEP, 1999). Application of lead arsenate on apple and peach crops was recommended by the New Jersey Agricultural Experiment Station, and these recommendations continued until 1967 when the use of other pesticides (primarily organochlorine pesticides) became established (NJDEP, 1999). BKGD-17 is apparently adjacent to an old fruit orchard, where lead arsenate would have been used as a pesticide. Consequently, lead and arsenic concentrations reported in the surface soil at BKGD-17 were excluded from the surface soil background data set. Additionally, an Integrated Exposure Uptake Biokinetic Model (IEUBK) guideline value of 400 mg/kg is being used as the risk screening level for lead in soil and sediment. This guideline is greater than any potential outlier values for lead in soil and sediment, therefore the presence of potential outliers in the soil and sediment background data sets has no effect on the risk evaluation of site data.

- Lead is a potential outlier in groundwater and surface water. Outliers are present in groundwater and surface water at concentrations of 5.99 µg/L and 11 µg/L, respectively. However, both of these concentrations are less than the MCL for lead (15 µg/L), which is being used as the risk screening level in groundwater and surface water. Therefore, the presence of potential outliers for lead in the groundwater and surface water background data sets has no effect on the risk evaluation of site data, and no outliers for lead were removed from the groundwater and surface water background data sets.
- Groundwater data from two background monitoring wells (PZ-21S and PZ-25S) were determined to contain outliers and thus, all groundwater results from these two wells were removed from the background data set. These two wells are located near a rail bed on the Modern Landfill property. Although analyte concentrations from these wells were below MCLs, data from these wells were removed from the background data set due to noticeably high total and dissolved isotopic uranium values derived from ballast leaching and nearby disturbed soil. Not only did these two samples have unusually high concentrations of uranium isotopes, but also had uranium isotopic ratios indicating that they may have been impacted by site contaminants (Rhodes et al 2006).
- A few background sample results, particularly those for metals collected in groundwater, may reflect the quality of the water migrating on site from the Modern Landfill located to the east of the NFSS. Despite potential outliers in these results, the risk screening values are much higher than the outlier values and therefore, the potential outliers do not present a risk concern and were not removed from the background data set.
- Potential outliers exist in groundwater samples for alpha and beta. The MCL, rather than a background concentration, is being used as the risk screening value for alpha and beta in groundwater. Because concentrations of alpha and beta in the background groundwater data set are less than the MCL, the presence of potential outliers for these two parameters in the background data set has no effect on the risk evaluation of site data. Thus, no outliers for alpha and beta were removed from the groundwater background data set.
- Outliers were identified for alpha, beta, total uranium, uranium-234, uranium-235, and uranium-238 in samples collected from background surface water locations SWBKGD-3 and SWBKGD-7. These constituents from these locations were removed from the surface water background data set based on outlier testing and elevated radiological concentrations for total uranium and uranium isotopes.
- Potential outliers exist in sediment samples for radium-226, thorium-230 and uranium-234. These radionuclides are present in sediment at concentrations that slightly exceed the calculated outlier limit. The potential outliers are present in samples collected at background locations SDBKGD-2 and SDBKGD-3. SDBKGD-2 is located in the West Ditch south of the IWCS and SDBKGD-3 is located in the ditch adjacent to the West Patrol Road in the northwestern corner of the NFSS, next to EU 1. Upon further evaluation of these data, it was determined that these potential outliers are not likely the result of activities conducted at the NFSS; therefore, the data were not removed from the background data set.

Background calculations were performed following evaluation of potential outliers and finalization of the NFSS background data set. For the purpose of calculating background, non-

radiological data qualified as not detected were set to a concentration of ½ the analytical detection limit. Radiological data that were evaluated as not detected were used at the reported activities.

A Shapiro-Wilk W Test (Gilbert 1987) was used to determine if the data distributions of the medium-specific background data sets were normal or lognormal. If a data distribution was determined to be significantly different from both normal and lognormal, it was evaluated as a non-parametric distribution. The calculation of the W statistic is as follows:

$$d = \sum_{i=1}^n (x_i - x_{avg})^2 \quad W = \frac{1}{d} \sum_{i=1}^k a_i (x_{(n-i+1)} - x_i)^2$$

where:

d = denominator of the W statistic
n = number of samples
 x_i = individual sample results
 x_{avg} = average result
k = n/2 if n is even or (n-1)/2 if n is odd
W = Shapiro-Wilk statistic
a = coefficient from table
 α = 0.05 (Gilbert 1987)

If the W value exceeds a tabulated value (Gilbert 1987) then the distribution can not be differentiated from a normal distribution.

A standard 95% Upper Tolerance Limit (UTL) (Gilbert 1987) was calculated for data that was determined to be normally distributed. Similarly, log transformed data were used to calculate a lognormal UTL. The standard 95% UTL calculation is shown below.

$$UTL = \bar{x} + k(s)$$

For lognormal data distributions, the equation used to calculate the 95% UTL with log transformed data is:

$$UTL = e^{\bar{x} + k(s)}$$

where:

\bar{x} = sample arithmetic mean,
k = k statistic table-value, dependent on the sample size (Gilbert 1987),
s = sample standard deviation, and
e = exponential conversion for lognormal data.

The maximum detected concentration was used as a surrogate for the UTL when the data distribution was determined to be neither normal nor lognormal. The maximum detected concentration was also used as a surrogate for the UTL when less than three sample results were available for any medium-specific analyte. The result of these data evaluations is a set of background screening values representing either the UTL or maximum detected concentration for each analyte within each medium. A background screening value was defined to be the lesser of the 95% background UTL or the maximum value in the background data set. Hereafter, a background screening value is referred to as a background UTL. Background UTLs are used to compare investigative data to existing background concentrations. If an analyte was not detected

in a medium-specific background data set, no background UTL was established for that analyte within that medium. For analytes with no background UTL, all detected values were forwarded to the BRA for screening purposes. A more detailed discussion of determination of background UTLs is presented in the BRA.

4.4.2 Determination of SRCs

The methodology for the determination of SRCs is consistent with the methodology presented in the BRA. The SRC summary tables presented in Sections 4.5 through 4.9 are the result of the SRC process outlined in Tables A-1 and A-2 of the BRA. SRCs were defined to be chemicals or radionuclides that were present in a given medium and EU at concentrations statistically greater, as defined below, than the corresponding background concentrations. SRCs were determined for soil (0 to 10 feet bgs), surface soil (0 to 0.5 feet bgs), sediments, surface water, groundwater, pipeline/utility sediments, and pipeline/utility water.

For each medium, analytical results for samples collected from both the NFSS and the background locations were compiled into data sets. For the purpose of this report, “data set” is defined to be all the analytical results for a given parameter from samples of a given medium, collected within a given EU. This approach allows the determination of SRCs for each EU that reflect the actual conditions and past historical uses.

For this RI, background samples were collected for groundwater, surface soil (0 to 0.5 feet bgs), soil (to depths of approximately 20 feet bgs), sediment and surface water and compiled into background data sets. Suitable locations for the collection of background pipeline/utility sediment and water samples were not identified. For these matrices, the background sediment and surface water data sets were used to determine SRCs.

The data sets were evaluated using several different statistical tests in accordance with the decision tree shown in Figure 4-1. The evaluation process is briefly described below.

Step 1:

First, the frequency of detection for each parameter in each data set was determined. Parameters that were not detected in at least five percent of the samples in each EU/medium were dropped from further evaluation and were not considered to be SRCs. Parameters found in at least five percent of the samples then moved on to the second step in the evaluation process.

Step 2:

In the second step, site sample results for each parameter were compared to the corresponding background screening values. A background screening value was defined to be the lesser of the 95% background UTL or the maximum value in the background data set. Parameters for which their site data sets contained at least one value that was greater than the background screening value were designated as Preliminary Site-Related Constituents (PSRCs). This step did not definitively determine if a particular parameter was a SRC or not. It was possible for a parameter that was not a PSRC to be deemed a SRC. However, the statistical requirements in this case were more rigorous than those required of parameters that were PSRCs. Parameters classified as PSRCs were evaluated by the methods described in Step 3a. Parameters that were not classified as PSRCs were evaluated by the methods described in Step 3b.

Step 3a:

Data sets for parameters classified as PSRCs were then compared to their corresponding background data sets. If the site data set and the background data set were either both normal or

both lognormal, the comparison was made using a one-tailed Analysis of Variance (ANOVA) at a level of confidence of 95%. If the normality or lognormality requirements were not met, a comparison was made using a one-tailed Wilcoxon Rank Sum test, also with a level of confidence of 95%. In some instances, either the site data set or the background data set was not amenable to analysis using either ANOVA or the Wilcoxon Rank Sum test (e.g. if more than 50% of the members in either data set were U flagged and not detected). In these cases, the parameters were declared to be SRCs based on the previous two steps of the evaluation process.

If the ANOVA analysis concluded that the mean value in the site data set for a PSRC exceeded the mean value in its corresponding background data set, or, analogously, if the Wilcoxon Rank Sum test concluded that the median value of the site data set exceeded its corresponding median value in the background data set, the parameter was declared a SRC. If the ANOVA analysis concluded the opposite (the site mean/median does not exceed the background mean/median) an additional test, called the weight of evidence test, was performed. The weight of evidence test consisted of a comparison between the maximum value in the PSRC data set and the background screening value. If the maximum value was more than ten percent greater than the background screening value, the parameter was considered a SRC. Otherwise, the parameter was not considered a SRC.

Step 3b:

A comparison between these site data sets and their corresponding background data sets was made using a one-tailed ANOVA analysis (or a one-tailed Wilcoxon Rank Sum test) as described above. If this analysis concluded that the site data set mean/median value was not greater than the corresponding background data set mean/median value, the parameter was dropped from further consideration and not considered to be a SRC. If this analysis concluded the opposite – that the site data set mean/median was greater than the background data set mean/median – an additional test was performed. In this case, the actual mean value of the site data set was compared to the actual mean value of the background data set. If the actual site mean exceeded the actual background mean, then the parameter was considered to be a SRC. Otherwise, the parameter was not considered to be a SRC.

The steps outlined above were used in the BRA to identify SRCs for each medium in each physical EU (1-14). SRCs were also identified on a site-wide basis for the following media:

- surface water in interconnected drainage ways (EU 15),
- pipeline sediment and water (EU 16),
- groundwater (EU 17), and
- deep soils (for use in Seasonal Soil Compartment (SESOIL) modeling and discussion of nature and extent in various EUs).

In this RI report, the EU-specific SRCs for soil, surface water, sediment, and groundwater (as determined in the preliminary steps of the BRA) were used for discussion of nature and extent of contamination within each EU. Risk from exposure to groundwater was to be evaluated in the BRA on a site-wide basis only. However, prior to combining EU-specific data to create a site-wide groundwater data set, preliminary screening of SRCs in each physical EU was performed to ensure that no areas exhibiting localized contamination were inadvertently dismissed. During this screening process, localized VOC contamination in groundwater was identified in EUs 4 and 13.

To fully address this localized VOC contamination, the BRA evaluated groundwater on an EU-specific basis for EUs 4 and 13, as well as for EU 17 (sitewide). Although EU-specific groundwater SRCs were developed for each physical EU, only groundwater in EUs 4 and 13 were evaluated on an EU-specific basis in the BRA. As mentioned above, this RI report used the EU-specific groundwater SRCs developed in the BRA for discussion of nature and extent of contamination.

4.5 SURFACE SOIL (0 TO 0.5 FEET) SRCs

Surface soil sample designations, locations and analysis parameters are discussed in Section 3.6 and are summarized in Table 3-4. Analytical results are presented in Appendix AA.

4.5.1 Background Sample Analytical Results

Fifteen background surface soil samples were collected from off-site locations which were unimpacted by past NFSS activities. Background surface soil sample locations are shown in Figure 3-14 and the background surface soil sample results are summarized in Table 4-5. Background surface soil results were used to determine surface soil SRCs using the statistical methods described in Section 4.4.

4.5.2 Summary of Surface Soil SRCs

For each EU, the number of surface soil samples collected, number of detects and the minimum and maximum concentrations measured for each analysis parameter are summarized in Tables 4-6 through 4-19. Nitroaromatic compounds, PAH compounds, VOCs and SVOCs were detected above the reporting limits in only a limited number of samples. Metals and radionuclides; however, were detected above the reporting limits in a large percentage of the samples. Tables 4-20 through 4-33 present the surface soil SRCs for each EU. These tables also list all of the samples that exceed the background screening value for each SRC. These samples are also shown on Figures 4-2 through 4-14.

An evaluation of the surface soil analytical results is presented in Section 5.

4.6 ALL SOIL (0 TO 10 FEET) SRCs

In support of the BRA, all soil samples collected from the interval of zero to ten feet bgs were evaluated as a single medium. This medium definition was designed to facilitate the estimation of dose and risk to residents, farmers, maintenance workers, industrial workers, constructions workers and visitors associated with intrusive activities such as excavations and other construction activities. Both surface soil analytical results and the analytical results from subsurface samples collected from depths of less than ten feet below grade were combined for this evaluation.

Subsurface soil sample designations, locations and analysis parameters are discussed in Section 3.7 and are summarized in Tables 3-6 and 3-7. Surface soil samples are discussed in Sections 3.6 and 4.5.

Analytical results for subsurface soil samples are presented in Appendix AA.

4.6.1 Background Soil Sample Analytical Results

Thirty-four background surface soil and subsurface soil samples were collected from off-site locations believed to be unimpacted by past NFSS activities. Subsurface soil samples were collected from depths ranging from five to 20 feet bgs and most of the subsurface soil samples were collected from depths between ten and 20 feet bgs. Because the number of background subsurface samples collected from depths between 0.5 feet and ten feet bgs was small, it was decided to include all available background subsurface soil samples in the evaluation, regardless of sample depth. Using a background data set that includes soil samples collected at depths greater than ten feet bgs generally results in lower background concentrations for those constituents which are commonly present at shallower depths due to human activity. Thus, this approach generates more conservative background concentrations. Background surface soil sample locations are shown on Figure 3-14. Background soil sample results are summarized in Table 4-34. Results are presented in their entirety in Appendix AA. Background soil results were used to determine soil SRCs using the statistical methods described in Section 4.4.

4.6.2 Summary of Soil SRCs

As discussed above, the evaluation of SRCs in soil considered only results from samples collected from the interval of zero to ten feet below grade and this was done in order to accommodate the needs of the BRA. Analytical results from samples collected from depths greater than ten feet are presented and discussed in Section 5.

For each EU, the number of samples collected, number of detects and the minimum and maximum concentrations measured for each analysis parameter are summarized in Tables 4-35 through 4-49. Tables 4-50 through 4-64 present the soil SRCs for each EU. These tables also list all of the samples that exceed the background screening value for each SRC. Then samples are also shown on Figures 4-2 through 4-14.

4.7 SURFACE WATER SRCS

Surface water sample designations, locations and analysis parameters are discussed in Section 3.8 and are summarized in Tables 3-9 through 3-11. Analytical results are presented in Appendix AA.

4.7.1 Background Sample Analytical Results

Nine background surface water samples were collected from locations on NFSS property, within a few feet of the site boundary where water flowed onto the site, and one sample was collected on Niagara-Mohawk property. Background surface water sample locations are shown in Figure 3-14 and the background surface water sample results are summarized in Table 4-65. Results are presented in their entirety in Appendix AA. Background surface water results were used to determine surface water SRCs using the statistical methods described in Section 4.4.

4.7.2 Summary of Surface Water SRCs

For each EU, the number of surface water samples collected, number of detects and the minimum and maximum concentrations measured for each analysis parameter are summarized in Tables 4-66 through 4-76. Nitroaromatic compounds, VOCs and SVOCs were detected in only a limited number of samples. Metals and radionuclides; however, were detected in a large percentage of the samples. Tables 4-77 through 4-87 present the surface water SRCs for each EU. These tables also list all of the samples that exceed the background screening value for each SRC.

Locations of the SRCs found in surface water in each EU are presented in Figures 4-15 and 4-16. An evaluation of the surface water analytical results is presented in Section 5.

4.8 SEDIMENT SRCs

Sediment sample designations, locations and analysis parameters are discussed in Section 3.9 and are summarized in Tables 3-12 through 3-14. Analytical results are presented in Appendix AA.

4.8.1 Background Sample Analytical Results

Background sediment samples were collocated with the background surface water samples. Background sediment sample locations are shown in Figure 3-14 and the background sediment sample results are summarized in Table 4-88. Background surface water samples are presented in their entirety in Appendix AA. Background sediment results were used to determine sediment SRCs using the statistical methods described in Section 4.4.

4.8.2 Summary of Sediment SRCs

For each EU, the number of sediment samples collected, number of detects, and the minimum and maximum concentrations measured for each analysis parameter are summarized in Tables 4-89 through 4-94. Nitroaromatic compounds, VOCs and SVOCs were detected in only a limited number of samples. Metals and radionuclides; however, were detected in a large percentage of the samples. Tables 4-92 through 4-94 present the sediment SRCs for each EU. These tables also list all of the samples that exceed the background screening value for each SRC.

Locations of SRCs in sediment in EU 5, 9, and 15 are presented in Figure 4-17. An evaluation of the sediment analytical results is presented in Section 5.

4.9 GROUNDWATER SRCs

Groundwater characterization, well installation and sample collection (designation and analysis parameters) are discussed in Section 3.10 and are summarized in Tables 3-15 through 3-18. Monitoring well locations are shown in Figures 3-7 through 3-13. Groundwater analytical results are summarized in Appendix AA.

4.9.1 Background Sample Analytical Results

Filtered and unfiltered background groundwater results were used for comparison purposes using the statistical methods described in Section 4.4. As part of this RI, background samples were collected from 26 wells and piezometers located on the Modern Landfill property, which is upgradient and east of the NFSS. These background groundwater sample locations are shown in Figure 3-14. In addition to the 26 groundwater samples collected from wells and piezometers located on the Modern Landfill property, the background groundwater data set also includes total and dissolved metals results for four samples collected as part of the LOOW RI. Background groundwater results are summarized in Table 4-95. Background sediment sample results are presented in their entirety in Appendix AA.

Two water-bearing zones, described in Section 2.3.2 are present at the NFSS. For the determination of groundwater SRCs, groundwater results for the two zones were combined in order to facilitate the BRA. Results for the two zones were evaluated separately in Section 5.

4.9.2 Summary of Groundwater SRCs

For each EU, the number of groundwater samples collected, number of detects, and the minimum and maximum concentrations measured for each analysis parameter are summarized in Tables 4-96 through 4-109. The SRCs and samples exceeding background screening values for each EU are shown in Tables 4-110 through 4-123. The locations of the SRCs identified during this investigation are shown in Figures 4-18 through 4-21.

Metals and radionuclides were most prevalent and were detected above background screening values in every EU. Pesticides, PAH compounds, SVOCs and VOCs were less prevalent but were detected in most, but not all, of the EUs. PCBs were detected in one EU and nitroaromatics were present in three EUs.

The groundwater database included results for samples collected from temporary and permanent monitoring wells. Typically, samples from TWPs were turbid (visibly contained suspended soil particles) while those collected from the permanent wells were less turbid and contained a smaller amount of suspended matter. As a result, turbid samples may contain higher concentrations of the parameters of interest than less turbid or clear samples. The comparison of the total and dissolved groundwater data to background criteria did not account for the turbidity of the samples and the resulting list of SRCs for the total groundwater data set may be skewed toward the more turbid samples. The impact of turbidity on SRCs is discussed and evaluated in Section 5.

4.10 PIPELINE/UTILITY WATER SRCs

All pipelines, sewers, sumps and drains at the NFSS are in EU 16. Pipeline water sample designations, locations and analysis parameters are discussed in Section 3.12. Manhole locations are shown in Figures 3-7 through 3-13. Analytical results are presented in Appendix AA.

Water samples were collected from manholes on storm sewers, sanitary sewers and process pipelines. They were also collected from sumps and floor drains. As a group, these samples are referred to as pipeline/utility water samples.

4.10.1 Background Sample Analytical Results

Background surface water results were used for comparison purposes. These results are presented in Section 4.7. The results are presented in their entirety in Appendix AA.

4.10.2 Summary of Pipeline/Utilities SRCs

The number of samples, number of detects and the minimum and maximum concentrations encountered for each analysis parameter are summarized in Table 4-124. Nitroaromatic compounds were not detected in sewer water samples and a limited number of PAH compounds, pesticides, dissolved radionuclides, VOCs and SVOCs were detected. Metals and radionuclides were detected in a large percentage of sewer water samples.

A list of the SRCs and samples exceeding background concentrations is provided in Table 4-125 and the analytical results for the drain oil samples are summarized in Table 4-126. The locations of the sewer water SRCs identified during this investigation are shown in Figures 4-22 and 4-23.

The constituents present in the sewer water are related to the types of sewer lines and the activities performed in the vicinity of drains or sumps associated with each type of sewer line. A detailed evaluation of the results from the pipeline/utility sampling is presented in Section 5.

Two samples of oil were collected from drains in Building 401. SRCs were not determined for these samples because a suitable background data set was not available for this matrix. These samples are discussed in Section 5.

4.11 PIPELINE/UTILITY SEDIMENT AND SOIL SRCs

All pipelines, sewers, sumps and drains at the NFSS are in EU 16. Pipeline/utility sediment sample designations, locations and analysis parameters are discussed in Section 3.12 and are summarized in Tables 3-20 through 3-22. Manhole locations are shown in Figures 3-7 through 3-13. Analytical results are presented in Appendix AA.

Pipeline/utility sediment samples were collected from manholes on storm sewers, sanitary sewers and process pipelines. They were also collected from sumps and floor drains. As a group, these samples are referred to as pipeline/utility sediment samples.

A small number of subsurface soil samples were collected from locations immediately adjacent to manholes and drains and for purposes of the BRA were considered to be in EU 16.

4.11.1 Background Sample Analytical Results

Background sediment results were used for comparison purposes for the pipeline/utility sediment samples results. These results are presented in Section 4.8. The soil background results are presented in Section 4.6.

4.11.2 Summary of Pipeline/Utilities SRCs

The number of samples, number of detects, and the minimum and maximum concentrations encountered for each analysis parameter in sediment and soils are summarized in Tables 4-127 and 4-128. Nitroaromatic compounds were not detected in sewer sediment or soil samples and a limited number of SVOCs were detected and identified as SRCs. PAH compounds, pesticides and VOCs were found in a larger number of sewer sediment/soil samples and identified as SRCs. Metals and radionuclides were detected in the largest percentage of sewer sediment samples and were identified as SRCs. The SRCs in pipeline sediment and soil are summarized in Tables 4-129 and 4-130.

The constituents present in the sewer sediment are related to the type of sewer line, and the activities performed in the vicinity of drains or sumps associated with each type of sewer line. The sewer lines at the NFSS are associated with activities that occurred in five discrete areas: the IWCS, the former LOOW WWTP, the former Shop Area, Building 401 (former boiler house) and the acid area. A detailed evaluation of the results from the pipeline/utility sampling or each of the five areas based on the type of sewer network is presented in Section 5. Analytical results are presented in Appendix AA. A list of the SRCs and samples exceeding background concentrations is provided in Tables 4-129 (sediment) and 4-130 (soil). The locations of the sewer sediment/soil SRCs identified during this investigation are shown in Figure 4-24.

4.12 NIAGARA-MOHAWK AREA (EU 9) SRCS

During the course of this RI, surface water, sediment, surface soil and subsurface soil samples were collected from the Niagara-Mohawk area. This area lies to the immediate west from the NFSS. Because the Niagara-Mohawk area is not part of the NFSS proper, the results from the samples collected on the Niagara-Mohawk area are presented separately from the NFSS results.

4.12.1 Background Sample Results

The background data sets for surface soil, soil, sediment, and surface water were used to evaluate the Niagara-Mohawk samples. These background data sets are presented in Sections 4.5, 4.6, 4.7 and 4.8.

4.12.2 Summary of Niagara-Mohawk SRCs

The analytical results for the Niagara-Mohawk samples are summarized in Tables 4-131, 4-133, 4-135, and 4-137. The full analytical reports are shown in Appendix AA.

The Niagara-Mohawk SRCs were determined using the methods described in Section 4.4 and are shown on Tables 4-132, 4-134, 4-136, and 4-138.

The locations of the soil SRCs in the Niagara-Mohawk property are shown in Figure 4-25.

5.0 NATURE AND EXTENT OF SRCS

5.1 INTRODUCTION

This section presents and discusses topics related to the nature and extent of SRCs. In previous sections of this report, the presentation of data and findings was organized around the 18 EUs developed for the BRA. The EUs for surface soil (0 to 0.5 feet bgs), all soil (0 to 10 feet bgs), groundwater, a portion of the surface water sample set, and a portion of the sediment sample set consist of areas that were based, in part, on historical activities at the site. The main ditch system at the site (consisting of a portion of the West Ditch, the Central Ditch, the Modern Ditch, and the South 16 Ditch) was considered to be a separate EU, designated EU 15. The pipeline/utility system at the site was also considered to be a separate EU, designated EU 16.

This organization is modified slightly in this section to more concisely and completely present the discussion of nature and extent. All information concerning nature and extent is presented under an organization based strictly on geographic area. For this section, nature and extent will be discussed under a framework of six NFSS areas and the Niagara-Mohawk Area. These areas were delineated based on EU designation and past use. The boundaries of these areas follow current EU boundaries shown in Figure 1-2. The main ditch system and the pipeline/utility system are discussed based on the physical area in which they occur. The seven EU areas that form the basis for discussion in Section 5 are:

- Baker-Smith Area and Vicinity: EUs 1 and 2;
- Acid Area: EUs 3 and 4;
- Building 434 Area and Vicinity: EUs 5 and 6;
- Shops Area: EU 8;
- IWCS and Vicinity: EUs 7, 10 and 11;
- Building 401 and Vicinity: EUs 12, 13, and 14; and
- Niagara-Mohawk Area: EU 9.

As discussed in Section 3, USACE conducted the RI under a phased approach. A brief synopsis of the phases of the investigation and their objectives is as follows:

- Phase 1 (initiated in March 1999) –to verify the presence and location of existing chemical constituents;
- Phase 2 (initiated in August 2000) – to further investigate those areas identified in Phase 1 as areas of interest; and
- Phase 3 (conducted from February 2001 through October 2003) – to collect additional information needed for a risk assessment and background comparison, and to further define the nature and extent of contamination present at the site.

Although the LOOW RI was a separate effort from the NFSS RI, some of the samples from the first phase of the LOOW RI were collected at the NFSS. These samples were collected because during the early stage of the LOOW RI it was thought that DERP-FUDS would be responsible for DOD-related contamination on the NFSS portion of the former LOOW. However, no samples were collected at the NFSS during later phases of the LOOW RI because contamination at the NFSS eventually fell under the authority of the FUSRAP program. Samples collected at the NFSS during the first phase of the LOOW RI were used to direct some sampling efforts during

the NFSS RI. Thus, some data from the LOOW RI has been included as part of the NFSS RI Phase 1 figures, tables, and discussion.

Specific investigative objectives for each EU, as they pertain to each phase of the RI, are discussed in this section with the investigative results to provide a logical explanation for the sequence of sampling activities conducted at each EU and to verify that RI sampling objectives were met.

The discussion of SRCs for each of the seven EU areas listed (grouped) above includes a brief description of the area that identifies the operational history of the EU(s), existing or former buildings, surface water features, remedial actions that have been performed, and any other pertinent information about the site. The occurrence and distribution of SRCs in soil, surface water, sediment, and groundwater are then presented for each EU. SRCs associated with underground utility lines are also identified. The evaluation of each EU area concludes with a discussion of media interactions, as well as an evaluation of contaminant sources and effects of past site use.

Following separate discussions of each EU area, a site-wide examination of nature and extent of the NFSS is presented. This discussion follows the same format used to discuss the individual EU areas. The occurrence of SRCs is described for each media across the entire site. In addition, general conclusions concerning media interactions, contaminant sources, and effects of past site use are discussed from a site-wide perspective.

SRCs identified and discussed for each of the EUs presented in this section are later summarized in Section 7 of this report. Section 7 also summarizes groundwater modeling results with respect to the SRCs within each EU and identifies the SRCs within each EU that were determined to be COCs and ROCs in the BRA.

5.1.1 General Discussion of Methods

Water and sediment samples that are included in EUs 15 and 16 are, in this section, presented in the discussion of the site area from which they were collected.

Over 80 sediment samples were collected on the NFSS. Later, during the preparation of the BRA, it was determined that 49 of the samples, which were collected from locations that are dry for much of the year, should be reclassified as soil samples. Thus, sediment samples collected from locations that are inundated less than 50% of the year were reclassified as soil samples. This reclassification was performed prior to the determination of SRCs; thus, the following EU-specific discussions of the nature and extent of SRCs reflect the reclassification of these samples as presented in the BRA.

The discussions of analytical results in this section were developed from SRC concentrations tabulated for each EU in Section 4. For all SRCs in all media, the samples which contained concentrations of one or more SRCs at concentrations in excess of the associated background screening levels are shown in tables presented in Section 4. These tables also show the value of these concentrations. In this section, where appropriate, specific sample results are presented and discussed as part of the consideration of nature and extent. However, in general, these values are not tabulated here and the reader is referred back to the tables in Section 4 for a complete presentation of such material.

For the purpose of discussing the nature and extent of SRCs in soil within each EU, surface soil samples were considered to be samples collected from 0 to 0.5 feet bgs, and subsurface soil samples were considered to be samples collected from 0.5 to 10 feet bgs. Soil samples collected at depths greater than 10 feet bgs were also addressed separately. This approach to the discussion of soil SRCs corresponds to figures presented in Section 4 that show the horizontal and vertical distribution of SRCs in soil within each EU.

Various groundwater quality parameters are included on the tables in Section 4. Groundwater quality parameters may include alkalinity, cation exchange capacity, chloride, cyanide, ethane, ethene, fluoride, methane, nitrogen, orthophosphate, phosphorus, sulfate, sulfide, oxygen demand, percent moisture, total dissolved solids, total suspended solids, and total organic carbon. These parameters have not been identified as SRCs, but have been used to qualitatively evaluate groundwater conditions at the NFSS, where appropriate.

Throughout the discussions of SRCs in this section, the term “total” refers to dissolved plus undissolved particulates within a sample. However, when the term is used for “total uranium”, it refers to the concentration of uranium in $\mu\text{g/L}$, rather than the sum of all uranium isotopes in pCi/L .

In general, ubiquitous elements that are present at low concentrations and are essential human nutrients are not discussed in this RI report. These chemicals are toxic only at very high doses and are considered to be human nutrients essential to a well-balanced diet. For these reasons, they typically are not considered hazardous to humans. Essential human nutrients include iron, magnesium, calcium, potassium, and sodium.

As part of the evaluation of nature and extent for this RI, and in support of groundwater modeling presented under separate cover, the groundwater data was examined to determine if it supported the conclusion that groundwater plumes of SRCs existed at the site. A groundwater plume was defined to be a group of wells or groundwater samples in proximity to each other which exhibited groundwater concentrations of a given SRC that exceeded the associated background screening level, or MCL, as appropriate. Where appropriate, plume extent also considered water results taken from manholes. For metal and radionuclide SRCs, both total and dissolved concentrations were used to evaluate the existence of a groundwater plume. However, only the dissolved concentrations were used to define isoconcentrations used in the groundwater model and presented in this RI report. This is partly due to the fact that RI groundwater samples were predominantly collected from temporary well points which, by nature, can exhibit high turbidity. Samples for dissolved analysis were filtered in the field at the time of collection, removing much of the turbidity. Dissolved concentrations were also used to define plumes during this RI because portions of a constituent in an unfiltered sample can be sorbed onto particulate matter rather than be dissolved in the groundwater. Hence, dissolved fractions of constituents are likely to be more mobile in groundwater than non-dissolved fractions. However, it should be noted that the BRA evaluated dose and risk from exposure to total concentrations of constituents in groundwater to ensure a more conservative assessment of risk to human health and to comply with specifications included in RAGS (EPA 1989).

5.1.2 Evaluation of Groundwater Data

The classic concept of a groundwater plume is a contiguous area of contamination within a uniform aquifer. In such a scenario, the plume migrates downgradient at a measurable rate and expands its volume of influence by diffusing laterally and vertically. An aquifer is a relatively uniform body of rock or sediment that has sufficient permeability to transmit water at a

reasonable rate. However, contamination can occur in a formation that does not fit the definition of an aquifer, in which case the uniformity of the aquifer is questionable, as is the presence of a classic plume.

The contaminated groundwater areas at the NFSS exist within a zone of low permeable material containing small lenses of sand with lesser amounts of silt and clay, and occasional gravel. The sand lenses extend a few tens of feet laterally and only a few feet vertically. There is very little groundwater flow in subsurface areas consisting mainly of clay where there are no silt lenses. Portions of the clay material often appear dry when sampled. Downgradient migration of groundwater through a sand lens is likely to be relatively fast, while migration through a tight clay unit may be very slow or non-existent. Therefore, the configuration of contamination in groundwater at the NFSS may be quite irregular, rather than uniform, as depicted by a classic, uniform plume. For this reason, the interpretation of the extent of contamination at the NFSS using the concept of a classic, uniform plume is probably not warranted. However, for the purpose of evaluating constituents present in groundwater for this RI, contaminated groundwater areas at the NFSS are referred to as "plumes".

The plumes were drawn from an evaluation of total and dissolved radiological and chemical analytical data for water samples collected from manholes and for groundwater samples. As mentioned previously, only the dissolved phase data set was used to define isoconcentrations for the radionuclide and metal plumes.

In general, groundwater plumes were drawn based solely on the available concentration data, though, where present, the location of subsurface utilities, interconnectedness of the sand lenses, and areas of subsurface disposal – which can create preferential flow pathways in the subsurface – were also considered. The evaluation did not consider the impact of other groundwater contaminant transport mechanisms such as the possibility of dessication fractures in the clay till. As such, some of the resultant plumes show concentration gradients increasing in directions that are hydraulically upgradient. This result indicates that the general shapes of the plumes may be more a reflection of the general geometry and location of the original release than the result of groundwater flow and transport mechanics at force in the intervening time since the original release. Many of the plumes may not be the result of point releases, but rather the result of releases that occurred over larger areas and the sizes of these areas may have been as large as the plumes themselves.

Groundwater plumes delineated and discussed in this section include those for dissolved total uranium, dissolved thorium-230, dissolved boron, dissolved manganese, PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, bis(2-ethylhexyl)phthalate and vinyl chloride. Although groundwater data exists for individual uranium isotopes, only dissolved total uranium groundwater plumes are discussed in this section. Analytical data for dissolved uranium isotopes were considered during the delineation process for the dissolved total uranium groundwater plumes, which are indicative of elevated uranium isotope concentrations in groundwater. Uranium isotope plumes were generated for groundwater modeling efforts and are provided as Figures 5-1 through 5-3 for informational purposes only.

5.2 BAKER-SMITH AREA AND VICINITY: EU 1 AND 2

The Baker-Smith area and vicinity consists of EUs 1 and 2. The area is bordered by the NFSS perimeter fence on the west and north, O Street on the south, and the New Naval Waste Area (EU 3) to the east. The West Ditch flows through the Baker-Smith area (EU 1) and the Central Ditch flows through EU 2.

During the operation of the LOOW, a pipe shop, machine shop, welding shop, and a store house were located in the Baker-Smith area near a rail line that ran roughly parallel to the West Patrol Road. The rail line is no longer present, though its location appears to coincide with an unnamed drainage ditch that flows north through the area. This unnamed ditch crosses the West Patrol Road approximately 70 feet south of the north perimeter fence, where it joins the O Street South Ditch, which flows south to the West Ditch. Except for the West Ditch, the ditches in EU 1 are typically dry and carry water only after storm events. During operation of the NFSS by AEC, K-65 and KAPL residues were stored in buildings located in the Baker-Smith area. The KAPL residues were later transferred to Oak Ridge National Laboratory and the K-65 residues were moved to a silo in EU 6. A remedial action was performed in the Baker-Smith area in 1981.

Building 433, also known as the radium storage vault and used to store sealed radium sources, was believed to be located in either EU 2 or 3. The exact location of this building is not known with certainty as conflicting locations are given in the historical record, although they all agree that the building was located a short distance east of Campbell Street, between N Street and O Street. Because of the uncertainty associated with the exact location of Building 433, areas in both EUs 2 and 3 were investigated as potential former locations of the building. A small portion of the New Naval Waste Area, where construction debris was stored, was also located in EU 2 near the intersection of N Street and Campbell Street. A remedial action was performed in the New Naval Waste Area in 1983.

5.2.1 Occurrence and Distribution of SRCs

As described in detail in the following sections, both EU 1 and 2 are impacted with SRCs at concentrations above the background screening levels.

5.2.1.1 Soils

Figures 4-2 and 4-3 summarize the occurrence of SRCs in soil at EUs 1 and 2.

Soil samples were collected at EUs 1 and 2 during Phase 1 of the RI to investigate the presence or absence of radiological, organic, and inorganic compounds near the former Baker-Smith shop and storehouse locations in EU 1, and the former acid area east of EU 2. The areas of the former building foundations were particular areas of interest in EU 1. Specific features investigated at EU 2 included two underground pipes found during a gamma walkover, concrete slabs, a former fuel storage area, the area near the former radium vault, and former railroad lines. Further investigation of compounds found in the soil near these areas during the LOOW RI was included as part of the Phase 1 soil sampling activities. Phase 1 sample results indicated the presence of organic, metal, and radiological SRCs in surface and subsurface soil at EUs 1 and 2.

Soil samples collected during Phase 2 of the RI served to delineate the nature and extent of compounds detected during Phase 1 activities. In addition, soil samples collected in EU 2 served to investigate the presence or absence of radioactive compounds near the former radium vault. Samples located along the northern property boundary in EUs 1 and 2 indicated the presence of organic, metal, and radiological SRCs above background UTLs. Samples located to bound Phase 1 results in the area of the former Baker-Smith building foundations indicated the presence of metal and radiological SRCs above background UTLs, mainly in the area west of the former buildings. Samples located within the southeastern area of EU 2 indicated the presence of organic, metal, and radiological SRCs above background UTLs.

The majority of the soil samples collected during Phase 3 of the RI were used to investigate the horizontal extent of surface radiological activity observed during the gamma walkover conducted during 2001. Additional samples collected during Phase 3 were used for characterization purposes, to investigate previously uninvestigated areas of the EUs, or to confirm previous sampling results. Phase 3 soil results further indicated the presence of organic, metal and radiological SRCs above background UTLs in EUs 1 and 2.

Sixty-seven surface and subsurface soil samples, collected during the three phases of the RI, were used for the evaluation of soils in EU 1. Three samples collected from EU 1, SD712-319, SD713-324, and SD714-326, were intended to be evaluated as sediment samples. However, as discussed in previous sections of this RI report, these samples were classified as surface soil samples to be consistent with exposure mechanisms considered in the BRA. Therefore, these samples were included in the discussion of soil samples collected at EU 1. General conclusions concerning the nature and extent of SRCs in soils at EU 1 are:

- Soil samples collected at depth indicate that the majority of SRCs within EU 1 are present within the upper 2 feet of soil.
- Several of the surface and subsurface soil samples collected from EU 1 contained concentrations of one or more radionuclides. Actinium-227, radium-226, and thorium-230 exceeded their respective background UTLs by a factor of 100 or more. Sample locations exhibiting these exceedances include 5A016, located near the western portion of the former Baker-Smith building foundations, and 746, located in the southeast area of EU 1 near the West Ditch. Location 503 also exhibited several exceedances of the background UTL by a factor greater than 10. This location in the vicinity of the former building foundations exhibited surface soil concentrations of uranium-234, uranium-235, uranium-238, and total uranium at concentrations between 70 and 100 times the background UTLs. These uranium isotopes were detected at other locations throughout EU 1, but only exhibited concentrations that exceeded the background UTLs by less than a factor of 10. Location 727 exhibited concentrations of actinium-227, radium-226, and thorium-230 that exceeded background UTLs by a factor greater than 10.
- Cesium-137 was detected above the background UTL at several locations within EU 1, but only at concentrations that exceeded the background UTL by less than a factor of 10. Cesium-137 was detected above the background UTL mainly in the southeastern portion of EU 1 and in the vicinity surrounding the former building foundations.
- Gamma walkover survey data and analytical data indicate that the areas impacted with concentrations of radiological SRCs that greatly exceeded background are small and discontinuous.
- Other radiological, metal and organic SRCs were found less frequently in surface and subsurface soils than the SRCs listed above and typically exceeded the background UTLs by much smaller multiples. Metals, pesticides, PAHs, VOCs, and SVOCs were most frequently detected in surface soil samples.
- Subsurface soil samples collected in EU 1 at depths greater than 10 feet bgs slightly exceeded background UTLs for several metals, thorium and uranium isotopes, and six VOCs. The majority of these exceedances occurred at locations 505 and 506 along the

northern boundary of the EU and at locations 502 and 503 near the former building foundations.

- Trench samples collected during Phase 3 in the central portion of EU 1 near the former building foundations were used to further investigate above-background gamma measurements observed in surface and subsurface samples collected following the gamma walkover. The location of the trench was selected to examine conductive, magnetic, and ferrous zone anomalies that were reported in the geophysical investigation of the area. As presented in Section 3, fill mixed with wooden and iron debris was found in Trench 501. No elevated gamma or PID measurements were noted during field activities. However, trench soil sample results indicated the presence of metal and radiological SRCs slightly above background UTLs within the upper 3 feet of soil.

Seventy-eight surface and subsurface soil samples collected during the three phases of the RI were used for the evaluation of soils in EU 2. General conclusions concerning the nature and extent of SRCs in soils at EU 2 are:

- In EU 2, the most commonly detected radiological SRCs in both surface and subsurface soil were thorium-230 and radium-226. Both thorium-230 and radium-226 were detected at concentrations above background UTLs throughout EU 2; however, exceedances of the background UTL by a factor of at least 10 were relatively few. Although not frequently detected, actinium-227 exceeded the background UTL by a factor greater than 10 in several surface soil samples located in the western and central portions of the EU. The other radionuclide SRCs were found at lower concentrations and in fewer samples.
- Cesium-137 was found in the surface and near surface soils at concentrations slightly above the background UTL across a wide portion of EU 2. The data indicates that the distribution of elevated concentrations of cesium-137 in surface and near surface soils is very saltatory and uneven. The only cluster of elevated (i.e. in excess of background) cesium-137 soil samples was found in the eastern periphery of the EU where the collection of samples was concentrated. Sampling of soils was focused in this area during Phase 1 (LOOW RI) to investigate the presence of contamination in the vicinity of the former radium storage vault. Further investigation of soils in this area was conducted during later phases of the NFSS RI to bound Phase 1 samples and to determine the horizontal extent of radiological contamination observed during the gamma walkover.
- In EU 2, several metals and organic compounds were either commonly found or found at relatively high levels. Sixteen PAH compounds, one PCB, four pesticides, two SVOCs and seven VOCs (including acetone, benzene, toluene, xylene, and others) were determined to be surface soil SRCs in EU 2. Four PAH compounds, three PCBs, five pesticides and eight VOCs were identified as subsurface SRCs. Soil samples containing concentrations of PAH compounds above the background UTLs are restricted mainly to the extreme eastern portion of the EU. The situation with metals is similar. In general, samples exhibiting concentrations of several metals and VOCs above surface soil and subsurface soil background UTLs are located mainly in the eastern portion of the EU at depths less than 5 feet bgs. In particular, boron, lead, and selenium were detected in this eastern area at concentrations that exceeded background UTLs by factors greater than 10.

- Subsurface soil samples collected in EU 2 at depths greater than 10 feet bgs exceeded background UTLs for several metals, radium-226, thorium-230, and five VOCs. All background UTL exceedances were by less than a factor of 10. Selenium and thallium were the metals that most frequently exceeded the background UTLs in deep soils throughout EU 2. Radium-226 and thorium-230 exceeded the background UTL in only one sample each. Exceedances of the background UTLs by VOCs (including benzene, toluene, xylene, and others) occurred mainly in the southeastern portion of the EU.
- An abandoned drum was found in the extreme southeast corner of EU 2, sampled, and then appropriately disposed. The drum residue contained elevated levels of total and isotopic uranium. Soil samples collected from beneath the drum contained metals, radionuclides, PAHs, pesticides, one PCB, and one VOC above the background UTLs. Based on analytical results, it does not appear that the drum was the source of PAH, pesticide, PCB, and VOC contamination in the soils beneath it.

5.2.1.2 Surface Water

Figures 4-15 and 4-16 summarize the occurrence of total and dissolved SRCs in surface water at the NFSS.

Three Phase 1 surface water samples were collected from road-side ditches and the West Ditch in EU 1 to investigate the presence or absence of SRCs in surface water near the property boundary and the Baker-Smith area, as well as downstream of the former storehouse (Building 444) and pipe shop (Building 445). Two Phase 1 surface water samples were collected from the Central Ditch in EU 2 to characterize the Central Ditch within this EU, and to investigate the presence or absence of SRCs near the property boundary and in the ditch downstream of the IWCS and the former IWCS stormwater ponds. General conclusions are:

- Several metals and radionuclides were determined to be surface water SRCs in EU 1 and EU 2. However, unlike the concentrations of SRCs in soils, the relative level by which samples exceeded the associated background UTLs was small. With the exception of dissolved silver and total thallium, no surface water SRC exceeded its associated background UTL by more than a factor of about five. Most exceedances were by a factor of two or less.
- All three surface water samples collected from EU 1 contained concentrations of dissolved silver which exceeded the background UTL. Radium-226 was the only radionuclide detected above the background UTL in surface water samples collected within EU 1.
- In EU 2, two surface water samples were collected from the Central Ditch. Dissolved silver was the only metal that exceeded its background UTL by a factor of 10 or more. Thorium-232, the only radionuclide detected in these surface water samples, was present at a concentration slightly above the background UTL in sample location SW709.

5.2.1.3 Sediment

Figure 4-17 summarizes the occurrence of SRCs in sediment at the NFSS.

Three Phase 1 sediment samples were collected from the Central Ditch in EU 2 to characterize the Central Ditch within this EU and to investigate the presence or absence of SRCs near the property boundary and in the ditch downstream of the IWCS and the former IWCS stormwater ponds.

General conclusions are:

- Two metals, manganese and selenium, were detected above background UTLs in sediment. The manganese concentration at location OTFL2 was almost three times the background UTL, while the manganese concentration at location SD709 was slightly less than twice the background UTL. The manganese concentration at location SD710 was just above the background UTL. Selenium was also detected at location OTFL2 at a concentration just above the background UTL.
- The correlation between surface water and sediment SRCs was not strong. This may be because many of the surface water analytical results are inflated by the presence of turbidity in the samples. There is not a corresponding mechanism for sediment samples which could also inflate analytical results.

5.2.1.4 Groundwater

Figures 4-18 through 4-21 summarize the occurrence of total and dissolved SRCs in the LWBZ and UWBZ at the NFSS.

In EU 1, groundwater samples were collected from three permanent wells and six TWP. In EU 2, groundwater samples were collected from four permanent wells and eleven TWPs.

Groundwater samples were collected in EUs 1 and 2 during Phase 1 of the RI to investigate the presence or absence of chemical and radiological compounds in groundwater at the NFSS property boundary and in previously uninvestigated areas, and to evaluate the presence and extent of compounds previously identified in soil during the LOOW RI. Groundwater areas of interest in EU 1 included the former welding shop (Building 443) and storehouse (Building 444) where radioactive residue was stored, and the former pipe shop (Building 445) where drums of L-30 and KAPL residues were stored. Features investigated at EU 2 included two underground pipes, concrete slabs, a former fuel storage area, the former radium vault (Building 433), and former railroad lines. Phase 1 sample results indicated the presence of organic, metal, and radiological SRCs in groundwater at EUs 1 and 2.

Groundwater samples collected during Phase 2 of the RI served to delineate the nature and extent of compounds detected during Phase 1 activities and to further provide data to characterize the EUs. Groundwater samples collected during Phase 3 of the RI served mainly to confirm previous results obtained during Phases 1 and 2 and to evaluate the presence of detected compounds at revised reporting limits. Phase 2 and Phase 3 sample results further indicated the presence of organic, metal, and radiological SRCs in groundwater in EUs 1 and 2.

General conclusions are:

- A dissolved total uranium groundwater plume was found to extend from the west-central portion of EU 2 through the northwest portion of EU 1. The plume, shown in Figure 5-4, trends from northwest to southeast. Based on the data shown in Figure 5-4, this plume

extends off site north of EU 1. The maximum dissolved concentrations of total uranium in this plume are approximately two to three times the background UTL. This plume could be related to localized areas of elevated activity up to 25,000 cpm (see Figure 3-1) that were identified in surface soils in the northwestern portion of EU 1 during the gamma walkover survey. Leaching from these surface soils could be affecting wells in this area.

- Other than uranium isotopes, the only other radionuclide detected above the background UTL in the dissolved phase was thorium-228. Dissolved thorium-228 was detected above the background UTL in EU 2 at well 808A.
- No radionuclides exceeded background UTLs by a factor of 10 or more in groundwater in EUs 1 or 2. However, three metals, total aluminum, silver and vanadium, exhibited concentrations exceeding background UTLs by a factor of 10 or more in both EU 1 and 2. Total chromium, cobalt, iron, manganese, and nickel exceeded background UTLs by a factor of 10 or more in EU 2 only, but at factors less than that of aluminum, silver and vanadium. No dissolved metal exceeded its background UTL in either EU 1 or 2 by a factor greater than 10. Antimony, barium, beryllium, cobalt, magnesium, nickel and thallium were detected relatively infrequently above the background UTL in the dissolved phase.
- Some of the groundwater SRCs in EUs 1 and 2, particularly metals and radiological compounds, were detected only in the TWPs. Many of the SRCs have an affinity for clay and other formation solids and tend to chemically bind to these materials. As a result of this affinity, turbid groundwater samples, such as those collected from TWPs, tend to have higher concentrations of SRCs than groundwater samples collected from permanent wells, which typically yield less turbid groundwater samples.
- Cesium-137 was detected in groundwater at locations MW404A and GW910A at concentrations of 61.5 pCi/L and 33.5 pCi/L, respectively. These well locations were sampled during Phase 2 to further evaluate the extent of radiological parameters observed in groundwater at temporary well points. MW404A is located near the former fuel oil storage area and in the vicinity of the former radium storage vault, while GW810A is located in the north-central portion of EU 2 in an area not previously investigated. GW810A was also sampled for radionuclides during Phase 3; however, no cesium-137 was detected in this sample.

Note that the above cited detections of cesium-137 were evaluated in the BRA and not found to pose an unacceptable risk, even when assuming water containing these concentrations was consumed (such as in the farming scenario). Furthermore, these detections of cesium-137 are below a drinking water MCL derived using 4 mrem/year as the annual dose rate limit (EPA 2000). The MCL equivalent for cesium-137, using a drinking water ingestion rate of 2 L/day for 365 days/year and ICRP-26/30 dosimetry (from Federal Guidance Report [FGR] 11), would be 110 pCi/L, which is well above the detected concentrations of cesium-137 in groundwater (Peterson et al. 2006).

- Two nitroaromatic compounds were found in EU 1 groundwater samples. 1,3,5-Trinitrobenzene was detected in samples GWBH62-275 and C5-VS-GW-D300 and cyclotetra methylene tetranitramine (HMX) was detected in sample C5-VS-GW-D300. All three of these detections were only slightly greater than the background UTL. HMX

is not known to have been manufactured at the LOOW and there is no record of HMX being stored at the LOOW, so this result is suspect. Nitroaromatic compounds were not detected in any of the other groundwater samples collected in EU 1 or 2.

- Three pesticide compounds, 4,4'-DDD, endosulfan II, and endosulfan sulfate, were detected at well MW505 at concentrations only slightly greater than the background UTL during Phase 3. These compounds were not found at measurable concentrations in the first sample, GW505-783, collected from this well. For this reason, these low pesticide detections are suspect.
- Three PAH compounds, benzo(a)anthracene, benzo(k)fluoranthene, and dibenzo(a,h)-anthracene were detected at well GW808A at concentrations only slightly greater than the background UTL during Phase 3.

5.2.1.5 Pipelines and Subsurface Utilities

Figures 4-22 and 4-23 summarize the occurrence of total and dissolved SRCs in pipeline water samples at the NFSS, while Figure 4-24 summarizes the occurrence of SRCs in pipeline sediment samples at the NFSS.

No pipelines or subsurface utilities are known to traverse EU 1. During the operation of the LOOW, administrative offices were located in this area. It is thought that sanitary sewer lines may have serviced this area, and if they did, they most likely ran to the north towards the facility wastewater treatment plant, located a short distance north of the NFSS perimeter fence.

A sanitary sewer traverses EU 2, flowing to the north, and following a path roughly parallel to Campbell Street. Lateral pipes, which served the acid area, the shops area, Building 401 and the Freshwater Treatment Plant (now part of the IWCS), feed this line. Two storm sewer lines in EU 2, running south of N Street and north of O Street and discharging to the Central Ditch, serviced the acid area. A drinking water line and a fire water line were routed through EU 2, just west of Campbell Street.

One sediment and one water sample were collected during Phase 1 of the RI as part of the LOOW RI sampling. During Phase 3 of the RI, three sediment samples and two water samples were collected from four manholes at EU 2. These manholes were part of the sanitary and storm water sewer systems. Manhole MH13 was sampled because it drained the former radium storage vault in the western acid area. Manholes MH15 and MH16 were sampled to further characterize the sewer system in EU 2. Manhole MH29, located southwest of the former sellite plant, was sampled to characterize the sewer system downgradient of the acid area fuel oil storage location. No manholes or outfalls exist for the drinking water lines so they were not sampled.

General conclusions are:

- The sediment sample collected from location C7-NFSS-ST9 during the LOOW RI contained detectable concentrations of calcium, iron, manganese, selenium, silver, several PAHs, two pesticides, and p-cresol that exceeded the background UTLs. The water sample from this location exhibited concentrations of silver, alpha-BHC, and toluene that exceeded background UTLs. Of these SRCs, silver in the stormwater sample was the only SRC to exceed the background UTL by a factor greater than 10.

- Uranium-234, uranium-235, and uranium-238 were detected at concentrations above background UTLs in a sediment sample collected from manhole MH16, southwest of the intersection of O Street and Campbell Street on the sanitary sewer line. The uranium isotopes exceeded their background levels by a factor of about 3. Calcium and mercury were also detected in this sediment sample at concentrations that slightly exceeded the background UTLs.
- No radiological SRC was detected in the water sample collected from manhole MH16 at a concentration above the background UTL. The following metals were found in the water sample at concentrations above their background UTLs: total thallium, dissolved antimony, dissolved mercury, dissolved nickel, dissolved silver, and dissolved vanadium. Total thallium and dissolved silver exceeded their background UTLs by a factor greater than 10, while the other metals exceeded their background UTLs by factors less than 10. Bis(2-ethylhexyl)phthalate was also detected in the water sample collected at this location.
- Radium-226 slightly exceeded its background UTL in the water sample collected from manhole MH15. No other parameters were detected at concentrations above their background UTLs in this water sample. No sediment sample was collected at this location.
- Sediment samples were collected from the southern storm sewer line from manholes MH13 and MH29, both located near Campbell Street. Both manholes were dry during the time they were sampled. No parameters exceeded background UTLs in sediment at manhole MH13. The sediment collected from manhole MH29 contained manganese, selenium, cesium-137 and several PAH compounds above the background UTLs. None of these SRCs exceeded the background UTLs by more than a factor of about two.

5.2.2 Media Interactions

Surface soils and near surface soils over significant portions of EUs 1 and 2 contain concentrations of several radionuclides that exceed background UTLs. At isolated locations, the magnitude of these exceedances is more than a factor of 100. However, these high concentrations of radionuclides in the soils appear to be spatially limited and relatively immobile. In general, the concentrations of SRCs decrease with depth and the maximum concentrations are found at the surface. The sole exception to this are the samples collected from location 5A016 where the maximum concentrations of radiological SRCs were found in the sample collected at one foot bgs.

There is minimal evidence that radionuclides in the surface and near surface soils are migrating to the groundwater. A dissolved total uranium groundwater plume was found to extend from the west-central portion of EU 2 through the northwest portion of EU 1. In EU 1, the three soil samples with the highest concentrations of total uranium (SS502-060, SS503-064, and SS504-692) do not directly coincide with the highest groundwater concentrations of dissolved total uranium. Likewise in EU 2, the soil samples with the highest concentrations of total uranium were all collected from locations that were hundreds of feet from the estimated footprint of the dissolved total uranium plume.

The uranium plume in EUs 1 and 2 is bounded by groundwater samples with uranium concentrations below UTLs; however in some cases, the samples are large distances (>350 feet)

from the edge of the plume, as shown on Figure 5-4. Due to the spatial distribution of the small number of groundwater samples, the plume size is fairly large. Additional groundwater sampling may be warranted in this area to better define the nature and extent of the uranium groundwater contamination, particularly to the north.

5.2.3 Sources and Effects of Past Site Use

As described above, radioactive wastes were once stored in EU 1 and a remedial action was performed in this area in 1981. A small portion of the New Naval Waste Area was located in EU 2. The former radium storage vault (Building 433) was also thought to have been located in EU 3 near the eastern portion of EU 2. A remedial action was conducted at the New Naval Waste Area in 1983.

- Elevated concentrations of several radionuclides were found across a wide portion of the area, chiefly in the central portion in the area of the former Baker-Smith buildings.
- Similarly, soil samples collected near the West Ditch contained radionuclides at concentrations that exceeded background UTLs by factors greater than 30, including actinium-227, radium-226, and thorium-230.
- The slightly elevated levels of cesium-137 found in surface soils in EU 1 may be attributed to the KAPL residues that were stored in this area. See Section 5.9 for a more detailed analysis of potential fission product contamination at NFSS.
- Radium-226 concentrations in surface and near surface soils above the background UTL were found across EU 2. In addition, several other radionuclides (including isotopic uranium and thorium-230) detected above background UTLs were also found in the area.
- An area of VOC contamination ranging from surface soil to depths greater than 20 feet was identified in the area of the former sellite manufacturing buildings and storage tanks. Past spills or leaks of chemicals used in this area could have resulted in the benzene, ethylbenzene, toluene, xylenes, carbon disulfide, acetone, butanone and hexanone contamination in this area.
- Several PAH compounds were found in the eastern portion of EU 2 at concentrations above the background UTLs. This area is a short distance from the main portion of the New Naval Waste Area, where demolition debris was reportedly stored. The New Naval Waste Area may have contributed to the elevated concentrations of PAH compounds found here.
- There appears to be correlation between elevated readings detected during the gamma walkover and soil samples collected during Phase 3. For example, samples collected within EU 1 in areas exhibiting elevated gamma walkover readings (i.e., east of the West Patrol Road, along the West Ditch, and at location 5A016) contained elevated levels of total uranium, radium-226, and thorium-230. Although only a few small areas of elevated gamma walkover readings were observed in EU 2, similar correlations were observed. For example, location SS4A013 also contained elevated levels of total uranium, radium-226 and thorium-230.

5.3 ACID AREA AND VICINITY: EU 3 AND 4

The acid area and vicinity consists of EUs 3 and 4. The area is bordered by EU 2 on the west, the NFSS perimeter fence on the north, O Street on the south, and EU 5 on the east. None of the major ditches on the site flow through EUs 3 and 4. These EUs are poorly drained and significant portions are covered by ponded water during wet periods. The water that does run off these areas is conveyed to the Central Ditch through the ditches along N Street and O Street.

The major portion of the New Naval Waste Area, where building debris was stored, was located within EU 3. Building 433, also known as the radium storage vault and used to store sealed radium sources, was believed to be located in either EU 2 or 3. The exact location of this building is not known with certainty as conflicting locations are given in the historical record, although they all agree that the building was located a short distance east of Campbell Street, between N Street and O Street. Because of the uncertainty associated with the exact location of Building 433, areas in both EUs 2 and 3 were investigated as potential former locations of the building. During the operation of the LOOW, nitric acid and other materials related to the manufacture of TNT were stored in the acid area (EU 4). During the 1950's, uranium rods were stored in Buildings 431 and 432 (Aerospace Corporation 1982). These buildings, formerly located near the boundary between EUs 3 and 4, were decontaminated and demolished in 1986.

Five abandoned drums were found in EU 4. As part of the RI, these drums were shipped off site for disposal. Soil samples were collected at the locations of these drums and are discussed in the following sections.

5.3.1 Occurrence and Distribution of SRCs

Within EU 3, radium-226 and thorium-230 were the most widely distributed and most commonly found SRCs, though several other radionuclides, metals and organic compounds were also determined to be SRCs. SRCs were more commonly found in surface and near surface soils than at depth.

The list of SRCs in EU 4 is similar to that of EU 3, though more organic compounds were determined to be SRCs in EU 4. Also, significant groundwater impacts were found in EU 4.

5.3.1.1 Soils

Figures 4-4 and 4-5 summarize the occurrence of SRCs in soil at EUs 3 and 4.

Soil samples were collected at EUs 3 and 4 during Phase 1 of the RI to investigate the presence or absence of radiological, organic, and inorganic compounds in and near the acid area. Features of particular interest at EU 3 included a hummocky area near the former railroad lines, a former fuel storage area, and former Building 433. Specific features investigated at EU 4 included the sulfuric acid storage and Building 432; a hummocky area near the former rail lines, tank cradles, and Buildings 431 and 432; the former nitric acid concentrator; and a concrete slab and potential UST. Buildings 431, 432, and 433 were demolished during previous remedial actions, although building foundations and slabs are still present. Soil sampling areas of interest are adjacent to and near these former buildings. Soil was also investigated along the northern NFSS boundary in EU 4 where run-off is received from the CWM property.

Further investigation of compounds found in the soil near these EUs during the LOOW RI was included as part of the Phase 1 soil sampling activities. Phase 1 sample results indicated the presence of organic, metal, and radiological SRCs in surface and subsurface soil at EUs 3 and 4.

Soil samples collected during Phase 2 of the RI served to delineate the nature and extent of compounds detected during Phase 1 activities. In addition, soil samples collected in EU 4 served to investigate the presence or absence of radioactive compounds along the southern boundary of the EU along the former haul road and rail line for the K-65 residue, as well as along the northern boundary of the NFSS.

The majority of the soil samples collected during Phase 3 of the RI were used to investigate the horizontal extent of surface radiological activity observed during the gamma walkover conducted during 2001. Additional samples collected during Phase 3 were used for characterization purposes or to confirm previous sampling results. Phase 3 soil results further indicated the presence of organic, metal and radiological SRCs above background UTLs in EUs 3 and 4.

Four trench areas were investigated in EU 3 and another four trench areas were investigated in EU 4. In EU 3, the trenches were excavated to investigate previously remediated soils, the radium vault area and a rubble-filled depression. Trenches in EU 4 were excavated to investigate debris piles and some underground piping and sewers. One trench in EU 3 (Trench 403) and two trenches in EU 4 (Trenches 406 and 408) were screened during excavation with a two step field-screening method to determine the presence or absence of TNT. The first step determined if TNT was present. If TNT was found, a second step was completed to determine if the TNT was present at concentrations greater than or equal to 10%. None of the field tests suggested that TNT was present at these concentrations in either EU.

The nature and extent of subsurface soils at depths greater than 10 feet is more certain for EU 4 than EU 3 because over 20 samples were collected in EU 4 at depths greater than 10 feet, while only three samples were collected at depths greater than 10 feet at EU 3.

Forty-eight surface and subsurface soil samples collected during the three phases of the RI were used for the evaluation of soils in EU 3. General conclusions concerning the nature and extent of SRCs in soils at EU 3 are:

- Actinium-227, radium-226, thorium-230, uranium-234, uranium-235, uranium-238 and total uranium were found in the surface soils at concentrations above background UTLs, with radium-226 being detected most frequently. Three samples exhibited concentrations of radium-226 that exceeded the background UTL by a factor greater than 10. These three samples, SS4B009-2280, SS4B014-2288, and SS4B021-2295, are all located in close proximity to each other in the west-central portion of the EU. Actinium-227 was also detected above the background UTL at a factor greater than 10 in two of these samples (SS4B009-2280 and SS4B021-2295). Sample SS4B010-2282, which exhibited the highest thorium-230 concentration, was also located in this portion of the EU. Sample SS4B009-2280 exhibited the highest concentrations of uranium-234, uranium-235, uranium-238, and total uranium found in surface soil at EU 3.
- Radionuclides exceeded background UTLs less frequently in subsurface soils. All of the radionuclide SRCs in surface soil are also SRCs in subsurface soil including thorium-228 and thorium-232. Of all of the radionuclides, radium-226 and thorium-230 most frequently exceeded the subsurface soil background UTL. Radiological SRCs in subsurface soil were present in trenching locations as well as at several scattered

sampling points. No radionuclides were identified as SRCs in subsurface soils collected at depths greater than 10 feet bgs from two sample locations.

- Within the west-central portion of EU 3, concentrations of radioactive materials were found that exceed the background UTLs by a factor of 10 or more. In other portions of EU 3, the magnitude of exceedances is much less and analytical data show that the occurrence of radioactive materials in soils at EU 3 at levels above background UTLs is restricted to a maximum depth of approximately two feet, except at trenching locations. However, this conclusion may be biased, as the majority of soil samples collected from depths greater than two feet were from trenching locations.
- Five soil samples were collected from three trenches (one each from Trenches 408 and 414 and three samples from Trench 413) to test for the presence of asbestos; however, asbestos was not detected in any of these samples.
- Twelve metals exceeded background UTLs in surface and subsurface soils in EU 3. All concentrations were less than about three times the background UTL. Additionally, two PAHs, two PCBs, eight pesticides, and three VOCs were detected above background UTLs in soil at EU 3. These SRCs were detected above background UTLs more frequently in subsurface soils, particularly in trenching locations and at depths less than 10 feet. However, these results may be biased because the majority of soil samples collected at depths less than 10 feet bgs were from trenching locations.
- Three subsurface soil samples were collected in EU 3 at depths greater than 10 feet. These samples exceeded background UTLs for three metals only, including selenium, sodium, and thallium.
- Trench 403 was excavated in the former acid area between O Street and N Street. Three feet of fill with organic matter, bricks, gravel and wood were observed in a rubble-filled depression at this trench location. Although a number of magnetic anomalies appeared to exist in the fill material, there were no elevated PID readings and no gamma measurements above background. Three soil samples were collected, two of which were from sand lenses. The third sample was collected from the grayish-brown clay at the bottom of the trench. The trench samples indicated the presence of metals, pesticides, PCBs, and VOCs above background UTLs in soil. Additionally, total uranium, uranium-234, uranium-235, uranium-238, radium-226, and thorium-230 were detected above background UTLs. All SRCs were present at concentrations only slightly greater than the background UTLs.

Three trenches (Trenches 411, 412, and 413) were dug in areas of disturbed ground in the New Naval Dump. The trenches were located to investigate for the presence of radiological parameters in soils near a form vault where bars of pure radioactive materials were stored at the western end of the acidification area. These trenches were investigated for radiological parameters only.

- Trench 411 was excavated to look at remediated soils from the New Naval Waste Area. This trench is located to the north of the former radium vault. Geophysical results indicate both ferrous and conductive zone anomalies in the area. The upper two feet of the trench penetrated a dark brown to black clay containing concrete rubble and rebar. A brownish-gray clay with occasional cobbles was observed below the debris zone.

Magnetic anomalies exist in the upper two feet of soil and gamma readings above background were observed at two locations. No elevated PID readings were noted. The trench was reoriented slightly so that the west end would not intercept a surface gamma area of elevated radioactivity. One soil sample was collected in a sand lens. The other two soil samples were collected in the upper debris layer. The two samples from the upper debris layer indicated the presence of total uranium, uranium-234, uranium-235, uranium-238, actinium-227, radium-226, and thorium-230 above background UTLs. All of these SRCs were present at concentrations less than 10 times the background UTL. No SRCs were identified in the sample collected from the sand lens.

- Trench 412, a 7-foot deep trench near the western border of EU 3, was excavated to investigate remediated soils in the New Naval Waste Area. Geophysical results indicate ferrous and metallic zone anomalies in the area. Dark brown clay with metallic debris and organic material was observed in the upper two feet of the trench. Underlying the debris layer was a brownish-gray clay with two sand lenses and a zone of white clay nodules. An area in the zone of white clay nodules exhibited an elevated PID reading. Additionally, there were many magnetic anomalies in the top two feet. No gamma readings were above background levels. Three samples were collected; one in a sand lenses, one within the zone of white clay nodules, and one in the brownish-gray clay. Thorium-230 slightly exceeded the background UTL in one of the samples. No other SRCs were identified in these three samples.
- Trench 413, located in the south-central part of EU 3, was excavated to investigate the radium vault area and the asbestos burial area. Geophysical results indicated one metallic zone anomaly. The upper layer of the trench contained cinders as well as a 2.5-foot ballast layer at the west end of the trench. Water infiltration prohibited some of the western portions of the trench from being excavated. A 2.5-foot layer of brown to black clay containing a light colored clay lens and a 4-inch iron pipe was observed below the cinders. The bottom two feet of the excavated portion of the trench contained a grayish-brown clay which contained a sand lens. A magnetometer anomaly was found at the location of the iron pipe; however, no gamma readings exceeded background and there were no elevated PID readings. Three subsurface soil samples were collected; one from just below the iron pipe, one from the light colored clay lens, and one from the sand lens in the grayish-brown clay. Uranium-235 was detected at a concentration slightly greater than the background UTL in the sample collected below the iron pipe. No other SRCs were identified in these three samples.

Ninety-six surface and subsurface soil samples collected during the three phases of the RI were used for the evaluation of soils in EU 4. General conclusions concerning the nature and extent of SRCs in soils at EU 4 are:

- Cesium-137, radium-226, and thorium-230 were widely distributed in surface soils at concentrations above background UTLs. The maximum concentration for each of these three isotopes was less than five times the background UTL. These three radionuclides were also detected at concentrations above background UTLs in subsurface soils at depths less than 10 feet mainly at trenching locations and former drum locations. However, sampling results may be biased toward these locations because most of the subsurface soils collected from depths less than 10 feet were from trenching and drum locations. Thorium-230 was infrequently detected at concentrations slightly above the background UTL in subsurface soils at depths greater than 10 feet.

- Americium-241, thorium-228, thorium-232, uranium-234, uranium-235, uranium-238 and total uranium were also found at concentrations above the background UTL in EU 4 surface and subsurface soils. However, these SRCs were found infrequently compared to the other radiological SRCs. Sample TB414-2844-05.5-004, collected from trench 414 (excavated in the western portion of the EU) at a depth of 5.5 feet bgs, had a uranium-234 concentration of 15.2 pCi/g. This result was almost ten times greater than the background UTL. Americium-241 only slightly exceeded its detection limit in two surface soil samples. The associated analytical uncertainties reported for these two samples, which are very close to the value of the results themselves, lowers the confidence of these detections.
- The radium-226 concentration in the four surface soil samples in the acid area just north of the junction of O Street and Castle Garden Road (samples SS417-054, SS4D014-630, SS4D012-628, and SS4D015-631) exceeded the background UTL by a factor less than five. These samples were collected near a former railroad bed. A ballast sample collected near these surface soil samples had a radium-226 concentration of 5.13 pCi/g. Thus, the data suggests that the railroad ballast may be contributing to the elevated radium-226 concentrations found at this location.
- Fourteen PAH compounds were detected in surface and subsurface soil at concentrations above background UTLs in EU 4 at depths less than 10 feet bgs. Soil samples collected from one trench location (TB408) and the locations of five abandoned drums contained one or more PAH compounds at concentrations above background UTLs. Several other scattered locations exhibited PAH compounds in surface soil that exceeded background UTLs. These samples were all located in the central and south-central portion of the EU.
- Metals were frequently detected in surface and subsurface soils in EU 4 at concentrations above background UTLs. Selenium and thallium were the metals most frequently detected above background UTLs. Boron, copper, and lead exhibited the highest exceedances in surface soil. Boron, lead, and sodium exhibited the highest exceedances in subsurface soil at depths less than 10 feet bgs. Each of these exceedances corresponded to locations of a trench or abandoned drum with two exceptions; lead exceeded the background UTL by a factor of at least 10 at locations EU042 and SS413. The magnitude of exceedance for soil samples not collected from locations of trenches or abandoned drums was typically by less than a factor of five.
- Detectable quantities of Aroclor-1254 and Aroclor-1260 were frequently found in surface and subsurface soil samples collected from EU 4. The maximum concentration of Aroclor-1254 was 714 µg/kg in surface soil sample SS4C001-618. The maximum concentration of Aroclor-1260 was 70,200 µg/kg in surface soil sample SS-DRUM07-3398. Several other soil samples collected from depths of one foot or less, mainly in the south-central portion of the EU, exhibited Aroclor-1260 concentrations greater than 1,000 µg/kg.
- Three pesticides and nine VOCs were detected in surface and subsurface soils at EU 4. Pesticides and VOCs were most commonly detected at trench and abandoned drum locations. Pesticides were also detected at several surface soil locations in the south-central portion of the EU. One or more of four VOCs (TCE, PCE, cis-1,2-DCE, and trans-1,2-DCE) were detected in surface or subsurface soil at locations MW424, SB415, and SS418.

- Subsurface soil samples collected in EU 4 at depths greater than 10 feet exceeded background UTLs for metals, benzo(g,h,i)perylene, pesticides, VOCs, and radionuclides. These exceedances occurred at widely scattered locations within the EU and, in most cases, were collocated with exceedances in samples collected from shallower depths. Widely scattered locations of samples that exceed background UTLs are spatially isolated with no definable source.
- An abandoned drum (Drum 2) found in EU 4 was sampled and appropriately disposed. Metals of note in the drum include boron and nickel. Low levels of benzene were found in the drum residue. A surface soil sample collected from beneath the drum contained metals, most notably nickel at twice the background UTL. Aroclor-1260 and indeno(1,2,3-cd)pyrene were also found. The soil boring sample collected from beneath the drum did not have any exceedances.
- The five abandoned drum locations investigated in EU 4 indicated the presence of metals, PAHs, PCBs, pesticides, SVOCs, VOCs, and radionuclides in soil at concentrations exceeding background UTLs and at depths of one foot or less bgs. Three metals, boron, copper, and sodium, exceeded background UTLs by a factor of at least 10 at abandoned drum locations. PAHs commonly exceeded background UTLs at the abandoned drum locations. Two PAHs, benzo(g,h,i)perylene and indeno(1,2,3-cd)pyrene, exceeded background UTLs by factors greater than 10. Cesium-137, thorium-230, and radium-226 were the radionuclides that most frequently exceeded soil background UTLs at abandoned drum locations. Radionuclide concentrations commonly exceeded the background UTLs by a factor of 5 or less. Five VOCs (acetone, cis-1,2-DCE, 1,1-DCE, PCE, and TCE), and two SVOCs (benzoic acid and 2-methylnaphthalene) were also detected above background UTLs at abandoned drum locations.
- Trench 404 was excavated in EU 4 to investigate piping and sewer lines. A 12-inch vitrified clay pipe was discovered at a depth of 2 feet. This pipe was surrounded with gravel and slag. A 36-inch concrete pipe was found at a depth of 7 feet. The southeastern end of the trench contained slag or gravel as the uppermost 18 inches and was not excavated to deeper depths due to groundwater infiltration. The concrete pipe exhibited the only magnetometer anomaly. There were no elevated gamma or PID readings. Three soil samples were collected at this trench location. One sample was collected from around the vitrified clay pipe just below the slag and gravel, and another sample was collected approximately one foot above the concrete pipe. The third sample was collected in the brown and tan clay which made up most of the soil from the trench. Aroclor-1260, pesticides, and thorium-230 were identified as SRCs in soil at this trench location.
- Trench 406 was excavated in EU 4 to investigate a debris pile. The trench was located just south of N street and east of Trench 404, and was oriented north-south. Steel, PVC, rubble and gray foam were found in the trench along with an 8-inch vitrified clay pipe and a 36-inch concrete pipe. The top foot of the trench contained a fine silty material like loess which was underlain by a brownish-gray clay. Several sand lenses were observed including one that contained oily gravel. A gravel backfill surrounded the 8-inch pipe. There were no magnetic anomalies, gamma readings above background, or elevated PID readings in the trench. Three soil samples were collected; one in the boundary between the clay and the loess, one in the oily gravel, and one in the clay at the bottom of the trench. Two metals, boron and sodium, were detected at this trench location at

concentrations that exceeded background UTLs by factors greater than 10. One PCB, one pesticide, eight VOCs, total uranium, and several radionuclides were also detected above background UTLs at this trench location.

- Trench 408 was also excavated to investigate a debris pile in EU 4. This trench was located east of Trench 406 but was oriented parallel to N Street. The upper few inches of the trench contained roofing debris and rubble. That debris overlaid a brown-clay with iron nodules. A 12-inch pipe was found at a depth of about 2 feet and there were several small magnetic anomalies. One section of the trench had slightly elevated gamma readings, but there were no elevated PID readings. One surface soil sample and three subsurface soil samples were collected. One of the subsurface soil samples was collected at the location of a magnetic anomaly. No SRCs were identified in the surface soil sample. Several metals, PAHs, pesticides, PCBs, VOCs, and radionuclides exceeded background UTLs in the subsurface soil samples.
- Trench 414 was excavated in EU 4 to investigate a debris pile near a building foundation. The soil in the area appeared disturbed or remediated. The trench was oriented north-south along the west side of the concrete foundation in the westernmost portion of EU 4. The upper 1 to 3 feet of the trench contained a dark brown to black loam with wood and concrete debris. Underlying the loam was brown clay containing bricks and concrete rubble. A white fibrous material was present in a short section of the boundary between the loam and the underlying clay. At the north end of the trench a concrete foundation was encountered at a depth of 5 feet. Immediately adjacent to the concrete foundation, at a depth of 5.5 feet, was a layer of wet ash-like material. The lower 4.5 feet of the 10-foot deep trench contained a brownish-gray clay that contained one lens of a dark stained soil. Magnetic anomalies attributed to rebar in the concrete were encountered, but no elevated PID measurements or gamma readings above background were observed. Three subsurface soil samples were collected from the trench; one from the zone of fibrous material at the base of the loam, one from the ash, and one from the dark stained soil. Total uranium activity in all three samples exceeded the background UTL. Several radionuclides including all three uranium isotopes exceeded the background UTLs in one or more soil samples. The sample collected from the wet ash-like material at a depth of 5.5 feet is suspected to contain enriched uranium. The uranium enrichment of this sample (TB414-2844-05.5-004) is further discussed in Section 5.9.4.4. This trench location was also the only trench location in EU 4 where cesium-137 was detected above the background UTL. No other SRCs were detected in any of the three soil samples.

5.3.1.2 Surface Water

Figures 4-15 and 4-16 summarize the occurrence of total and dissolved SRCs in surface water at the NFSS.

No surface water samples were collected in EU 3 during the RI. A single surface water sample was collected in EU 4 during Phase 1 from a location adjacent to the mixed acid storage area and the associated sumps and piping. Sample SW740-390 was collected from a ponded area near Sump 25 to investigate the presence or absence of SRCs. A total of 20 metals were found in this sample at concentrations above background UTLs. However, none of these metals were found in the dissolved phase at concentrations above background UTLs. This indicates that the results may be attributable, in large part, to turbidity in the sample. No radionuclides or organic compounds were found at concentrations above background UTLs in this sample.

5.3.1.3 Sediment

Sediment samples were not collected from ponded areas or surface drainageways in EU 3 or 4. Sediment samples collected from the sewer systems are discussed later in this section.

5.3.1.4 Groundwater

Figures 4-15 and 4-16 summarize the occurrence of total and dissolved SRCs in the LWBZ and UWBZ at the NFSS.

Three TWP's were sampled in EU 3 during Phase 1 of the RI to investigate the presence or absence of radiological and chemical compounds in the groundwater near the former railroad lines and the property boundary, and to investigate previously identified compounds in soil near this area. Four permanent wells and nine TWP's were sampled in EU 4 during the RI to investigate the presence or absence of radiological and chemical compounds in the groundwater near the former railroad lines, tank cradles, former nitric acid concentrator, a potential former UST, Buildings 431 and 432, and the property boundary. Groundwater samples were also collected in EU 4 to investigate previously identified compounds in soil and groundwater near this area.

- Several metals were detected at concentrations above background UTLs in EU 3, although only manganese exceeded its screening level in both the total and dissolved phase in more than one well. The data indicates that a manganese plume is present in EU 3. This plume is shown on Figure 5-5. Trench 403 which runs through the area of the plume shows no elevated concentrations of manganese in soil. Additionally, sediment and water samples from nearby pipes and sumps exhibit no elevated manganese concentrations. A pipe, which is part of the acid sewer line and composed of vitrified clay, runs through the plume area. This pipe is unlikely to be the source of manganese in groundwater unless the pipe was cracked and a liquid with a high manganese concentration leaked from the pipe. There is also a concrete structure that impinges on the southern portion of the plume. This structure may represent a tank support, and it is possible that corrosion from a tank or the structure has influenced metal concentrations in the groundwater. Iron is also elevated in the groundwater sample collected nearest to the structure. The iron concentration in this sample is approximately two times greater than the background groundwater concentration. This observation supports the possibility that manganese concentrations in groundwater are products of corrosion.
- Several PAHs, heptachlor epoxide and carbon disulfide were detected in sample C5-AC-GW-BP3 in EU 3. PAH exceedances also occurred at three locations in EU 4.
- Total uranium, thorium-228 and uranium-238 were detected slightly above background UTLs in sample GW409-212. Total uranium was detected slightly above the background UTL in sample GW407-210.
- The data indicate that there is a boron plume in the central portion of EU 4. This plume is shown on Figure 5-6.
- A dissolved total uranium groundwater plume is present in the north-central portion of EU 4 near the former nitric acid concentrator. The configuration of this plume is defined by wells 415A, 4D003, and 4D005. As shown in Figure 5-4, the concentrations of

dissolved total uranium in this plume are approximately twice the background UTL of 16.7 µg/L.

- Dissolved thorium-228 and dissolved thorium-230 were detected above background UTLs in groundwater at two locations in the north-central portion of EU 4. This small plume, which is not collocated with a dissolved total uranium plume, is shown on Figure 5-7. Total concentrations of cesium-137, radium isotopes, and thorium isotopes were also greater than background UTLs in this EU; however, cesium and radium concentrations within the EU are not coincident with the thorium plume. Furthermore, the detection of cesium-137 was below a derived drinking water MCL (110 pCi/L, as described in Section 5.2.1.4), which is well above the detected concentration of cesium-137 in groundwater.
- Seventeen VOCs and four SVOCs (bis(2-ethylhexyl)phthalate, carbazole, di-n-butyl phthalate, isophorone) were detected in EU 4 groundwater samples at concentrations above background UTLs. Most of these compounds were detected in samples collected from permanent well MW415A. Several of these compounds were also found in other nearby wells. Groundwater plumes containing the following compounds are present in EU 4:
 - PCE
 - TCE
 - Cis-1,2-DCE
 - Trans-1,2-DCE
 - Vinyl Chloride

Figures 5-8 through 5-12 show the extent of these plumes. Concentrations of these VOCs within these plumes greatly exceed the National Primary Drinking Water Maximum Contaminant Levels (MCLs).

The organic compounds observed in the groundwater plumes may degrade through the process of natural attenuation; however, the effectiveness of natural attenuation is highly dependent on the degradation potential of the compounds present and the microbial conditions of the subsurface environment. Natural attenuation also relies on the processes of dispersion and dilution which are dependant on the local groundwater flow rates. Low groundwater flow rates at the NFSS will not greatly promote natural attenuation of organic compounds; however, because the groundwater plumes in EU 4 contain compounds included in the degradation chain of PCE and TCE, there is evidence that natural attenuation processes (mainly microbial) may be occurring at this location. Additionally, methane, a natural attenuation indicator parameter, was detected at well MW415A, which also may indicate that biodegradation is occurring.

- Acetone, benzene, 2-butanone, carbon disulfide, chloroform, 1,1-DCE, ethylbenzene, 4-methyl-2-pentanone, methylene chloride, 1,1,2-trichloroethane, styrene, and total xylenes were detected infrequently in one or two samples at concentrations above the background UTLs.

5.3.1.5 Pipelines and Subsurface Utilities

As shown on Figures 4-22, 4-23, and 4-24, sanitary sewers, storm sewers, and acid/process sewers traverse EUs 3 and 4. The acid/process lines form a complex pipe network, with many line junctions and laterals. Also, an aboveground piping system and a series of open sumps also drained to the acid/process sewer. Many of the man-hole covers and collars on these sewers are damaged and it is apparent that surface water, soil, leaves and other materials freely infiltrate these systems. In the case of the acid/process sewer, the aboveground pipes and open sumps also provide infiltration points.

Sediment and water samples were collected from this system as part of the LOOW RI. Sediment and water samples were also collected from pipelines and subsurface utilities during Phase 3 of the NFSS RI. In EU 3, Phase 3 sediment samples were collected from one pipe, one sump and one manhole. In EU 4, Phase 3 sediment samples were collected from nine pipes, six sumps, and four manholes. Five water samples were also collected in EU 4 during Phase 3; one from a pipe and four from manholes.

The list of SRCs found in the water and sediment samples collected from the sewers, pipes and sumps is very extensive. Metals, PAHs, Aroclor-1260, pesticides, VOCs, SVOCs, and several radionuclides were found at concentrations above background UTLs. The results associated with the three sewer systems present in EUs 3 and 4 are discussed below.

Acid/Process Sewer System

Acidic wastewater from the production, concentration and storage of acids was discharged to this sewer system, which flowed to the west, beyond the NFSS border, where it combined with other process wastewater lines and eventually discharged to the wastewater treatment plant located in the southwest corner of the site. The acid/process sewer system was constructed of vitrified clay pipe.

One sewer water sample, PIPE28W, was collected from an exposed pipe in EU 4 that is not known to be connected to any of the sewer lines. The pipe appeared to have been broken-off above the ground surface. The pipe was made of heavy gauge steel and may have been a part of the steam generation system or an acid process transfer line. An oily residue and lids from oil and paint cans were found in the pipe. The concentrations of several PAHs were among the highest found in sewer water samples collected in this RI and in previous investigations. Several metals were also detected in this sample above background UTLs. Although the function of this pipe is not known, this sample location was included in the discussion of the acid/process sewer system.

- Twenty sediment samples were collected from the acid/process sewer lines within the boundaries of EUs 3 and 4 during Phase 3. Five additional sediment samples were also collected from this system during Phase 1 as part of the LOOW RI. Several metals were found in one or more sediment samples at concentrations which exceeded the background UTLs. In all cases, the magnitude of exceedance was less than about four. With the exception of lead, mercury, and selenium, no metal was found in more than three samples. Selenium was the only metal detected above background UTLs in the samples collected in EU 3. The locations of samples exhibiting metal exceedances in EU 4 are scattered throughout the EU, with no apparent pattern to the distributions.

- Many organic SRCs, including PAHs, Aroclor-1260, SVOCs, VOCs and pesticides were found in the sediment samples at concentrations above background UTLs. These SRC exceedances occur in the eastern portion of EU 3 and sporadically over a wide portion of EU 4.
- Two subsurface soil samples associated with pipelines in the acid concentration area were collected during Phase 1 at depths of 2 to 2.5 feet. These two samples, C7-NFSS-SO-PIPE1 and C7-NFSS-SO-PIPE2, exhibited concentrations above the UTL for four metals, three PAHs, and seven pesticides; of these constituents, only fluorene exceeded its UTL by a factor of 10 or greater. This fluorene exceedance was in sample C7-NFSS-SO-PIPE2 only.
- Thirteen metals were found in either the total or dissolved phase in one of the water samples (PIPE28W-2056) in EU 4 at concentrations above background UTLs. Nine dissolved metals were detected above the background UTLs in this sample. Thorium-228, thorium-230, thorium-232, uranium-234, uranium-235, and uranium-238 were detected above background UTLs in sample MH35W-2038. PAHs were found in both water samples; however, concentrations of PAHs that exceeded background UTLs by a factor of 100 or more were observed only in sample PIPE28W-2056.
- Heptachlor epoxide was detected above the background UTL in sample C7-NFSS-WW-ST6.
- TCE, cis-1,2-DCE and PCE were found in water samples MH32W-2036 and MH35W-2038 at the concentrations ranging from 2.6 µg/L to 225 µg/L. These three compounds were also found in groundwater in the vicinity of these samples. These results are discussed further in the groundwater section for this EU.

Sanitary Sewers

The sanitary sewers at the NFSS were routed to the original WWTP, located northwest and outside of the NFSS property boundary. The main sanitary sewer line, located along the west side of Campbell Street, is oriented north-south and lateral lines extended into EUs 3 and 4. The sanitary lines located on the NFSS were constructed of 24-inch diameter vitrified clay pipe.

- Two sediment samples, MH19S-2028 and MH37S-2040, were collected from the sanitary sewer system in EUs 3 and 4. Cesium-137 was detected at a concentration slightly above the background UTL in sample MH37S-2040. No other SRCs were found in these samples at concentrations above background UTLs.
- One water sample, MH31W-2035, was collected from the sanitary sewer. Cesium-137, radium-226, uranium-234, uranium-235, and uranium-238 were detected in this sample at concentrations greater than the background UTL. The cesium-137 concentration in this sample (2.02 pCi/L) was the highest concentration found in sewer water samples collected during this investigation. Cis-1,2-DCE was also detected in this sample.

Storm Sewers

A total of 4,340 linear feet of stormwater sewer lines were present on the NFSS. Two separate east-west oriented lines are located south of N Street and north of O Street. Stormwater runoff, principally from EUs 3 and 4, was routed to the storm water sewer system and discharged at two outfalls located in the Central Ditch. The lines consisted of 24-inch vitrified clay pipe. One

sediment sample, MH22S-2029 was located from a storm sewer located in the north-central portion of EU 4, and one water sample, MH26W-2032, was collected from a storm sewer located in the south-central portion of EU 4.

- Cesium-137 was detected slightly above the background UTL in sediment sample MH22S-2029. Three VOCs, cis-1,2-DCE, PCE, and TCE were also detected in this sample.
- Several metals were detected at concentrations greater than background UTLs in water sample MH26W-2032. The concentrations of SRCs detected in this sample were less than twice the background UTL, except for dissolved silver whose concentration was almost 30 times greater than the background UTL.

5.3.2 Media Interactions

There is a likely interaction between the groundwater plumes shown on Figures 5-8 through 5-12 and the pipeline system in EU 4. Elevated concentrations of TCE, cis-1,2-DCE and PCE were found in water samples collected from manholes MH32 and MH35 on the acid/process sewer. At manhole MH32, the depth to water was 11.83 feet bgs and at manhole MH35 the depth to water was 10.67 feet bgs. Monitoring well MW415A, which is in the vicinity of these two manholes and is near the center of the identified groundwater plumes, was sampled on two occasions. The depth to groundwater at MW415A in September 2000 was 10.3 feet bgs and in May of 2003 it was 14.04 feet bgs. Since the acid/process sewer was constructed of vitrified clay pipe – a type of material commonly subject to infiltration and exfiltration problems – and the acid/process line is at an elevation that is at times submerged below the water table, a hydraulic connection likely exists between the acid/process sewer and the groundwater plumes. It should be noted that the pipeline contamination is limited to manholes in the vicinity of the plume (near MW 415). Thus, VOC contamination appears not to have spread within the pipeline or along pipeline bedding in EU 4. Plume maps in this area were developed taking into account interactions between the various media.

The soils data for manganese and total uranium do not suggest a potential source for the plumes of these SRCs. In EU 3, where the manganese plume was located, none of the soil samples exceeded the background screening level for manganese. In EU 4, only eight soil samples collected in the EU exceeded the background UTL for uranium-234, and none of the exceedances were collected from a location within the footprint of the total uranium plume. Similarly, for uranium-238, only nine soil samples within the EU exceeded the background UTL, and none of the exceedances were collected from a location within the footprint of the total uranium plume.

5.3.3 Sources and Effects of Past Site Use

The New Naval Waste Area was located in EU 3 and an acid storage area was located in EU 4. A radium storage vault (Building 433) was located in the New Naval Waste Area in EU 3. Uranium rods were known to be stored in Buildings 431 and 432, located a short distance east of EU 3.

- The metals and organic compound results for surface soils in EU 3 are consistent with known past activities at this location. The New Naval Waste Area was known to contain demolition debris. Such materials could be related to the metals and PAH compounds now found in the area. This might also account for the pesticide found in groundwater.

- Most of the radionuclides present in EU 3 may be due to activities conducted and waste stored at the New Naval Waste Area and from activities at the former radium storage vault (Building 433). The analytical data is indicative of the radioactive wastes streams known to have been transported and stored at the NFSS.
- The groundwater in EU 4 is impacted with PCE, TCE and several other VOCs. There were no known past uses in this EU which would account for these findings. PCE was commonly used for industrial purposes during the operational time period of the LOOW, though given the safety concerns of storing solvents near acids, it is unlikely that this release occurred during the operation of the LOOW. Historically, TCE was not used at ordnance plants during WWII. TCE was not commonly used until after the war. However, TCE can be a degradation product of PCE. Although the source of the VOCs was not established, their presence may be due to past storage activities of the military and AEC. As presented in greater detail in Section 7.3.4, the VOC plumes are within the UWBZ at a depth of approximately 10 to 15 ft bgs and appear to be located in a topographic low in the GLC near monitoring well 415. There is no correspondingly high vadose zone soil contamination associated with the groundwater contamination in EU 4. CWM currently operates a VOC groundwater extraction and treatment system north of NFSS.
- Metals are present in the groundwater at EU 4, perhaps resulting from the storage and transport of acids which, if spilled, could cause mobilization of metals from soils.
- No known source for the elevated concentration of dissolved silver in the storm sewer could be identified.
- One groundwater sample at EU 4 also contained bis(2-ethylhexyl)phthalate, which was probably used as a plasticizer in the explosives manufacturing process, and 1,1,2-TCE, a breakdown product of the solvents likely used in the area.
- The metals and PAHs found in EU 4 soils could be a result of the transportation and storage of acids and the general industrial operations performed around the buildings. These activities might also account for the presence of PCBs and PCE and observed breakdown products in soils.
- The radionuclides present in EU 4 soils are likely a result of the general transportation and storage of residues on the NFSS site and not from any activity specific to EU 4.
- There appears to be correlation between elevated readings detected during the gamma walkover and soil samples collected during Phase 3. For example, samples 4B009, 4B014, and 4B021 were collected in the western portion of EU 3 in areas exhibiting elevated gamma walkover readings. In general, these samples also showed analytical results with higher levels of radionuclides, particularly, total uranium and radium-226. Several portions of EU 4 exhibited fairly large areas with only slightly elevated gamma walkover readings. Samples collected in these areas generally exhibit only slightly elevated levels of radionuclides. Location 4C002, near the southeastern border of the EU appears to be in a small area of slightly higher gamma walkover readings. This sample location exhibited elevated levels of total uranium, radium-226 and thorium-230.

- Soils data from EU 4 do not suggest a potential source for the dissolved total uranium and thorium-230 groundwater plumes observed in this area. Concentrations of radionuclide SRCs in soil, as well as in sediment and water collected from the underground utility lines are generally less than three times the background UTLs and appear to be unrelated to the plume footprints. The highly industrialized nature of historical operations conducted in this EU may provide a general explanation for the presence of groundwater plumes in this area. Former abandoned drums, as well as the many underground pipelines and sewer lines traversing this EU, may represent historical sources for the concentrations of SRCs currently observed.

5.4 PANHANDLE AREA: EU 5 AND 6

The Panhandle Area, consisting of EUs 5 and 6, is located in the northeastern portion of the site. It is bordered to the north and east by CWM Chemical Services Inc. Landfill and Modern Landfill to the south.

Building 434, a water tower during the operation of the LOOW and later a storage facility for the K-65 residues, was located in EU 6. In the 1980's, the K-65 residues were slurry transferred to the IWCS through a pipeline. The pipeline passed through EU 5 along O Street.

A thaw house, located in EU 6 near Building 434, was used to store and dry 300 drums of P-54 residues containing 37 tons of residue and 740 lbs of U_3O_8 . P-54 is the code name for the lead sulfide cake produced from the processing of L-30 and L-50 ore at the Linde refinery. Barrels containing six tons of P-56 residues with 176 lbs of U_3O_8 were also stored in the thaw house. P-54 is the code name for the regenerated lead sulfate cake produced from the processing of L-30 and L-50 ore at the Linde refinery. This material was first stored in the filter building (Building 410) and was later shipped off-site for disposal.

Ammonia storage facilities were present in EU 5 during operation of the LOOW and some foundation material was found in the EU. In 1953, an explosion and fire that was not related to the storage or use of ammonia occurred immediately south of the Panhandle Area.

5.4.1 Occurrence and Distribution of SRCs

Soil samples were collected at EUs 5 and 6 during Phase 1 of the RI to investigate the presence or absence of radiological, organic, and inorganic compounds near the site boundaries, the former K-65 storage tower, and previously uninvestigated areas. The acid area and some LOOW sampling locations were of particular interest in EU 5. The areas near former Building 434 were of particular interest in EU 6. Specific features investigated in EU 5 included the former ammonia plant, the explosion site, and the northern and southern boundaries of the NFSS site. The 1953 explosion and fire that was investigated by some of the EU 5 samples occurred off-site immediately south of the Panhandle Area. In EU 6, the boundaries of the site and locations around the former water tower, which was used to store K-65 residues, were specifically targeted for investigation. Further investigation of compounds found in the soil near these areas during the LOOW RI was included as part of the Phase 1 soil sampling activities. Phase 1 sample results indicated the presence of organic, metal, and radiological SRCs in surface and subsurface soil in EUs 5 and 6.

Soil samples collected during Phase 2 of the RI served to delineate the nature and extent of compounds detected during Phase 1 activities as well as to investigate some areas not covered by previous sampling. In EU 5, the haul road (O Street) for K-65 residues was further investigated,

as was a tank cradle. In EU 6, soil in the former thaw house area was sampled, including several locations where walkover data indicated elevated radiation levels. Additionally, the site boundary near the Modern Landfill and explosion site was investigated. Phase 2 sample results indicated the presence of organic, metal, and radiological SRCs that exceeded background UTLs in surface and subsurface soil in EUs 5 and 6.

The majority of samples collected in Phase 3 of the RI were radiological samples used to further investigate areas found to be above background by the gamma walkover or were random samples used to verify the walkover results. Additional samples were used to further delineate individual results from Phases 1 and 2. Results from Phase 3 sampling indicated SRCs exceeding background UTLs for metals, PAHs, PCBs, pesticides, VOCs, and radiological constituents.

In EU 5 during Phase 3, a trench (Trench 410) near some foundation material was excavated and sampled with the intent of locating a potential UST.

A total of ninety-one surface and subsurface soil samples collected during the three phases of the RI were used to evaluate soils in EUs 5 and 6. Three of these soil samples were collected from the trench in EU 5. Additionally, one sample collected from EU 5 (SD737-381) and four samples collected from EU 6 (SD731-368, SD732-370, SD733-373, and SD734-375) were intended to be evaluated as sediment samples. However, as discussed in previous sections of this RI report, these samples were classified as surface soil samples to be consistent with exposure mechanisms considered in the BRA. Therefore, these samples were included in the discussion of soil samples collected at EUs 5 and 6.

Samples containing concentrations of SRCs above background UTLs appear to be randomly scattered in EUs 5 and 6 because many of the samples in this area were collected using a stratified random sampling approach to verify gamma walkover results and areas of suspected contamination. A localized area of elevated radioactivity was observed at location 6A001 (EU 5) and the area at the intersection of McArthur and O Streets (EU 6).

The SRCs in EUs 5 and 6 are predominantly radionuclides, especially in soils, though several metals and organic compounds are also SRCs. The following sections present the occurrence and distribution of SRCs, by media.

5.4.1.1 Soils

Figures 4-6 and 4-7 summarize the occurrence of SRCs in soil at EUs 5 and 6.

Forty-five soil samples collected during the three phases of the RI were used in the evaluation of soils in EU 5. General conclusions concerning the nature and extent of SRCs in soils at EU 5 are:

- The radionuclides that most frequently exceeded background UTLs in surface soil were cesium-137, radium-226, and thorium-230. Uranium isotopes and actinium-227 were also detected above background UTLs in surface soils. All of these radionuclides were detected above background UTLs in subsurface soil, with the exception of actinium-227 and cesium-137.
- The highest radium-226 concentration was found in surface soil sample SS6A001-2317. This sample was collected from an area near the east end of the O Street North Pond where elevated gamma radiation was identified during the site-wide gamma walkover

survey. This sample had a radium-226 concentration of 285 pCi/g, more than 200 times the background UTL. The radium-226 concentration in sample SB6A001-2318-2.0, collected from a depth of two feet bgs from the same sample location, was 6.33 pCi/g. Three surface soil samples collected from locations within 40 feet of SS6A001-2317 exhibited concentrations of radium-226 that only slightly exceeded the background UTL. Actinium-227 was also detected in surface soil at this same location at concentrations that exceeded the background UTL by a factor of almost 200.

- The concentrations of radionuclides (other than actinium-227 and radium-226) in surface and subsurface soils were generally less than five times the background UTLs.
- PCBs and pesticides were detected infrequently above background UTLs at several widely spaced locations in EU 5. The maximum depth at which PCBs were found was one foot bgs. Pesticides were found at a maximum depth of 1.5 feet bgs. PAHs were detected above background UTLs at a single surface soil location in the northwestern portion of EU 5. Ten VOCs were detected at widely-spaced locations in EU 5 at relatively low concentrations slightly above the detection limits. Most of the VOCs were detected in surface soils; however, benzene, toluene and xylenes were detected in surface and subsurface soil near the southwestern boundary of the EU at location 420. Other VOCs detected above background UTLs in subsurface soil were associated with trenching location TB410.
- Metals were detected above background UTLs in surface and subsurface soils at several locations throughout EU 5, but at concentrations generally less than 5 times the background UTL. Most of these metals were detected within the upper one foot of soil.
- Subsurface soil samples collected in EU 5 at depths greater than 10 feet bgs exceeded background UTLs for boron, cadmium, selenium, thallium, radium-226, thorium-230 and acetone. Metal exceedances occurred at four widely scattered locations within the EU. VOC exceedances occurred at sample location 811 and radionuclide exceedances occurred at sample locations 811 and 421.
- One trench, Trench 410, was excavated in EU 5 to investigate a potential UST northwest of some foundation material. The trench is 6 feet deep and 65 feet long, oriented east-west, and consists of dark brown to black loam overlying a brownish gray mottled clay and gray clay. There were no magnetometer anomalies, no gamma readings exceeding background, and no elevated PID readings in the trench. All three subsurface soil samples collected exhibited one or two detected VOCs (1,1-DCE and toluene). One sample exhibited a concentration of thorium-230 that slightly exceeded the background UTL.

Forty-six soil samples collected during the three phases of the RI were used to evaluate soils in EU 6. General conclusions concerning the nature and extent of SRCs in soils at EU 6 are:

- In the southeastern portion of EU 6, surface soil samples contained elevated concentrations of actinium-227, cesium-137, radium-226, thorium-230, total uranium, and uranium isotopes. One of these locations, 6B005, also exhibited exceedances of background UTLs for protactinium-231, radium-226, thorium-230, total uranium, and uranium isotopes at depths of up to 2 feet bgs. Pavement samples collected in this general area also had elevated concentrations of radiological parameters.

- No radiological SRCs were detected at concentrations above background UTLs in soil samples collected from depths greater than two feet bgs in EU 6.
- PCBs were detected in surface soil at five locations in EU 6. Three of the samples were located either near the northern property boundary with CWM or in a drainageway flowing onto the NFSS from CWM. In EU 6, pesticides were detected in surface soil along the northeastern boundary of the NFSS, as well as in subsurface soil to a depth of 2 feet bgs along the southeastern boundary of the NFSS. Eight VOCs were detected above background UTLs in surface soil from three locations in EU 6; two locations are in the western area of the EU and one location is in the southeastern area of the EU.
- Metals were detected in surface and subsurface soils at several locations throughout EU 6, but at concentrations generally less than 5 times the background UTL. The most frequently detected metals include cadmium, selenium, and thallium in both surface and subsurface soils.
- Subsurface soil samples collected in EU 6 at depths greater than 10 feet exceeded background UTLs for cadmium, selenium, thallium, acetone, benzene, toluene, and xylenes. These exceedances occurred mainly in the southwestern portion of the EU near where the K-65 tower (Building 434) once stood.

5.4.1.2 Surface Water

Figures 4-15 and 4-16 summarize the occurrence of total and dissolved SRCs in surface water at the NFSS.

Ten Phase 1 surface water samples were collected from EU 5 to investigate the runoff from the acidification area, the former water tower (Building 434) where K-65 residues were stored, and the associated thaw house. In addition, surface water samples were used to evaluate runoff from adjacent properties and from haul roads used to move the residues to the water tower. Six of the samples were collected from ponded areas near N and O Streets and four were collected from ephemeral drainageways. Four Phase 1 surface water samples were collected in EU 6 from ephemeral drainageways which flow onto the NFSS to evaluate the runoff from the former water tower and thaw house as well as from the haul roads and adjacent properties. Surface water samples from EU 5 or 6 exceeded background UTLs for explosives, metals, radionuclides, PAHs, PCBs, and VOCs. Findings and conclusions are:

- No dissolved radionuclides were detected at concentrations greater than the background UTLs in any of the surface water samples collected from EUs 5 and 6.
- Four PAH compounds were detected at EU 5 in sample SW730-365, collected from a ponded area north of O Street at concentrations greater than the background UTLs. The concentration of each PAH was less than 1 µg/L. The PAH compounds were not detected in the other four samples collected from this ponded area. Sample SW737-380, collected from the northwestern portion of EU 5, contained a low concentration of total xylenes.
- Aroclor-1260 was detected in one sample located along the eastern boundary of EU 6.
- Several total and dissolved metals were detected above background UTLs in surface water collected from EUs 5 and 6. However, dissolved silver is the only metal in the

dissolved phase that exhibited concentrations that exceeded the background UTL by a factor greater than 10. Five locations exhibited such an exceedance; four in EU 5 and one in EU 6. Three of the samples in EU 5 were collected in the ponded area north of O Street. However, the dissolved silver concentrations were below the secondary MCL of 0.1 mg/L.

5.4.1.3 Sediment

Figure 4-17 summarizes the occurrence of SRCs in sediment at the NFSS.

Nineteen Phase 1 sediment samples collected within EU 5 were used to evaluate the impact of runoff from the former acidification area, the former K-65 storage tower, and adjacent properties and haul roads used to move the residues. Some Phase 1 and 3 samples exceeded their respective background UTLs for VOCs and radiological parameters.

- EU 5 sediment samples contained concentrations of three radionuclides above background UTLs. Cesium-137 and total uranium slightly exceeded the background UTL in sample SD735-377. This sample was collected in the northeastern portion of the EU.
- One VOC, methylene chloride, was detected in two sediment samples; one collected from the N Street South Pond and one collected from the O Street North Pond.

5.4.1.4 Groundwater

Figures 4-18 through 4-21 summarize the occurrence of total and dissolved SRCs in the LWBZ and UWBZ at the NFSS.

In EU 5, groundwater samples were collected from four permanent wells and four TWPs. During Phase 1, groundwater was investigated from the LWBZ and UWBZ to evaluate the presence, absence and migration of chemical and radiological parameters in groundwater in the vicinity of the former K-65 storage tower, along the haul roads used to move the K-65 residues, and in the vicinity of a 1953 explosion. Groundwater was also investigated to evaluate the presence and extent of organic and inorganic compounds previously identified in soil during the LOOW RI. Three temporary wells were sampled in Phase 2 to evaluate the presence or absence of radiological and non-radiological constituents associated with a 1953 explosion, the haul roads and railroad used to move the K-65 residues, and a drum storage and handling area, as well as to further evaluate previous sampling results. During Phase 3, one of the LWBZ wells and one of the UWBZ wells were resampled to confirm results from the initial sampling.

In EU 6, groundwater samples were collected from four permanent wells and five TWPs. During Phase 1, groundwater was investigated to evaluate the presence, absence and migration of chemical and radiological parameters in the LWBZ and UWBZ in the vicinity of the former K-65 storage tower. Two temporary wells and two permanent wells were sampled in Phase 2 to further delineate previous sampling results along the eastern boundary of the EU and to further evaluate the radiological constituents near the location of the K-65 storage tower. Two permanent wells were sampled during Phase 3 to confirm results of earlier sampling and to further evaluate the chemical and radiological constituents present.

Comparison of the groundwater analytes in EUs 5 and 6 to background UTLs indicate that background UTLs were exceeded for metals, pesticides, VOCs, SVOCs, and radiological parameters.

The SRC list for EU 5 includes 17 metals and four radionuclides. In EU 6, the SRC list includes 21 metals, total uranium, seven radionuclides and three organic compounds. The majority of the SRCs were found in samples collected from temporary wells points. The groundwater sample collected from well BH57 contained several dissolved metals at concentrations above background UTLs. This well, at 101.5 feet deep, is substantially deeper than any of the background wells and it is possible that the samples collected from the background wells are not consistent with groundwater quality in deeper portions of the Queenston Formation. If this is true, the background statistics may underestimate the true 'background' conditions for well BH57 (and thus, the Queenston Shale formation).

- No groundwater plumes were identified in EU 5 or 6.
- The majority of the groundwater SRCs were detected in samples from TWPs which were more turbid than samples from permanent wells. Thus, sample results may be biased high due to measuring metal contributions from particulate matter in the groundwater samples.
- With the exception of well BH57 in the LWBZ, radiological parameters were not found in the dissolved phase in groundwater samples collected in EU 5 or 6 at concentrations exceeding background UTLs. Well BH57 is screened in the unweathered portion of the Queenston Formation at a depth interval of 91.5 to 101.5 feet. The deepest background well is screened at a depth interval of 41.4 to 44.8 feet. Therefore, the background data set may not be representative of groundwater samples collected at well BH57. This may explain why concentrations of dissolved radiological parameters exceed background UTLs at this well.

5.4.1.5 Pipelines and Subsurface Utilities

Figures 4-22 and 4-23 summarize the occurrence of total and dissolved SRCs in pipeline water samples, while Figure 4-24 summarizes the occurrence of SRCs in pipeline sediment samples.

Sediment was collected at Manhole MH24, which is located in the storm sewer system in the acid area near haul roads for the former K-65 residue. This sediment sample showed exceedances of the background UTL for cesium-137 and uranium isotopes. No water samples were collected from pipelines or subsurface utilities in EUs 5 and 6.

5.4.2 Media Interactions

Soil sample results show that the distributions of radiological parameters are variable and mainly restricted to the upper two feet of the soil column. Of the organic compounds found above background UTLs in the soils in EUs 5 and 6, only 2-butanone was detected above the background UTL in EU 6 groundwater.

Surface and near surface soil samples indicate the southeast corner of EU 6 had significantly elevated concentrations of several radionuclides, some several hundred times the background UTL. The elevated concentrations in soils correlate with the results from the gamma walkover in

the southeast corner of the EU, as well as a sample (6B001) collected in an area of elevated gamma walkover readings along N Street. The remainder of the samples collected in the EU had concentrations below or near background UTLs. Concentrations of SRCs in soil do not appear to be impacting groundwater.

5.4.3 Sources and Effects of Past Use

The K-65 residues were stored in Building 434, located in EU 6. During the remedial activities in the 1980's, a pipeline, which traversed both EUs 5 and 6, was constructed to transfer the K-65 residues from Building 434 to the IWCS. Elevated concentrations of radiological SRCs were found in the surface soils near the intersection of O Street and MacArthur Street. Pavement samples from these streets also contained elevated concentrations of radiological parameters. Road core sample results are provided in Table 4-2. With the exception of station 6A001 in EU 5 and the southeast corner of EU 6, the Panhandle Area appears to exhibit only minor impact from AEC/DOE activities.

- The concentrations of metals in groundwater in EU 5 may be consistent with the propensity for water to accumulate on the surface and promote leaching of metals from soils in these low lying areas.
- Elevated metals and radiological concentrations in soils in EU 5 cannot be attributed to any specific prior activities. Radiological constituents in soil may have resulted from the transportation of residues along haul roads or in the slurry pipeline from EU 6 to the IWCS. Although metals are present above background UTLs they do not exceed risk levels.
- In EU 6, there are numerous metals in groundwater in both the total and dissolved phases, which exceed background UTLs. These cannot be attributed to any specific NFSS activities, and may be artifacts of turbid samples collected from TWPs.
- Radionuclides in groundwater and soil in EU 6 may be related to the storage of K-65 residues in Building 434 and the use of N Street, O Street and McArthur Street as haul roads for residues.
- Pesticides, PCBs and VOCs are also present in the soils at EU 6. The pesticides appear to be related to ditches along the haul roads and so may be the results of pest control efforts. The PCBs are also near ditches and may represent the results of spills during transportation or use of PCB-containing oil for dust control on the roads. Most of the VOCs were found near haul road ditches and Building 434, and the VOCs may be related to activities conducted at or near this building.
- Elevated gamma walkover readings in EU 5 occur mainly in the southeastern corner of the EU and along O Street. Correlation does appear to exist between elevated readings detected during the gamma walkover and soil samples collected during Phase 3. For example, sample location 6A001, located just north of the O Street North Pond in the southeastern portion of the EU, exhibited elevated levels of total uranium, radium-226 and thorium-230.
- No elevated gamma walkover readings were observed in the remediated location of the K-65 storage tower within EU 6. Locations along N Street exhibit some elevated activity,

as do very small areas in the southeastern corner of the EU. Correlation does appear to exist between elevated readings detected during the gamma walkover and soil samples collected during Phase 3. Phase 3 sample location 6B005, located north of O Street, exhibited elevated levels of total uranium, radium-226, thorium-230 and protactinium-231, which correlate with gamma walkover results. Samples collected along N Street in the northern portion of the EU exhibit only slightly elevated levels of some radionuclides. Other samples collected prior to Phase 3 also confirm the presence of radionuclides in areas of elevated gamma walkover readings. For example, sample location 606, located in the southeastern corner of the EU, exhibited high levels of radionuclides.

5.5 SHOPS AREA: EU 8

The shops area is located in the east-central portion of the NFSS, north of Building 401. It is bordered to the north by the acid area, to the south by the Building 401 Area, to the east by Modern Landfill, and to the west by Campbell Street. This area once contained a parking garage, equipment maintenance garage, material shed, general storehouse, combined shops, millwright shop, and riggers shop. None of these buildings remain although some concrete building foundations are still present. Radioactive residues were stored in several of the former buildings and corroded uranium billets were cut into smaller sections in the riggers shop. A debris pile that acted as a former radiological storage site is present in the southeastern portion of the EU.

5.5.1 Occurrence and Distribution of SRCs

Samples containing the highest concentrations of SRCs are generally clustered in two areas: the combined shops and the debris pile.

The SRCs in EU 8 are predominantly radionuclides, especially in soils, though numerous metals and organic compounds are also SRCs. The occurrence and distribution of SRCs is presented by media below. Several sediment samples were collected from this EU. However, as discussed in Section 5.1.1, only sediment samples collected from the Central Ditch, the West Ditch, the Modern Ditch and the South 16 Ditch were evaluated as actual sediment samples. Due to the fact that drainage areas within this EU are inundated less than 50% of the year, all sediment samples from this EU, with the exception of sample SD722-347, were evaluated as surface soil samples in this section.

5.5.1.1 Soils

Figure 4-9 summarizes the occurrence of SRCs in soil at EU 8.

Phase 1 surface and subsurface soil samples were collected in EU 8 to evaluate the presence or absence of inorganic, organic and radiological constituents in a number of areas. The specific targets were areas investigated in the LOOW RI, concrete rubble piles, a K-65 drum storage area, railroads, a pipeline, Building 430, a uranium rod storage area, change houses, and a service house. The LOOW RI samples had been collected to get general characterization information on the LOOW. Additionally, three samples collected from EU 8 (SD723-349, SD724-351, and SD725-353) were intended to be evaluated as sediment samples. However, as discussed in previous sections of this RI report, these samples were classified as surface soil samples to be consistent with exposure mechanisms considered in the BRA. Therefore, these samples were included in the discussion of soil samples collected at EU 8. In Phase 1, concentrations of

explosives, metals, PAHs, PCBs, pesticides, radionuclides, SVOCs, and VOCs exceeded their respective background UTLs in surface and subsurface soil samples.

During Phase 2, surface soil samples were used to delineate the radiological and semivolatile findings of previous sampling and to investigate a gamma walkover reading elevated with respect to background. One Phase 2 subsurface soil sample was collected to evaluate the elevated reading obtained during the gamma walkover. Phase 2 analytical results indicated that concentrations of metals, PAHs, radiological parameters, and SVOCs exceeded background UTLs in surface soil samples. The lone subsurface soil sample (SB314-415) contained concentrations that exceeded background UTLs for some radiological parameters.

Phase 3 sampling was conducted at EU 8 to provide a basis for further evaluation of the results of earlier sampling. Surface and subsurface soils samples were mainly analyzed for radiological parameters. However, some samples were analyzed for other analyte groups to investigate a debris pile and to confirm previous results for organic and inorganic constituents. Five trenches were excavated in EU 8 during Phase 3 to investigate potential USTs, pipelines, debris piles, and petroleum stained soils. Concentrations of analytes in trench samples exceeded background UTLs for metals, PAHs, PCBs, radionuclides, SVOCs, and VOCs. One hundred and forty-four soil samples collected during the three phases of the RI were used to evaluate soils in EU 8. Conclusions and findings are:

- The majority of surface and subsurface soils in the EU appear to be impacted with varying concentrations of actinium-227, cesium-137, radium-226, thorium-230, total uranium, and uranium isotopes. With the exception of samples collected in the vicinity of the combined shops area, the concentrations of radionuclides were generally less than three times the background UTLs. Several soil samples, all from the combined shops area, contained concentrations of actinium-227, radium-226, thorium-230, and various uranium isotopes ranging from approximately 20 to 1000 times the background UTLs. The highest concentrations of radionuclide SRCs were encountered at the surface to a depth of 2 feet, with decreased concentrations at depths greater than 2 feet.
- Several PAHs and two SVOCs were detected at concentrations that greatly exceeded background UTLs in the upper three feet of soil at EU 8. Some PAH and SVOC compounds exceeded their respective background UTLs by several hundred times. The samples with the highest concentrations were collected along W Street, near the intersection with 6th Street. A former machine shop was located near these sample locations. Oils, lubricants and other PAH source materials were likely used in this shop.
- Pesticides are present at scattered locations across the EU. Most exceedances are less than 3 feet deep; however, three exceedances occur at 8 feet bgs. Aroclor-1260, a PCB, was found at several locations within the EU.
- Concentrations of analytes in subsurface soil samples collected in EU 8 at depths greater than 10 feet bgs exceeded background UTLs for metals, thorium-230, benzo(g,h,i)perylene, and five VOCs. These exceedances occurred at widely scattered locations within the EU.
- Trench 301 was excavated to investigate a pipe and suspected UST south of Z Street. Twenty feet of the trench were excavated to a depth of 6 feet, and the remaining 30 feet of the trench were excavated to a depth of 3 feet. One section of the trench containing a

water valve was only excavated to a depth of 1 foot. The shallower section of the trench was capped with asphalt with approximately 2 feet of gravel above a blue-gray clay. A 4-inch steel pipe and rebar were observed in the deeper section of the trench. One area of darkly stained soil was observed in the upper portion of the first 5 feet of the trench. This stained soil was sampled at a depth of 3.5 feet bgs. Two other samples were collected at depths of 1.0 and 1.5 feet bgs. The sample collected from the stained soil area exhibited concentrations of the following constituents that exceeded background UTLs: selenium, thallium, 1,1-DCE, 2-butanone, acetone, and toluene. The two shallower samples exhibited metals, PAHs, radiological parameters, SVOC and VOC results above background UTLs. The shallow sample located near the water valve also exhibited a total uranium concentration that exceeded the UTL.

- Trench 302 was excavated to investigate a debris pile on the east end of EU 8, south of Z Street. The debris pile contained large blocks of concrete, so no gamma walkover was performed in this area. Two feet of black loam with brown and gray clay was encountered below the base of the pile, down to the 9 foot total depth of the trench. No magnetic anomalies and no elevated gamma readings were encountered in the trench. One small area of a white powdery substance was encountered in the black loam at a depth of approximately 1 foot. Three soil samples were collected from the trench at depths of 1, 6, and 8 feet. The three samples exhibited concentrations that exceeded the background UTLs for the following parameters: metals, Aroclor-1260, 4,4'-DDE, 4,4'-DDD, radium-226, thorium-230, 1,1-DCE, acetone, and toluene. The sample collected from the area of the white powdery substance also exhibited a total uranium concentration that exceeded the background UTL.
- Trench 305 was excavated to further investigate the debris pile initially investigated by Trench 302. The upper foot of the trench contained dark loam with railroad ballast or slag. One sand lens was encountered at a depth of 4 feet. The total trench was 5 feet deep and 85 feet long and oriented in a northwest to southeast direction ending just north of the South 16 Ditch and just west of the ditch along Castle Garden Road. No magnetic anomalies or areas of gamma radiation above background were encountered. Three subsurface soil samples were collected. Two of the three subsurface soil samples exhibited radiological activities above background UTLs. Both of these samples exhibited background UTL exceedances for total uranium, thorium-230, and uranium-235. One sample also exhibited background UTL exceedances for uranium-234 and uranium-238. This sample was collected at a depth of 5 feet in grayish-brown clay near the southeastern end of the trench. No other SRCs were identified for samples collected at this trench location.
- Trench 303 was excavated just south of X Street to investigate a potential UST north of a building foundation. There was a ferrous zone anomaly indicated in this area during the geophysical survey. The trench was 7 feet deep and oriented east-west. A sample was collected from a small area of dry tar-like material found at a depth of approximately 1 foot. Two samples were also collected from sand lenses at depths of 5 feet. All three samples exhibited VOC concentrations that exceeded background UTLs. VOCs exceeding background UTLs at this trench location include 1,1-DCE, acetone, methylene chloride, and toluene. The sample collected from the dry tar-like material contained levels of radium-226 and thorium-230 that exceeded background UTLs.

- Trench 304 was excavated southeast of a building foundation between Z Street and the South 16 Ditch. The trench was 7 feet deep and 73 feet long. It was excavated to investigate an open sump and some underground piping. Some gross contamination had been observed in one of the pipes, PIPE 74, during an earlier investigation. A discussion of the results for this pipe sample is included later in this section. The surface soil from the trench consisted of black loam with large gravel. A sample was collected from a black stained zone observed below a depth of one foot at the beginning of the trench. Additionally, a 1-inch copper pipe and a 6-inch VCP were encountered within the first 12 feet of the trench at depths of approximately 1.5 and 2 feet, respectively. No magnetometer anomalies, gamma readings above background, or elevated PID measurements were encountered. The sample collected from the black stained soil near the building foundation was the only sample that exhibited any analyte concentrations exceeding background UTLs. Total uranium, as well as all three uranium isotopes, exhibited activities that exceeded background UTLs in this sample. No other exceedances were observed.

5.5.1.2 Surface Water

Figures 4-15 and 4-16 summarize the occurrence of total and dissolved SRCs in surface water at the NFSS.

During Phase 1, four surface water samples were collected to determine the presence or absence of SRCs in the shops area and to further evaluate organic and inorganic compounds detected above evaluation criteria during the LOOW RI sampling. Three of these samples were collected from small drainageways, which carry water only after rain events. Sample SW722-346 was collected from the Castle Garden East Ditch near its confluence with the South 16 Ditch.

- Metals were detected in all four of the surface water samples at concentrations above their respective background UTLs.
- No dissolved radionuclides were detected at concentrations above the background UTLs. Low concentrations (less than 0.3 pCi/L) of total thorium-230 and total thorium-232 were detected in some of the samples.
- Two nitroaromatic compounds were detected in sample SW723-348. 2,6- and 2-amino-4,6-dinitrotoluene (DNT) were detected at concentrations of 0.34 µg/L and 0.28 µg/L respectively. This sample was collected from a small ditch located between Castle Garden Road and 6th Street.

5.5.1.3 Sediment

Figure 4-17 summarizes the occurrence of SRCs in sediment at the NFSS.

Three Phase 1 sediment samples were collected to evaluate the ditches in the shops area. An additional six samples were collected during Phase 3. After further evaluation, most of these samples were all reclassified as soil samples. However, one Phase 1 sediment sample (SD722-347) collected from the South 16 Ditch east of Castle Garden Road was retained as a sediment sample. The only SRC detected in this sample at a concentration above the background UTL was methylene chloride.

5.5.1.4 Groundwater

Figures 4-18 through 4-21 summarize the occurrence of total and dissolved SRCs in the LWBZ and UWBZ at the NFSS.

During Phase 1, groundwater samples were collected from three permanent and twelve temporary wells. The purposes of the permanent well groundwater samples were to evaluate the LWBZ in the vicinity of a titanium alloy storage area, a concrete rubble pile, a K-65 drum storage area, and soils that were identified in the LOOW RI as having contained organic and inorganic constituents. The twelve temporary groundwater well samples were taken to evaluate the presence or absence of radiological and non-radiological constituents in the shops area, specifically, near a rubble pile, along the site boundary, in the vicinity of a fuel oil pipeline and a uranium rod storage area, in the area of Building 430, and near some LOOW RI sampling that indicated the presence of organic and inorganic constituents.

Two additional permanent groundwater wells were sampled in Phase 2 to evaluate earlier findings. Both of these wells and another permanent well not previously sampled were sampled in Phase 3 to confirm earlier findings and expand the analyte list. Findings and conclusions from the sampling of all permanent and temporary wells are:

- A dissolved total uranium groundwater plume is present in the southeastern portion of the EU in the area of former storehouse Buildings 420 and 421. The plume appears to be approximately centered beneath a large debris pile located west of Castle Garden Road and south of Z Street near the South 16 Ditch. This plume, shown in Figure 5-4, could be related to two localized areas of elevated activity ranging from 13,000 to 37,000 cpm (see Figure 3-5) that were identified in surface soils south of Z Street and southeast of EU 8. Leaching from these surface soils could be affecting wells in this area.
- A second dissolved total uranium plume is present in the southwestern portion of the EU near former Building 423. This plume may be associated with the utility lines in this area. Elevated concentrations of tetrachloroethene were also found in two samples in this area; however, no plume was drawn because only one of the samples exceeded the MCL.
- Thirteen dissolved metals were detected above background UTLs in groundwater at EU 8. Of these dissolved metals, antimony, barium and nickel were the most frequently detected above the background UTL. However, total silver was consistently detected at over 20 times the background UTL.
- Low concentrations of VOCs, SVOCs, pesticides, and PAHs were detected in several wells. However, the distributions were very sporadic and it was determined that the results did not indicate the presence of groundwater plumes.
- Low concentrations of two nitroaromatic compounds, (1,3,5-trinitrobenzene and RDX) were detected separately in two different samples. However, the detection of RDX is suspect as it was never manufactured at the LOOW and is not a breakdown product of TNT.

5.5.1.5 Pipelines and Subsurface Utilities

Figures 4-22 and 4-23 summarize the occurrence of total and dissolved SRCs in pipeline water samples, while Figure 4-24 summarizes the occurrence of SRCs in pipeline sediment samples.

During Phase 3, water and sediment samples were collected from seven manholes on the sanitary sewer system in EU 8. The purpose of this sampling was to evaluate the sediment and water in the sewer for radiological, inorganic, and organic constituents. The sewer and associated laterals flowed from the buildings in EU 8 to the west, connecting the main sanitary line located along Campbell Street. Three of these manholes were sampled during the LOOW RI. The manholes from which these samples were collected are shown below.

Sample	Matrix	Manhole
C7-NFSS-WW-SS9	Water	MH43
C7-NFSS-SL-SS10	Sediment	MH44
C7-NFSS-WW-SS10	Water	MH44
C7-NFSS-WW-SS8	Water	MH41

Sediment and water samples were also collected from an exposed pipe, PIPE 74, found in the foundation of the former Vehicle Repair Shop. One subsurface soil sample also associated with PIPE74 was collected at a depth of 7 feet. It is not known if this pipe is part of the sanitary sewer system. Findings and conclusions are:

- Metals, at concentrations above the background UTLs, were detected in three samples collected from the sanitary sewer system. Total antimony concentrations that exceeded the background UTL at manholes MH41 and MH43 during Phase 1 were not confirmed during Phase 3. The water sample from manhole MH12 contained dissolved lead, dissolved selenium and dissolved silver at concentrations above the background UTLs. The concentrations for dissolved lead and dissolved silver were more than ten times greater than the background UTL in this sample. Of all the manholes sampled within EU 8, MH12 is the furthest downstream. None of the upgradient sanitary sewer water samples contained elevated concentrations of metals.
- Several PAH compounds were found in the EU 8 sanitary sewer sediment samples. However, no PAH compounds were found above the background UTL in the sediment sample collected from MH12 – the last manhole before the sanitary sewer exits EU 8 and joins the main line west of Campbell Street. This suggests that the PAH compounds in the sanitary sewer sediments are not very mobile within the sanitary sewer system. No PAH compounds were found at concentrations above the background UTLs in any of the sanitary sewer water samples collected in EU 8. Additionally, VOCs and SVOCs were infrequently detected in EU 8 sanitary sewer sediment and water samples.
- Both water and sediment samples were collected from Pipe 74, located on the pad of the former Vehicle Repair Shop. Although this pipe does not appear on any available site drawing, it appears to lead to a sump. The lead concentration in the sediment sample collected from this pipe was more than ten times greater than the background UTL. This sediment sample also contained VOCs. The pipe was sampled a second time to confirm the VOC results. The VOC concentrations for the two sediment samples are shown in the following table.

Compound	Concentration (µg/kg)	
	Pipe74S-2068	Pipe74S-3692
Cis-1,2-DCE	Not Detected	9.71
2-Butanone	57	832
Carbon Disulfide	19.5	61.3
Ethylbenzene	14.4	7.95
PCE	13.1	431
Toluene	156	62.1
TCE	Not Detected	28.4
Xylenes (total)	64	12

- Low levels (less than 1 µg/kg) of TCE, PCE, and cis-1,2-DCE were detected in the sediment sample collected from manhole MH45, which is the nearest manhole to PIPE 74.
- Radiological SRCs were detected in water samples at concentrations above the background UTLs at several sanitary sewer locations. Manhole MH45W exhibited the greatest exceedances above background UTLs. Total and dissolved radionuclides generally exceeded the background UTLs in this sample by factors between three and five.
- Radiological SRCs, and in particular the uranium isotopes, were commonly found in the EU 8 pipeline sediment samples. The sediment sample collected from PIPE 74 also contained elevated concentrations of the uranium isotopes. The radiological SRCs appear to be relatively immobile in the sediments, as evidenced by the fact that the concentrations of radiological SRCs were much lower in the sample collected from manhole MH12, which is the manhole furthest downstream in the EU 8 sanitary sewer system.
- Subsurface soil sample SB-PIPE74-7.0-3657 was collected in association with PIPE74 and exhibited concentrations of thorium-232, uranium-235, and acetone that exceeded their background UTLs. Both thorium-232 and uranium-235 exceeded the background UTLs by less than a factor of 5.

5.5.2 Media Interactions

Discounting the SRCs found in the sewer lines, the highest concentrations of organic and radionuclide SRCs were in the combined shops and debris pile areas. The remainder of the EU contained isolated detections of various organic, inorganic and radiological compounds at significantly lower concentrations. The vast majority of SRCs above background UTLs were found at depths of three feet or less from the ground surface. At locations where samples were collected both at the surface and at 1.0 to 1.5 feet below the surface, concentrations were typically several times less at the greater depth. Soil samples collected from depths of 4 to 5 feet in Trench 305 contained concentrations of uranium isotopes at 1 to 3 times the background UTL. These samples alone do not explain the presence of the dissolved total uranium groundwater plume in the vicinity of the combined shops and debris pile. However, interaction of shallow groundwater in this area (3 to 4 feet bgs) with debris and permeable material observed in the trench area (railroad ballast which likely contains some amount of uranium [see Table 4-2 for examples of railroad ballast samples collected on NFSS], and a sand lens, both encountered in Trench 305)

may represent a plausible explanation for the generation of the dissolved total uranium groundwater plume.

The presence of numerous pipelines and subsurface utilities may also help to explain the presence of organic compounds and radionuclides in groundwater and subsurface soils near utility lines. Figure 5-4 indicates the potential enhancement of a groundwater plume by these pipelines and utilities.

5.5.3 Sources and Effects of Past Uses

As described above, the former buildings within EU 8 have been used for a number of activities consistent with the results of analytical sampling.

- The use of these buildings as vehicle maintenance and repair shops during operation of the LOOW may account for the presence of PAHs, metals, SVOCs, and VOCs in soil and groundwater at EU 8. Such compounds are prevalent in oils, solvents, paints and lubricants that would have been used at the former building locations.
- Radionuclides in soil and groundwater are probably the result of storage of residues in some of the buildings and the debris pile, as well as from their transportation to and from those areas.
- The gamma walkover survey conducted in EU 8 focused on roads and some former building locations south of Z Street and between W and X Streets in the shops area. Most of the gamma walkover data showed only single points of elevated gamma activity. Several single point locations exhibiting elevated gamma walkover readings also had analytical results that indicated elevated levels of total uranium, actinium-227, cesium-137, radium-226, and thorium-230.

5.6 IWCS AND VICINITY: EU 7, 10 AND 11

The IWCS and vicinity consists of EU 7, 10 and 11. The area is bordered by the NFSS perimeter fence on the west and south, O Street on the north, and Campbell Street on the east.

EU 7 is a large grassy area north of the IWCS. In a 1944 oblique, a large building was located in EU 7; however, no buildings currently exist in this EU. During the remedial actions of the 1980's, several large temporary ponds (shown on Figure 1-2), principally used for the management and storage of stormwater, were located in this area. EU 7 is also the location of the former DOE Organic Burial Area, which was delineated during trenching activities performed for this RI. In 1984, the DOE Organic Burial Area was originally used for the disposal of organic materials stockpiled at Lutts Road and O Street. Materials known to have been disposed in the area included roofing timbers, wooden debris, and organic material from clearing activities (BNI 1984b, 1985). Material placed in the DOE Organic Burial Area was intentionally separated from the IWCS contents to avoid settlement that would result from the degradation of this organic material.

The predominant feature in EU 10 is the IWCS. Prior to the construction of the IWCS, the LOOW freshwater treatment plant was located at the southern end of the EU. The Middlesex Sands, F-32, L-30, L-50, and K-65 residues are currently stored in the remnants of the freshwater treatment plant, which are now contained in the IWCS. Likewise, the R-10 pile, formerly

unprotected and stored in the open north of the freshwater treatment plant, is also contained in the IWCS.

EU 11 is 'L' shaped and located both east and south of EU 10. During the operation of the LOOW, a fire house was located in the central portion of this EU and a parking lot was located in the southern portion. Later, during the remedial actions of the 1980's, several temporary ponds used to hold treated slurry water, decontamination water, and stormwater prior to release were located here.

5.6.1 Occurrence and Distribution of SRCs

5.6.1.1 Soils

Figures 4-8, 4-10, and 4-11 summarize the occurrence of SRCs in soil at EUs 7, 10 and 11.

During Phase 1, collocated surface and subsurface soil samples were collected to assess the presence or absence of organic, inorganic and radiological parameters. Surface soil sample locations included dewatering ponds 4 and 5, the organic burial area and a former "lay down" area, an area south of Building 401 and the southwestern site boundary. Phase 1 surface soil sample results indicated the presence of metals, radiological parameters, and VOCs above background UTLs. Phase 1 subsurface soils indicated only metals exceeded background UTLs.

Phase 2 soil samples were collected to evaluate previous remediation efforts, to assess the soil contaminants associated with groundwater results, to delineate previous sampling results, and to assess gamma walkover results. Of special interest were the area west of Building 401, the decon pad, and the western and southern boundaries of the NFSS site. Several samples were collected at locations exhibiting gamma readings that were very high relative to background gamma results. Results from analysis of Phase 2 surface soil samples show that metals, PAHs, pesticides, radiological parameters, and SVOCs exceeded background UTLs. Phase 2 subsurface soil samples exhibited exceedances of background UTLs similar to that of surface soil samples with the addition of VOCs.

The primary reason for Phase 3 soil sampling was to further investigate or confirm previous sampling results, especially from the gamma walkover. However, Building 409, the water storage pits, the organic burial area, and the integrity of the dike around the IWCS were also further investigated. Several samples were also collected to evaluate soils near locations exhibiting elevated groundwater results. The Phase 3 surface and subsurface soils exceeded background UTLs for metals, PCBs, PAHs, pesticides, SVOCs, VOCs, and radiological parameters. During Phase 3, samples were also collected from seven trenches. The trenches were concentrated in EUs 7 and 11 and targeted the organic burial area, a disposal area, water storage pits and elevated gamma readings. The trench samples from EU 7, in particular, contribute to the background UTL exceedances for PAHs, PCBs and pesticides.

Additionally, eighteen samples collected from EUs 7, 10 and 11 were intended to be evaluated as sediment samples. However, as discussed in previous sections of this RI report, these samples were classified as surface soil samples to be consistent with exposure mechanisms considered in the BRA. Therefore, these samples were included in the discussion of soil samples collected at these EUs.

Seventy-two soil samples collected during the three phases of the RI were used to evaluate soils at EU 7. Similarly, 68 soil samples were used to evaluate soils in EU 10 and 89 soil samples were used to evaluate soils in EU 11. Findings and conclusions are:

- Several surface and subsurface soil samples collected from EU 7 contained elevated concentrations of radiological SRCs including actinium-227, cesium-137, radium-226, thorium isotopes, total uranium, and uranium isotopes. Concentrations of these SRCs in surface soil frequently exceeded background UTLs by factors of more than 10. One location in the western portion of the EU (SS8D009) exhibited concentrations of radionuclides that exceeded background UTLs by a factor of 300. The distributions of these high concentrations are very sporadic. Most surface and near surface soil samples (less than two feet bgs) were located in areas of high gamma radiation found during a gamma walkover survey of the site. The results of the gamma walkover survey, as shown on Figure 3-4, indicate that areas impacted by radionuclide SRCs are sporadic and discrete. The soil samples with the highest concentrations of radionuclide SRCs were collected from these areas. Most of these areas loosely coincide with the haul route used during the construction of the IWCS.
- Subsurface soil samples collected in EU 7 at depths greater than 10 feet bgs exceeded background UTLs for metals and four VOCs (1,1-DCE, acetone, benzene, and toluene). These exceedances occurred at widely scattered locations within the EU. Thorium-228 and thorium-230 were found at soil boring location 838 at a depth of 14 feet bgs and uranium-235 was found in soil boring 837 at a depth of 9 feet bgs. In addition, Aroclor-1254 was found at soil boring 840 and 4,4-DDT was found at soil borings 836 and 837 at depths greater than 10 feet bgs.
- The former DOE Organic Burial Area was delineated during trenching activities performed for this RI. This burial area was found to contain railroad ties, general demolition debris, slag, ash-like material, miscellaneous office waste, plastic pipe, and apparently unused environmental sample containers. During the excavation of the trenches, field gamma screening indicated many areas with elevated gamma radiation at depths down to approximately five feet bgs. Some of the concentrations found in the trench soil samples exceeded background UTLs by a factor of more than 10. Sample TB802-2903-03.8-096, collected from a depth of 3.8 feet bgs, exhibited radium-226 and thorium-230 concentrations that exceeded the background UTLs by more than a factor of 20. Metals, VOCs (2-butanone, acetone, ethylbenzene, methylene chloride, and toluene), several PAH compounds, and PCBs were also detected in soil samples collected from trenches.
- All soil samples collected from EU 10 were collected from areas outside the IWCS so as not to jeopardize the integrity of the cap or dike. Metals and radiological parameters were frequently detected in surface and subsurface soils to a depth of approximately 2 feet bgs. Approximately one third of all soil samples collected from depths of two feet or less exceeded the background UTLs for one or more radiological parameters. Radium-226, thorium-230, and uranium isotopes were the most commonly detected radionuclides in surface and subsurface soil. However, in general, the magnitude of radionuclide exceedances was typically small and in most cases was by a factor of three or less. Also, the distributions of the exceedances are sporadic and are more indicative of localized areas of concentrations elevated above background UTLs rather than broad areas which are uniformly impacted. Samples with higher relative exceedances of radiological

parameters were frequently located near samples that contained much lower concentrations.

- Three surface soil samples were collected from near the toe of the slope on the east side of the IWCS, just beyond the subsurface cutoff wall and cap, and west of the Central Ditch. Several PAH compounds were found in these samples at concentrations that exceeded the background UTLs. PAH exceedances in EU 10 occurred primarily in the area between the east side of the IWCS and the Central Ditch, and to the south of the IWCS. Aroclor-1260, pesticides, carbazole, and four VOCs (1,1-DCE, 2-butanone, acetone, and toluene) were also detected at sporadic locations at EU 10, mainly within the upper 2 feet of soil.
- Subsurface soil samples collected in EU 10 at depths greater than 10 feet bgs exceeded background UTLs for metals, thorium-228, thorium-230, thorium-232, uranium-235, Aroclor-1254, 4,4'-DDE, 4,4'-DDT, and two VOCs (1,1-DCE and acetone). Most of these exceedances occurred on the east and south sides of the IWCS.
- Several metals and radionuclides, as well as total uranium, five VOCs, four SVOCs, fourteen PAHs, two PCBs, and two pesticides were detected above background UTLs in surface and subsurface soils in EU 11. PAHs and SVOCs were mainly detected along the eastern edge of the EU in two sample locations, 2A002 and 2A003.
- Some of the highest concentrations of radiological SRCs found on the NFSS were in soil samples collected from EU 11 in the parking area east of Campbell Street, near the main entrance to the site. The radium-226 concentration in surface soil sample SS830-1036 was 386 pCi/g. This sample also had a thorium-230 concentration of 304 pCi/g. These values are approximately 200 to 400 times greater than the background UTLs. An actinium-227 concentration of 132 pCi/g, which is approximately 1,600 times greater than the background UTL, was also observed in this sample. Because of these findings, an exploratory trench, Trench 812, was excavated in the parking area. Surface soil sample TS812-2928-062 had a uranium-234 concentration of 8,340 pCi/g, almost 5,000 times greater than the background UTL, and a uranium-235 concentration of 886 pCi/g, which is approximately 10,000 times greater than the background UTL. Field gamma screening performed during the excavation of this trench indicated that the area of elevated gamma activity from which TS812-2928-062 was collected was restricted to a small area and that the elevated gamma activity did not extend below the asphalt pavement. Samples collected in this parking area at depths greater than 2 feet below grade did not contain elevated concentrations of radiological SRCs. This location may have been a staging area for inbound trucks during the operation of the NFSS and sloughing of loads while the trucks were in the parking area may account for the sporadic and shallow nature of the elevated radiological SRCs found here.
- Another small area of radiological impact in EU 11 is located due south of the IWCS, near the site perimeter fence. The surface soil sample SS8A014-2181 had a thorium-230 concentration of 68.5 pCi/g, which is approximately 45 times greater than the background UTL. Approximately four feet to the west of SS8A014, soil sample TB813-2925-8.0-013 was collected from trench T813 at a depth of 8 feet. This sample had a thorium-230 concentration of 31.2 pCi/g – approximately 20 times greater than the background UTL. The nearby surface soil samples SS801-070, SS8A008-2180, and SS8A010-2182 did not contain elevated levels of thorium-230, indicating that the extent of the elevated

concentrations of thorium-230 was limited in this part of the site. Surface soil sample SS819-706, collected near the decontamination pad used during the remedial activities performed in the 1980's, contained uranium-234, uranium-235, and uranium-238 above the background UTLs.

- There is some evidence of radiological impacts in the northern portion of EU 11, in the vicinity of the DOE water treatment plant which was operational during the remedial activities performed in the 1980's. Sample TB810-2908-01.8-041 had elevated concentrations of radium-226 and thorium-230. Other soil samples collected in this area also exceeded the background UTLs for radionuclide SRCs, although the level of exceedance was generally small, on the order of five times or less. Three VOCs (1,1-DCE, acetone, and toluene) were detected in subsurface soil in this same general area.
- Subsurface soil samples collected in EU 11 at depths greater than 10 feet bgs exceeded background UTLs for metals, radium-228, thorium-228, thorium-230, thorium-232, 4,4'-DDT, and three VOCs (acetone, toluene, and xylenes). These exceedances occur at widely spaced locations within the eastern and southern portions of the EU.
- Trench 802 was excavated to investigate the organic burial area in EU 7. Trench 802 consisted of a complex of excavations including a 230-foot long north-south trench and a 198-foot long east-west trench. The excavation uncovered a large volume of wood, debris and concrete along with a brown clay fill. One overpack drum was uncovered in the east-west portion of the trench. There were numerous elevated gamma readings and magnetic anomalies encountered. No samples were collected in the east-west trench. Three soil samples were collected in the north-south trench. Metals and radionuclide results exceeded background UTLs in all three samples. Thorium-230 and radium-226 exceeded background UTLs by greater factors than did metals or other radionuclides. Total uranium, PCBs, PAHs, pesticides and VOCs also exceeded background UTLs.
- Trench 808 was also excavated to investigate the organic burial area in EU 7. This trench consisted of two segments; one oriented east-west excavated to a depth of 4.5 feet, and one oriented northeast-southwest excavated to a depth of 10 feet. Chips of material with very high gamma readings were encountered in both trench segments. The highest of these readings was 688,000 cpm at a depth of about $\frac{3}{4}$ of a foot in the east-west trench. No elevated PID readings or magnetic anomalies were measured in the northeast-southwest trench; however, several small magnetic anomalies were measured in the east-west trench, and an area of slightly elevated gamma readings was observed approximately a foot and a half below the chip of material with the highest gamma reading. Three soil samples were collected; one from the brown clay fill, one from the debris of the northeast-southwest trench, and one from the deeper brown clay of the east-west trench. The deeper sample exhibited concentrations of selenium, thallium, acetone, and toluene that exceeded background UTLs. The two shallower samples also exhibited background UTL exceedances for thallium, selenium, Aroclor-1254, radium-226, thorium-230, acetone, methylene chloride, and toluene.
- Trench 809 was excavated in EU 11 to evaluate the location of former water storage pits just west of Campbell Street and north of the Hitmann Building. The trench was 50 feet long, 4 feet deep and oriented northwest to southeast. The northwestern most portion of the trench was only excavated to a depth of 1 foot due to the presence of utilities. At the

southeastern end of the trench at a depth between 3 to 4 feet, a 36-inch concrete pipe and an 8-inch steel pipe were encountered. The top foot of the trench consisted of brown loam with gravel and slag. Two soil samples were collected from this upper foot of material. Another soil sample was collected at a depth of approximately 1 foot. There were numerous small magnetic anomalies in the upper foot of the trench and several elevated gamma measurements were collected. No elevated PID measurements were noted. All three soil samples exhibited radiological activities above background UTLs. One surface soil sample exhibited a single pesticide detection, and total uranium was measured above the background UTL in the subsurface soil sample.

- Trench 810 was also excavated to investigate the water storage pits. It was located west and north of Trench 809 near the EU 10 boundary and oriented along the boundary in a north-south direction. There were no elevated PID readings and only one elevated gamma measurement. Three feet of disturbed soil was encountered for the entire 55-foot length of the trench. A single sand lens was encountered near the southern end of the trench, below the disturbed soil, at a depth of 5.5 feet. One sample was collected from the sand lens and two samples were collected from the disturbed soil. All of the samples exhibited metals concentrations above background UTLs. Both the disturbed soil samples exhibited total uranium concentrations and radiological activities above background UTLs. Two VOCs, acetone and toluene, were detected in the samples. One SVOC, diethylphthalate, was detected in the sample collected from the sand lens.
- Trench 811 was a north-south trending trench located at the north end of EU 11 near the EU 10 boundary. This trench was also excavated to investigate a water storage pit. The upper 4 to 5 feet of the trench is brown silty clay with fill and debris. This is underlain by brown sand that extends the entire length of the trench from a depth of 4 to 5 feet bgs to a depth of 6 or 7 feet bgs. Brown clay lies below the brown sand in some areas of the trench. Magnetic anomalies were observed at the surface; however, no elevated PID readings or gamma readings that exceeded background were noted. A piece of pond liner material was excavated from the fill at a depth of approximately 2 feet. All three of the subsurface soil samples collected from the trench exhibited metals concentrations and radiological activities above background UTLs. Additionally, one sample exhibited a total uranium concentration that exceeded the background UTL and another sample exhibited detections of 1,1-DCE and acetone.
- Trench 812 was excavated in the southeastern portion of EU 11 to investigate an elevated gamma walkover measurement in an area paved with asphalt. The trench was 62 feet long and 5 feet deep and is oriented west-southwest to east-northeast. The upper few inches of the trench consist of asphalt, with large gravel present to a depth of 2 feet. A layer of clay fill material and possible clay fill material extends to a depth of 3 feet, and gray-brown clay is present as the lower most excavated layer. The area with the elevated gamma reading (as high as 100,000 cpm) was observed just south of the trench. No magnetic anomalies, elevated PID measurements or elevated gamma readings were noted below the asphalt pavement. Three subsurface soil samples were collected from the gray-brown clay or the possible fill material located just above the native soil. All three of the subsurface soil samples exhibited metals concentrations above background UTLs, and the one closest to the surface gamma anomaly exhibited radiological activities above background UTLs. There was also one surface soil sample collected from the asphalt in this trench which exhibited radiological activities above background UTLs. Plutonium-239/240, radium-226, and thorium-230 were detected above background UTLs in this sample. Additionally, uranium-234, uranium-235, and uranium-238 were

detected in this sample at levels that exceeded the background UTLs by factors of 5,000 to 10,000.

- Trench 813 was excavated in EU 11 to investigate an elevated gamma walkover reading. The trench is oriented west-southwest to east-northeast in the vicinity of the intersection of Lutts Road and R Street. The trench is 40 feet long and 4 feet deep. One elevated gamma reading was observed 13 feet from the west end of the trench at a depth of approximately 0.8 feet. No elevated PID readings were noted. The upper 1.5 to 3.5 feet of the trench consisted of fill material and two samples were collected from this material. Both of the samples exhibited radiological activities above background UTLs. The third sample, collected from the native brown silty clay, showed exceedances of the background UTL for total uranium, radium-226, thorium-230, thorium-232, and uranium isotopes.

5.6.1.2 Surface Water

Figures 4-15 and 4-16 summarize the occurrence of total and dissolved SRCs in surface water at the NFSS.

Surface water samples were collected from EUs 7, 10, and 11 in Phases 1 and 3 to assess runoff from the IWCS, the organic burial area, and the storm-water ponds. Metal and radiological background UTLs were exceeded in surface water samples during both Phases 1 and 3.

Two surface water samples were collected from EU 7, four were collected from EU 10 and one was collected from EU 11. Eight additional samples, previously presented in EU 15, were collected from the Central Ditch from locations within EU 7, 10 and 11 and are included in this discussion.

- In EU 7, sample SW744-681 contained the highest concentrations of thorium-228, thorium-230, and thorium-232 found in any surface water sample collected at the NFSS. This sample was collected at the junction of the South O Street Ditch and a drainage way which flows north through the western portion of EU 7. The concentrations of the three thorium isotopes in sample SW711-316, collected from the South O Street Ditch a short distance upgradient from SW744-681, were all below the analytical detection limit, indicating that the source of the thorium in SW744-681 is in or near the drainageway and not in the South O Street Ditch.
- Thorium isotopes were also found in surface water samples collected from small ditches draining the west side of the IWCS and from the Central Ditch, though in these samples the concentrations were very low – less than 0.32 pCi/L.
- The radium-226 concentration in sample SW701-292, collected from a small ditch that drains the west side of the IWCS to the West Ditch in EU 10, was 3.66 pCi/L. This is 7.5 times greater than the radium-226 background UTL of 0.487 pCi/L. Radium-226 also exceeded the background UTL in samples collected from the Central Ditch in EU 10, but by smaller factors.
- Uranium-234 and uranium-238 were detected in one surface water sample in EU 7 at levels that slightly exceeded the background UTLs.

5.6.1.3 Sediment

Figure 4-17 summarizes the occurrence of SRCs in sediment at the NFSS.

Eleven sediment samples collected during Phases 1 and 3 were used to evaluate sediment in the Central Ditch and the South 31 Ditch within EUs 7, 10 and 11. These samples were collected to assess the migration of constituents from the IWCS, the organic burial area and stormwater pond locations. Two of the samples collected from the Central Ditch that were at or below a depth of 1 foot were used to assess the vertical migration of constituents. Sediment samples collected from these three EUs in ditches or drainageways other than the Central Ditch have been reclassified as soil samples. These reclassified samples have been included in the soils discussion for these EUs.

- Boron was the only SRC identified in sediment samples within EU 7. Boron was detected above the background UTL in the furthest downstream sediment sample within EU 7.
- Boron, iron, and manganese exceeded background UTLs in upstream sediment samples collected from the Central Ditch within EU 10. Thorium-228 slightly exceeded the background UTL in a sample collected near the conjunction of the South 31 Ditch with the Central Ditch.
- No SRCs were identified in the one sediment sample collected from the South 31 Ditch within EU 11.

5.6.1.4 Groundwater

Figures 4-18 through 4-21 summarize the occurrence of total and dissolved SRCs in the LWBZ and UWBZ at the NFSS.

Groundwater samples were collected during all three phases of the RI from EUs 7, 10 and 11. In EU 7 all of the samples were collected from temporary wells while in EUs 10 and 11 both permanent monitoring wells and temporary wells were sampled. Phase 1 samples were collected to evaluate the presence or absence of chemical and radiological parameters in the UWBZ and LWBZ in the vicinity of the IWCS, to assess the groundwater in the vicinity of the organic burial area and De-watering Pond 4, to assess the groundwater near the “lay-down” area and De-watering Pond 5, and to assess the groundwater near the former “stockpile” area. Phase 2 samples were intended to confirm the results of previous findings and to further refine the extent of constituents identified during previous sampling. Phase 3 sampling was performed to obtain further confirmation of previous sampling and to investigate the integrity of the clay dike around the IWCS.

Phase 1 results indicated that groundwater from the three EUs exceeded background UTLs for metals and radiological parameters. Phase 2 results also indicated that metals and radiological parameters exceeded background UTLs. Phase 3 results indicated metals, PCBs, pesticides, SVOCs, VOCs, and radiological parameters exceeded background UTLs.

Ninety-three TWP and permanent wells were sampled in EUs 7, 10, and 11. During the multiple phases of the RI, some permanent wells were resampled in support of a groundwater monitoring program at the site and other wells were resampled to confirm previous results. Findings and conclusions from these results are:

- Several dissolved metals were detected in groundwater samples collected from EUs 7, 10, and 11. In EUs 7 and 11, the exceedances tended to be infrequent and only slightly above background UTLs; however, several samples in EU 10 contained concentrations of dissolved metals which exceeded background UTLs by factors of more than ten. These elevated samples were in every case isolated and may be indicative of either natural variation in the background concentrations of metals in groundwater or of a past release which was spatially limited or has not migrated. No groundwater plumes were identified for metals in EUs 7, 10, or 11.
- Several dissolved total uranium groundwater plumes were identified in this area. These plumes are shown on Figure 5-4. Groundwater near the north and west sides of the IWCS is impacted with uranium. There are also minor isolated plumes east of the IWCS and in the western portion of EU 7. A dissolved total uranium plume, located south of the IWCS in EUs 10 and 11, appears to be associated with the sanitary sewer and water lines in this area (i.e. infiltration, exfiltration, and migration along bedding material).
- Dissolved thorium-230 groundwater plumes were identified north of the IWCS in EUs 7 and 10 and south of the IWCS in EUs 10 and 11 (see Figure 5-7). Samples defining the plume north of the IWCS exhibit dissolved thorium-230 concentrations up to almost three times the background UTL. These concentrations are greater than those defining the plume to the south of the IWCS, which exhibits dissolved thorium-230 concentrations that are generally less than 1.5 times the background UTL.
- Cesium-137 was detected in groundwater in three Phase 2 samples in EU 10 at concentrations ranging from 4.41 to 57.1 pCi/L. All three of these locations were resampled for radionuclides during Phase 3; however, cesium-137 was not detected in these samples. Cesium-137 was detected at an additional location (OW07B) during Phase 3 at a concentration of 2.12 pCi/L.

Note that the above cited detections of cesium-137 were evaluated in the BRA and not found to pose an unacceptable risk, even when assuming water containing these concentrations was consumed (such as in the farming scenario). Furthermore, these detections of cesium-137 are below a derived drinking water MCL (110 pCi/L, as described in Section 5.2.1.4), which is well above the detected concentrations of cesium-137 in groundwater.

- SVOCs, VOCs and PCBs were infrequently detected above background UTLs in EUs 7 and 11. Two pesticides (4,4'-DDE and 4,4'-DDT) were detected in samples located mainly along the western portion of EU 11 near the boundary with EU 10 and to the south of the IWCS. SVOCs [bis(2-ethylhexyl)phthalate and phenol], and VOCs (2-butanone, acetone, and methylene chloride) were more frequently detected in groundwater in EU 10, mainly south of the IWCS. A bis(2-ethylhexyl)phthalate plume present in EU 10 is shown on Figure 5-13.

5.6.1.5 Pipelines and Subsurface Utilities

Figures 4-22 and 4-23 summarize the occurrence of total and dissolved SRCs in pipeline water samples, while Figure 4-24 summarizes the occurrence of SRCs in pipeline sediment samples.

Seven sanitary sewer manholes were sampled in EUs 10 and 11. Another manhole on the sewer line (MH05) was sampled in EU 11. No manholes were sampled in EU 7.

Water and sediment samples were collected from the manholes located on the sanitary sewer line. The sanitary sewer line was approximately eight to ten feet below grade, which places it near or slightly above the water table. Water was present in the sanitary sewer at all the sampled manholes and sediment was present in five of the sampled manholes. The lower portion of MH06 was filled with concrete and the sanitary sewer is thought to be blinded at this location. An additional lateral line not shown on available site drawings enters MH06 from the west, at an elevation above the concrete plug. Sanitary sewer manholes MH03 and MH04 may be sump or water valve locations. Findings and conclusions are:

- Elevated concentrations of uranium isotopes in both the dissolved and total phases were observed in water samples collected from sanitary sewer manholes MH06 and MH08, located southeast of the IWCS. The greatest concentrations of these isotopes occurred at manhole MH06 where uranium isotopes exceeded the background UTLs by a factor of 50 or more. The concentrations of uranium isotopes observed in a water sample collected from manhole MH07, located on the same line between manholes MH06 and MH08, were not as highly elevated as those at manholes MH06 and MH08. Resampling of the manholes confirmed these results. No dissolved uranium isotopes exceeded background UTLs in water samples collected from manholes MH03, MH04, MH09, and MH10 which are located north of manholes MH06, MH07, and MH08.
- The water sample collected from manhole MH05 exhibited concentrations of metals and uranium isotopes that exceeded background UTLs.
- Sediment samples were also collected from sanitary sewer manholes MH03, MH04, MH07, MH08, and MH09 (no sediment was present in MH06 or MH10). Thorium and uranium isotopes were found in samples collected at manholes MH07 and MH08 at concentrations that were approximately twice the background UTLs. Unlike the water samples collected from MH07 and MH08, a significant difference in the concentrations of the radionuclides in these two sediment samples was not observed. The concentrations of the uranium isotopes in the sediment sample collected from manhole MH09 were elevated, both relative to background UTLs and to the other sediment samples collected from the sanitary sewer manholes. However, the water sample collected from MH09 did not exhibit elevated isotopic uranium concentrations relative to other manhole water samples. During the collection of these samples, the field crew measured the pH, conductivity, and DO concentrations in the manholes prior to sample collection. The water in MH09 had higher conductivity, DO and pH than the other manholes in this area. These differences in water chemistry may be suppressing the solubility of uranium compounds in MH09. Radiological isotopes were also detected in sediment samples collected from manholes MH03 and MH04 at concentrations approximately twice the background UTLs.
- PAH compounds and metals were frequently detected at concentrations that exceeded background UTLs in sediment samples collected from MH03, MH04, and MH09. VOCs and SVOCs were infrequently detected in these samples. Similar concentrations of PAH compounds, VOCs, SVOCs, and metals were not observed in the other samples collected from manholes in this area.

5.6.2 Media Interactions

The uranium plume north of the IWCS could be related to localized areas of elevated activity ranging from 15,000 to 53,000 cpm (see Figure 3-4) that were identified in surface soils north of the IWCS during the gamma walkover survey. Leaching from these surface soils could be affecting wells north of the IWCS. The uranium plume south of the IWCS is collocated with the sewer lines in the area and this plume may be related to the elevated uranium concentrations found in manhole MH06. The concentrations of the uranium isotopes in MH06 are greater than the estimated concentrations of those isotopes in the groundwater in the vicinity of MH06. However, the highest concentrations in the plume occur very near a subsurface water line. This water line heads northeast and intersects the path of the sanitary sewer near manhole MH06. The depth at which the water line was installed is not known, though water lines were typically installed at depths shallower than sanitary sewer lines. The water line may be a preferential flow path exhibiting higher uranium concentrations than would be expected to be found in other flow paths through the native soil.

The highest isotopic thorium concentrations found at the NFSS in surface water was in a sample collected in a drainageway that flows north through EU 7, north of the IWCS. Many surface and near surface soil samples collected in the watershed of this drainageway also contained elevated concentrations of thorium and these soils may be the source of the thorium found in the water sample. The drainageway discharges to the South O Street Ditch and from there to the West Ditch. The relatively small flow volume of this ditch is apparently attenuated by the flow in the South O Street Ditch and the West Ditch. None of the thorium isotopes were detected in sample SW712-318, collected from the West Ditch downgradient from EU 7.

5.6.3 Sources and Effects of Past Site Use

Presence of compounds in groundwater and soil within these EUs is consistent with the past uses of the site.

- The burial area in the west central area of the site is consistent with the presence of metals, PCBs and radiological constituents in EU 7. Although this was labeled as a clean burial area, there were also several holding ponds present for dewatering of the K-65 slurry. These ponds may have also contributed radiological constituents to the environment.
- The presence of cesium-137 in EU 7 may be related to the EU's proximity to EUs 1 and 2 where the KAPL waste was stored.
- EUs 10 and 11 exhibited metals, pesticides, VOCs, radiological constituents and one SVOC in groundwater. The presence of these compounds may be related to the activities of the AEC since this is the location of the IWCS and the location of several of the holding ponds used for dewatering liquids during filling of the IWCS. In addition, there are numerous supply and waste pipelines that traverse the area. Some of these constituents may be migrating to groundwater along the pipelines or through the fill around the pipelines.
- Considerable construction activities have taken place that have disturbed the soils. Some areas of soil exhibit the presence of metal and radiological SRCs. These SRCs are likely related to the construction of the IWCS (i.e. residue placement, R-10 stabilization,

consolidation of contaminated soil, final grading and capping) and to activities at Building 401 located just east of EU 11.

- Elevated concentrations of metals were found in sediment and water collected from manhole MH09 in EU 11. Elevated concentration of PAH compounds were also found in the sediment at this manhole location. This manhole is located at the junction of a lateral line from Building 401 with the main sanitary sewer. Many of the PAH compounds and metals found in manhole MH09 were also detected at elevated concentrations in and around Building 401, which may be the source for these compounds and metals.
- As documented in Section 2 of this RI report, the IWCS was constructed over the former LOOW freshwater treatment plant. Several different radioactive wastes and residues were stored in the buildings and lagoons that were part of the plant. Prior to the construction of the IWCS, the R-10 pile was located on the ground north of the plant and was left unprotected. Building 409, formerly located south of the IWCS, was used for the storage of uranium scrap metals. Some or all of these past activities may be responsible for the uranium groundwater plumes now evident at the site.
- Correlation appears to exist between elevated readings detected during the gamma walkover and soil samples collected during Phase 3. Small areas of high gamma walkover readings were observed in the vicinity of the former organic burial area and along the O Street South Ditch west of the Central Ditch in EU 7. Several soil samples collected in these areas exhibited elevated levels of radium-226 and thorium-230. Elevated gamma readings were identified northwest of the IWCS, along the east side of the IWCS and in the southeast corner of EU 10. No soil samples appear to have been collected to directly evaluate these areas.
- The highest gamma walkover readings within EU 11 were directly northwest of former Building 403 and in the area of the intersection of Campbell Street and R Street, which corresponds to the location of Trench 812. Subsequent soil sampling in these areas indicated the presence of elevated total uranium, radium-226, and thorium-230. Some elevated gamma walkover readings along Campbell Street, particularly in the east side ditch, corresponded to soil samples with elevated radium-226 activities. A sample in the South 16 Ditch that exhibited an elevated gamma walkover reading contained elevated actinium-227, radium-226 and thorium-230.
- Groundwater and soil data in both EU 7 and the northern portion of EU 10 indicate that the DOE Organic Burial Area is the likely source of the thorium plume north of the IWCS. The burial area was originally used for the disposal of organic materials stockpiled at Lutts Road and O Street. Material known to have been disposed in this area includes roofing timbers, wooden debris, and organic material from clearing activities (Bechtel National, Inc. 1984, 1985). During trench excavation activities conducted during this RI, the burial area was found to contain railroad ties, general demolition debris, slag, ash-like material, miscellaneous office waste, plastic pipe, and apparently unused environmental containers. Thorium concentrations observed in soil and groundwater in this area may be the result of residual contamination from this collection of debris. Surface and subsurface soils in the vicinity of the burial area in EU 7 exhibit moderate concentrations of thorium isotopes, with one sample (SS8D009) exhibiting a concentration of 536 pCi/g. Four samples immediately north of Ponds 1 and 2 either exhibited no exceedances of the background UTLs for thorium isotopes or only low

levels of thorium isotopes, thus the historic use of Ponds 1 and 2 is not thought to be the source of the thorium in groundwater in EU 7.

- The source of the thorium-230 in groundwater south of the IWCS is likely associated with historical use of Building 409 during construction of the IWCS. According to unpublished construction reports, treated slurry water from various bays in Building 411 was pumped to Building 409 for additional settling prior to being pumped to Ponds 3 and 4. Building 409 underwent a gross decontamination operation using a high pressure wash in October 1985 after removal of the 'yellow cake' that had accumulated during its use as an intermediate settling basin. Building 409 was then demolished, the rubble filled with fillcrete, and covered with backfill to a minimum depth of two feet. Inefficiencies in the transfer process or decontamination process may have led to the thorium groundwater contamination, as the K-65 residues are known to contain elevated levels of thorium-230.

5.7 BUILDING 401 AND VICINITY: EU 12, 13 AND 14

Building 401 and vicinity consists of EU 12, 13, and 14. The area is bounded by the South 16 Ditch on the north, Modern Landfill on the east and south, and by Campbell Street on the west.

EU 12 is a vacant wooded tract located between the shops area (EU 8) and Building 401. No production or storage activities are known to have occurred in EU 12. The Building 401 Ditch flows north through the EU, where it joins the South 16 Ditch, which continues to the west, joining the Central Ditch in EU 10.

The main feature in EU 13 is Building 401, a large structural steel building. During the operation of the LOOW, Building 401 was a power house, generating steam for use in the TNT production facilities. Later, the building housed a boron-10 (a nonradioactive isotope) separation process. During active use of the NFSS as well as during previous remedial activities, the building was used to temporarily store and stage radioactive waste and KAPL wastes.

EU 14, bounded on two sides by Modern Landfill, is a wooded tract. Both the South 31 Ditch and the Modern Ditch flow through the area and join near the northwest corner of the area. The South 31 Ditch continues to the west, joining the Central Ditch in EU 10. No production or storage activities are known to have occurred in EU 14.

5.7.1 Occurrence and Distribution of SRCs

5.7.1.1 Soil

Figures 4-12 through 4-14 summarize the occurrence of SRCs in soil at EUs 12, 13, and 14.

Thirty-eight surface and subsurface soil samples collected during the three phases of the RI were used to evaluate soil in EU 12. Phase 1 samples were collected to assess the presence or absence of chemical and radiological parameters around Building 401, a concrete bunker northwest of Building 401, and the eastern boundary of the NFSS site. Other Phase 1 samples were used to evaluate a former rail line, some residual coal near Building 401, and runoff from the Modern Landfill. Phase 2 samples were collected to evaluate data from the gamma walkover or to bound the extent of results from previous sampling. Phase 3 samples were collected to further investigate the results of the gamma walkover, to evaluate some areas of the EU that had not previously been investigated, and to delineate the results of earlier trenching.

Results from soil sampling in EU 12 indicate that metals, PAHs, PCBs, pesticides, SVOCs, VOCs and radiological parameters, exceeded background UTLs.

Seventy-two surface and subsurface soil samples collected during the three phases of the RI were used to evaluate soils in EU 13. Phase 1 samples were collected to evaluate previous sampling results, to investigate potential USTs and the location of a fuel storage tank, to investigate Building 407, and to investigate a concrete pad, fill pipes, and an area of stressed vegetation near Building 401. Phase 2 samples were collected to further investigate the results of the gamma walkover. Phase 3 samples were collected to investigate previously un-sampled areas, to evaluate the soils under Building 401, to evaluate a potential UST, to investigate a tank cradle, and to further define the horizontal extent of inorganic compounds identified during previous sampling. Phase 3 samples were also used to investigate several trenches. The trenches sampled in Phase 3 were installed to investigate potential tanks, a storm sewer, and a spoils pile.

Forty-nine surface and subsurface soil samples collected during the three phases of the RI were used to evaluate soil in EU 14. Phase 1 samples were collected to assess the inorganic, organic and radioactive constituents along the southern site boundary and in an area where TCE had previously been detected. Phase 2 samples were used to bound the results of earlier sampling, and to evaluate areas of the site boundary that had not previously been investigated. Phase 3 samples were used to investigate a drum storage area, to further investigate the findings of the gamma walkover, and to further delineate previous sampling results. Trench samples were also collected during Phase 3.

Additionally, one sample (SD719-341) collected from EU 12 was intended to be evaluated as a sediment sample. However, as discussed in previous sections of this RI report, this sample was classified as a surface soil sample to be consistent with exposure mechanisms considered in the BRA. Therefore, this sample was included in the discussion of soil samples collected at this EU. Findings and conclusions are:

- Radionuclides most frequently detected above background UTLs in EU 12 surface and subsurface soils include cesium-137, radium-226, thorium-230, uranium-234 and uranium-238. The majority of the background UTL exceedances occurred within surface soils. Two samples collected in the northwestern portion of EU 12, SS218-400 and SS219-401, exhibit the highest concentrations of these radionuclides. These two samples also exhibit elevated levels of actinium-227. Both of these samples were collected from localized areas with elevated gamma radiation readings, as determined by a limited gamma walkover survey.
- The evaluation of the results for radiological parameters leads to the conclusion that the distribution of radiological SRCs within EU 12 is erratic with small areas containing elevated concentrations of radiological parameters. The surface soil in the southeast corner of the EU appears to be largely contaminated with radionuclides.
- Metals, PAHs, PCBs, SVOCs, and VOCs also exceeded background UTLs in surface and subsurface soils within EU 12, but much less frequently than radiological parameters. Subsurface soil samples collected in EU 12 at depths greater than 10 feet bgs exceeded background UTLs for metals, radium-228, thorium isotopes, uranium-235, and three VOCs (1,1-DCE, acetone, and carbon disulfide). Most of these exceedances occurred in only a few samples in the northwestern and southeastern portions of the EU.

- The radium-226 concentration in sample SS203-003, collected approximately 80 feet south of Building 401 in EU 13, was 1,140 pCi/g – the highest radium-226 concentration measured at the NFSS. The gamma radiation at this location measured 200,000 cpm. This sample consisted of a single ‘nugget’, which accounted for almost the entirety of the gamma radiation measured at this location. When the site-wide gamma walkover survey was performed after the ‘nugget’ was removed, elevated gamma radiation was no longer present at this location.
- The radium-226, thorium-230 and actinium-227 concentrations in sample SS221-403, approximately 35 feet southeast of Building 401, were more than 100 times greater than the background UTLs. Uranium isotopes were also detected in this sample location at concentrations that exceeded the background UTLs by factors greater than 10. This is consistent with the results of the site-wide gamma walkover survey, which found evidence of an area at this location with gamma radiation that was elevated relative to background gamma results. Both the gamma walkover survey and the sample data show that the area impacted with radium-226 is restricted to the unpaved area immediately southeast of Building 401. While some radiological SRCs were found in other soil samples collected south and east of Building 401, the concentrations of radiological SRCs found in these samples, with the exception of SS203-003, were less than three times the background UTLs. Additionally, sample SS220-402, located northwest of Building 401, exhibited concentrations of radionuclides that were at least 20 times greater than the background UTLs, particularly, actinium-227, radium-226, and uranium-238.
- Metal exceedances in EU 13 soil samples occurred throughout the EU. Most of the metals exceedances were two to three times the background UTLs. South of Building 401, boron was found at concentrations greater than twenty times the background UTLs in trench samples. Subsurface samples collected from this area tended to have higher boron concentrations than the surface samples. The highest boron concentration measured in EU 13 was found in a soil sample collected from a depth of 5.2 feet below grade south of Building 401.
- Ten soil samples were collected from beneath the floor slab in Building 401. Boron, selenium, and thallium were commonly detected metals in these samples. However, boron was found at elevated concentrations (up to five times greater than the background UTL) in several of the samples. PCBs and pesticides were also commonly found in these samples. The maximum PCB concentration (441 µg/kg) was for Aroclor-1254 in SB-Core01-0.5-3731. The maximum pesticide concentration (8.58 µg/kg) was for 4,4'-DDT in sample SB-Core02-0.5-3733. Chlorinated solvents, including 1,1-DCE, cis-1,2-DCE, PCE, trans-1,2-DCE, and TCE, were also detected in these samples. While most of the concentrations of these compounds were less than 10 µg/kg, some sample concentrations ranged as high as 66 µg/kg (cis-1,2-DCE). PCE was found in six of the ten samples at concentrations ranging from 0.71 to 12.9 µg/kg. TCE was found in eight samples with concentrations ranging from 0.437 to 227 µg/kg. The soils beneath the floor appear to be minimally impacted with PAHs and radionuclides. PAHs were detected in only a couple of locations mainly at concentrations less than five times the background UTLs. Most isotopic concentrations were at or near background UTLs.
- Four exploratory trenches were excavated around Building 401. Trench 201 was excavated near the southwest corner of Building 401 to investigate the possible location of an UST. The trench was excavated to depths of 1 to 5 feet bgs, but no tank was found.

However, a series of concrete structures was observed in the trench. The purpose of these structures is not known, though it is thought that they may in some way be associated with one or more USTs that may have been located adjacent to Building 401. There is what appears to be a vent pipe located at the southwest corner of the building. However, no definitive evidence of the existence of USTs was found here. No chemical evidence suggesting the presence of USTs was found in the soil samples collected from Trench 201. Results from three subsurface soil samples collected at this trench location indicated that selenium, thallium, thorium-230, naphthalene, 2-methylnaphthalene, 1,1-DCE, and toluene exceeded background UTLs. A sample was collected from what appeared to be a piece of building material found in Trench 201 at a depth of approximately 2.4 feet bgs. Analysis determined that the sample contained approximately 15% chrysotile asbestos.

- Trenches 202 and 205 were excavated in the area of the former leaching pit located south of Building 401. Trench 202 was excavated to investigate a storm sewer grate and associated piping. The trench was excavated to between 4 and 7 feet bgs; however, no piping was uncovered. During the excavation of this trench, a distinct odor, variously described as ‘pesticide-like’ and ‘similar to chlorinated solvents’, was noted. However, none of the chemical results for soil samples collected from this trench identified the chemical constituent responsible for this odor. Small concentrations of several VOCs and one pesticide were observed in the soil samples collected from Trench 202, but given the small concentrations in the samples, it is unlikely that the detected compounds are responsible for the odor. Other results indicated several metals and radionuclides exceeded background UTLs at this trench location. Trench 205 was excavated in EU 14 to further investigate the organic/pesticide odor observed at Trench 202. Trench 205 is oriented east-west with the western end near the southern end of Trench 202. Several sand lenses were encountered at depths below 5 feet. Three subsurface soil samples were collected, all of which exhibited concentrations of metals and at least one VOC above background UTLs. Additionally, one sample exhibited total uranium and uranium-235 above background UTLs.
- Subsurface soil samples collected in EU 13 at depths greater than 10 feet bgs exceeded background UTLs for metals, thorium-230, thorium-232, 4,4-DDE, 4,4-DDT, and five VOCs (1,1-DCE, acetone, carbon disulfide, toluene, and xylenes). These exceedances occurred at widely scattered locations within the EU.
- Trench 203 was excavated north of Building 401 to investigate a potential UST. The upper 3 feet of the excavation included firebrick and fill debris in a brown clay matrix. Also uncovered was a 12” diameter pipe and a crushed steel bucket. One surface soil sample and two subsurface soil samples were collected from the trench. Surface and subsurface soil results indicate that metals and radionuclides slightly exceed background UTLs. Surface soil samples also indicated the presence of anthracene, acetone, methylene chloride, PCE and toluene. Additionally, acetone, methylene chloride, PCE, toluene, and TCE were detected in subsurface soil samples at this trench location.
- Trench 204 was excavated to investigate a spoils pile southeast of Building 401. The trench lies mostly within EU 13 with the south end of the trench positioned in EU 14. The trench was excavated to a depth of 10 feet from the top of the spoils to 5 feet below the base of the pile. Three subsurface soil samples were collected in the brown-gray clay underlying the fill material. The sample analytical results exhibited concentrations of uranium-238 and total uranium just above background UTLs. No samples were collected

in the fill material because no magnetic, or gamma anomalies were observed and no PID measurements were elevated.

- Approximately two-thirds of the soil samples collected in EU 14 contained concentrations of one or more radiological SRCs that exceeded background UTLs. However, with the exception of a few isolated locations, the magnitude of exceedance was small. In most cases, the concentrations of radiological SRCs were less than three times the background UTLs, though small areas containing radiological SRCs at much higher levels are present. The concentration of radium-226 in surface soil sample SS816-703, located adjacent to the perimeter road in the southeast corner of the EU, was 299 pCi/g – the fourth highest radium-226 concentration measured at the NFSS. A short distance away, in surface soil sample SS8B001-2430, the radium-226 concentration was 16.8 pCi/g. Other samples collected in this vicinity contained concentrations of radium-226 that were near or below the background UTL. Other samples collected at this location exhibited elevated concentrations of actinium-227 as well. This is consistent with the findings of the site-wide gamma walkover survey, which identified an impacted area along the road at the location of these two samples.
- Elevated concentrations of radiological SRCs and boron were found in surface and subsurface soil samples collected in the northwest portion of EU 14, north of the South 31 Ditch in an area formerly used by the AEC as a sludge pit. The purpose of the sludge pit is not known, though apparently it was constructed contemporaneously with the production of boron-10 in Building 401. Surface soil sample SS2B014-2374 exhibited a radium-226 concentration of 126 pCi/g, which was more than 100 times greater than the background UTL. The total uranium concentration in this sample was 9.96 µg/g, approximately three times greater than the background UTL. A surface soil sample collected in this area (SS202-002) exhibited a concentration of boron of 283 mg/kg. Several subsurface soil samples collected at this area also exhibited boron concentrations greater than 10 times the background UTL with the greatest concentration observed at location BH223. This location exhibited a boron concentration of 1,580 mg/kg, which is more than 150 times the background UTL. Small concentrations of VOCs were also found in surface and subsurface soil samples collected from the sludge pit.
- Subsurface soil samples collected in EU 14 at depths greater than 10 feet bgs exceeded background UTLs for metals, and two VOCs (1,1-DCE and acetone). These exceedances occurred in two widely spaced locations along the southern and northern perimeter of the EU.

5.7.1.2 Surface Water

Figures 4-15 and 4-16 summarize the occurrence of total and dissolved SRCs in surface water at the NFSS.

During Phase 1, three surface water samples were collected from both EU 12 and 14. These samples were taken to assess surface water from Building 401 and the southern shops area (EU 8), as well as from the Modern Landfill to the east of the site. In EU 12, two surface water samples were collected from the South 16 Ditch along the northern portion of the EU. The other surface water sample in EU 12 was also collected in the northern portion of the EU south of the South 16 Ditch. In EU 14, two surface water samples were collected in the South 31 Ditch, one at the conjunction with the Modern Ditch and one at the eastern boundary of the EU. Another

surface water sample was collected in Modern Ditch along the southern boundary of the EU where the Modern Ditch enters the site. O-cresol was the only SRC identified in the surface water sample collected south of the South 16 Ditch in EU 12. Several metals, in both the dissolved and total phases, were detected in the other surface water samples from EUs 12 and 14 at concentrations above background UTLs. No consistent pattern was identified in the spatial distribution of the metals concentrations detected in the samples. Two VOCs, 4-methyl-2-pentanone and benzene, were detected in the sample collected at the conjunction of the South 31 Ditch and the Modern Ditch.

No surface water samples were collected from drainageways in EU 13. The nearest surface water sample collected downgradient from EU 13 was SW716-329, collected from the South 31 Ditch in EU 11. This sample, which is also downgradient from the sludge pit in EU 14, contained the highest dissolved boron concentration (628 µg/L) found in any surface water sample collected at the NFSS. However, a sediment sample, collocated with SW716-329, did not contain elevated concentrations of boron.

5.7.1.3 Sediment

Figure 4-17 summarizes the occurrence of SRCs in sediment at the NFSS.

Six sediment samples were collected in EU 12 and 14 at points collocated with the surface water samples; however, sample SD719-341 was later reclassified as a soil sample. These samples were collected to assess the sediments from Building 401 and the southern shops area (EU 8), as well as from the Modern Landfill to the east of the site. Several metals were detected in the sediment samples at concentrations above background UTLs, though, like the surface water samples, no consistent pattern was identified in the spatial distribution of the metals concentrations detected in the samples. Additionally, cesium-137 exceeded the background UTL in the sample collected from the South 31 Ditch at the eastern boundary of EU 14 (SD718).

5.7.1.4 Groundwater

Figures 4-18 through 4-21 summarize the occurrence of total and dissolved SRCs in the LWBZ and UWBZ at the NFSS.

In EU 12, groundwater samples were collected from six TWPs and one permanent well; in EU 13, groundwater samples were collected from 13 TWPs and five permanent wells; and in EU 14, groundwater samples were collected from seven TWPs and one permanent well. Phase 1 groundwater samples were collected in EU 12 to determine the affect that Building 401 activities had on groundwater, and to define the groundwater constituents along the eastern site boundary. The permanent well was sampled during Phases 2 and 3 to assess previous sampling results at a temporary well. Phase 2 groundwater samples were also used to further investigate metals, radiological and VOC results from previous sampling within EU 13. In EU 13, groundwater samples were collected for the purpose of evaluating the groundwater in the immediate vicinity of Building 401, including the paint shop and some USTs, and for further investigating previous sampling results. Groundwater sampling in EU 14 was used to assess the groundwater at the southern and eastern boundaries of the NFSS site and to investigate areas near Building 401 that had not been previously sampled. A total uranium groundwater plume was identified in this area and is shown on Figure 5-4. Findings and conclusions are:

- Total and dissolved metals and radionuclides were detected above background UTLs in all three EUs. Additionally, fluoranthene, di-n-butylphthalate, pentachlorophenol, and phenol were detected above background UTLs in groundwater within the northwest corner of EU 12. Fluoranthene, phenanthrene, five pesticides, bis(2-ethylhexyl)phthalate, phenol, and five VOCs (1,2-DCE, 2-butanone, chloromethane, methylene chloride, and PCE) were detected above background UTLs in groundwater within EU 13. Six PAHs, bis(2-ethylhexyl)phthalate, di-n-butylphthalate, and phenol were detected above background UTLs in groundwater within EU 14.
- A dissolved total uranium groundwater plume was identified northwest of Building 401, centered on monitoring well MW-215A in EU 12. Concentrations of dissolved total uranium in this plume were approximately 2 to 3 times the background UTL of 16.7 µg/L.
- A dissolved total uranium groundwater plume was also identified in the area south of Building 401. Concentrations of dissolved total uranium in this plume were up to 3 times the background UTL of 16.7 µg/L. Concentrations of uranium in the plume do not show a direct relation to total uranium surface soil concentrations. The relationship between soil and groundwater uranium concentrations may be more evident with additional groundwater data. Also, past remedial actions may have removed most of the SRCs in the surface soil, leaving the 'foot print' of the original impacted area evident in the groundwater. The uranium plumes in EU 13 could be related to sporadic areas of localized elevated activity ranging from approximately 34,000 to 93,000 cpm (see Figure 3-5) that were identified in surface soils in EU 13 during the gamma walkover survey. Leaching from these surface soils could be affecting wells in this area.
- A north-south trending boron plume was found within the central portion of EU 13. This plume is shown on Figure 5-14. The highest concentration of dissolved boron within this plume is centered on wells MW213 and MW213A. Some of the water samples collected from the Building 401 floor drains also had high levels of dissolved boron.

Building 401 drain samples contain elevated levels of boron which could be a potential source for the boron plume. Therefore, the plume presented in Figure 5-14 is shown to extend beneath the building. The drain samples did not contain elevated concentrations of uranium; thus two separate uranium plumes are presented north and south of Building 401 in Figure 5-4.

5.7.1.5 Pipelines and Subsurface Utilities

Figures 4-22 and 4-23 summarize the occurrence of total and dissolved SRCs in pipeline water samples, while Figure 4-24 summarizes the occurrence of SRCs in pipeline sediment samples.

During Phase 3, two manholes, MH01 and MH02, were sampled in EU 13. Manhole MH01 was sampled only for water and manhole MH02 was sampled for both water and sediment. Both were sampled to determine the impact of the Building 401 activities on the sanitary and storm water sewer systems in EU 13. MH01 is known to be located on a sanitary sewer that serviced Building 401. The line on which MH02 is located, south of Building 401, is not shown on available site drawings for the NFSS and the purpose of this line is not known. Conclusions and findings are:

- Water sample MH01W-2000 contained dissolved aluminum, boron, chromium, copper, nickel, silver, and other dissolved metals at concentrations above background UTLs. The concentrations of dissolved aluminum and silver exceeded the background UTLs by a factor of more than 20. The dissolved boron concentration found in the sample exceeded the background UTL by a factor of almost three. The other dissolved metals exceeded their background UTLs by factors that ranged from approximately two to eight. Concentrations of total radium-226, total uranium-234, and total uranium-238 slightly exceeded the background UTLs in this sample.
- In water sample MH02W-2001, dissolved nickel, total thallium, total radium-226, total thorium-230, and total thorium-232 were identified as SRCs.
- In sediment sample MH02S-2002, arsenic, boron, nickel, selenium, and zinc were identified as SRCs. The concentrations of these parameters in MH02S-2002 were all less than three times the background UTLs. Anthracene, naphthalene, phenanthrene, 2-methyl naphthalene, and dibenzofuran were also identified as SRCs in this sediment sample.

Fourteen floor drains in Building 401 were also sampled during Phase 3 of this RI. The purpose of sampling these drains was to assess the chemical and radiological impacts that could have been introduced into the sewer system(s) by site activities at Building 401. Site drawings showing the piping for these drains were not available and the destination for materials entering these drains is not known. Sediment was present in all 14 drains. Water was present in only six of the drains. In most of the drains with water, the volume of water present was insufficient to satisfy all analytical requirements, so the analytical lists were reduced to accommodate the limited sample size. Oil was present in three of the drains, though the amount present in one of the drains was insufficient for analysis. Samples of the oil were collected and submitted for SVOC, metals, pesticide, PCB, and radiological analysis. Findings and conclusions are:

- The sediment samples collected from the drains contained many metals at concentrations above background UTLs. Boron and mercury, in particular, were many times higher than background UTLs. Sample Drain06-S-3711 had a boron concentration of 11,700 mg/Kg and two others had boron concentrations over 7,000 mg/Kg. The mercury concentrations in three of the drain sediment samples exceeded 200 mg/Kg. Aroclor-1254 was present in 12 of the 14 sediment samples, at concentrations as high as 84,900 µg/kg. 4,4'-DDT was detected in three samples, at concentrations as high as 60,900 µg/kg. Various PAHs, SVOCs, and VOCs, including chlorinated solvents, were frequently detected in the sediment samples. TCE was detected in seven of the thirteen drains at concentrations ranging from 1.87 to 217 µg/kg. PCE was detected in eight of the samples at concentrations ranging from 0.345 to 1,000 µg/kg.
- Radiological SRCs were also present in the floor drain sediment samples, though the magnitudes of exceedances were not nearly as extreme as that observed for some of the metals and organic compounds. Drain03-S-3705 exhibited the highest uranium isotope concentrations detected in the drain sediment samples. Uranium-234, -235, and -238 were detected at the following concentrations: 26.2 pCi/g, 6.99 pCi/g, and 28.5 pCi/g. The other isotopes were detected at smaller concentrations.
- Four water samples collected from the drains were submitted for total metals analysis. Many metals were found at concentrations over 100 times greater than background

UTLs. However, these results were to a large degree attributable to solids present in the samples. Sample Drain04-W-3706 tended to have higher concentrations of total metals than the other drain water samples. Unfortunately, the volume of water available in Drain04 was not sufficient to also allow analysis for dissolved metals.

- Dissolved thorium isotopes were detected at levels that exceeded background UTLs at drain location Drain01. 2-Butanone, acetone, bis(2-ethylhexyl)phthalate, 4,4'-DDT, Aroclor-1254 and Aroclor-1260 were also infrequently detected in drain water samples.
- Oil samples were collected from Drain03 and Drain04. Aroclor-1254 was detected in both samples. The concentration in Drain03-O-3720 was 83,800 µg/kg and in Drain04-O-3719 it was 214,000 µg/kg.

5.7.1.6 Building 401 Floor Slab Core Samples

In Phase 3, ten core samples were collected from the floor slab of Building 401. These samples were analyzed for metals, PAHs, PCBs, SVOCs, and radionuclides. Metals and radionuclides were detected in all of the samples. The highest concentrations of radionuclides were less than 2 pCi/g, except for one sample which contained 5.7 pCi/g of plutonium-239. PCBs were detected in eight samples with a maximum detection of 26,000 µg/kg for Aroclor-1254. PAHs were also detected in a number of samples with the maximum concentration of 135 µg/kg for phenanthrene. SVOCs were found in nine of the samples and included bis(2-ethylhexyl)phthalate and di-n-butylphthalate. Di-n-butylphthalate exhibited the highest concentration at 2,540 µg/kg.

5.7.2 Media Interactions

Elevated concentrations of boron were found in all media sampled in this area. There appears to be two principal source areas for boron: Building 401 and the 'sludge pit' south of Building 401 (see Figure 1-2). Building 401 may be the source for the boron groundwater plume found in this area. Boron levels that exceeded the background UTL by factors greater than 200 were found in sediment samples collected from some of the floor drains inside Building 401. Dissolved boron was also detected in water samples collected from the floor drains at concentrations that exceed the background UTL by as much as a factor of about 20. The sludge pit south of Building 401 may be the source of boron found in surface water downgradient from the sludge pit.

5.7.3 Sources and Effects of Past Site Use

During the operation of the LOOW, Building 401 served as a steam generation plant. Later, the DOE extracted boron-10 in the building. At times, the AEC, the DOE, and their contractors, housed and stored radioactive wastes in the buildings.

- Chemicals typical of industrial facilities were found in and around Building 401. Pesticides, PCBs, PAHs, SVOCs, VOCs, metals and radiological constituents were found in EUs 12, 13, and 14. The presence of these constituents is consistent with the uses of Building 401. PCBs, SVOCs, metals and radiological constituents all exceed risk levels in some areas of the three EUs.
- Impacts resulting from the past use of the building as a storage and staging facility for radioactive materials are found throughout the three EUs, particularly in low lying areas such as ditches.

- Elevated concentrations of boron were found in all sampled media.
- Correlation does appear to exist between elevated readings detected during the gamma walkover and soil samples collected during Phase 3. Within EU 12, areas of gamma walkover readings that were elevated relative to background gamma results occurred mainly along service roads and rail lines. Other small areas of elevated gamma walkover readings occurred in the northwestern area of the EU. A few soil samples indicated slightly elevated levels of radionuclides in these areas. Scattered single point locations exhibiting elevated gamma walkover readings were identified in EU 13; however, no Phase 3 soil sampling was conducted at these locations. As previously discussed, analytical results from a Phase 2 soil sample location are consistent with results of the gamma walkover survey. Within EU 14, analytical results are consistent with elevated gamma walkover readings identified at scattered single point locations in the northwest portion of the EU and at the intersection of Castle Garden Road and R Street.

5.8 NIAGARA-MOHAWK PROPERTY, EU 9

The Niagara-Mohawk property is adjacent to the western boundary of the NFSS. The West Ditch is the principal site feature of the Niagara-Mohawk property.

5.8.1 Occurrence and Distribution of SRCs

5.8.1.1 Soil

Figure 4-25 summarizes the occurrence of SRCs in soil at EU 9.

During Phase 3, soil samples were collected from along the West Ditch. These samples were collected to evaluate the presence or absence of inorganic, organic and radiological parameters on the Niagara-Mohawk Property. Thirty-five soil samples were collected on the Niagara-Mohawk Property. Seven of these samples were collected from the West Ditch, collocated with surface water samples, and initially classified as sediments. For purposes of the BRA, these seven samples were later reclassified to be surface soils and are being evaluated as surface soils in this section. Findings and conclusions are:

- The radium-226 concentration in sample SS913-2105 was 17.8 pCi/g, approximately 20 times greater than the background UTL. This sample was located on the top of the east bank of the West Ditch, a few feet west of the NFSS perimeter fence at a small area of elevated gamma activity discovered during a limited gamma survey of the Niagara-Mohawk property. A second sample, SB913-2474-1.5, was collected from a depth of 1.5 feet bgs at this location. The radium-226 concentration in the second sample was 0.966 pCi/g, which was less than the background UTL. The radium-226 concentrations in collocated surface soil sample SSEU093-3342 and subsurface sample SB-EU093-3322-2.0, collected from a location only 2.5 feet from SS-913-2105, were both below the background UTL, indicating that the extent of elevated radium-226 around SS913-2105 is very limited.
- The concentration of thorium-230 in sample SS913-2105 was approximately 20 times greater than the background UTL. Like the radium-226 found in this sample, the extent of the elevated concentration of thorium-230 was limited and the concentration of thorium-230 in nearby samples was less than the background UTL.

- The total uranium concentration in sample SS905-2089, located on the west bank of the West Ditch, approximately 120 feet northwest from SS905-2089, was 13.5 µg/g, approximately four times the background UTL. The total uranium concentration in the collocated subsurface sample, SB905-2090-2.0, collected from a depth of two feet bgs, was slightly lower, 12.2 µg/g, but still exceeded the background UTL.
- Several other soil samples contained concentrations of one or more radionuclides that exceeded background UTLs, though the magnitude of exceedance in these other samples was much lower – by a factor of two or less.
- The radium-226 concentration in three of the reclassified sediment samples slightly exceeded the background UTL for surface soils. However, they were significantly less than the background UTL for radium-226 in sediment.
- Metals, PCBs, pesticides, SVOCs (2-chlorophenol, m,p-cresols, and phenol), and VOCs (1,1-DCE, benzene, and toluene) exceeded background UTLs in soil samples collected from the Niagara-Mohawk property. The presence of these constituents may be due to the property's vicinity to historical operations (i.e. the unprotected R-10 pile and the construction activities conducted at the IWCS in the 1980's).

5.8.1.2 Surface Water

Figures 4-15 and 4-16 summarize the occurrence of total and dissolved SRCs in surface water at the NFSS.

Ten surface water samples were collected from the West Ditch on the Niagara-Mohawk property. Findings and conclusions are:

- The concentration of dissolved americium-241 in sample SW920-2122 was 16.9 pCi/L. However, the uncertainty associated with this result, as reported by the laboratory, was nearly as high, 15.2 pCi/L, and the confidence in this result is low. SW920-2122 was collected from the West Ditch, immediately south of where it enters the NFSS in EU 1. None of the other surface water samples collected from the West Ditch on the Niagara-Mohawk property contained detectable quantities of americium-241. Americium-241 was not part of the analytical list for surface water samples collected on the NFSS.
- Several other samples had concentrations of dissolved thorium isotopes and uranium isotopes at levels slightly above background UTLs. There is no apparent pattern evident in the spatial distributions of these exceedances. These exceedances may be attributable to the natural variation in the concentrations of these isotopes in the environment.

5.8.1.3 Sediment

Figure 4-17 summarizes the occurrence of SRCs in sediment at the NFSS.

Nine sediment samples were collected from the West Ditch on the Niagara-Mohawk property. Except for the northernmost two samples, SD919-2119 and SD920-2121, the samples were later reclassified as surface soil samples. Radium-228 and thorium-228 slightly exceeded background UTLs in one or both of these samples.

The results for the reclassified samples are presented in the discussion of soil, above.

5.8.1.4 Groundwater

No groundwater samples were collected on the Niagara-Mohawk Property.

5.8.2 Media Interactions

There is no current direct evidence that SRCs are migrating from the NFSS onto the Niagara-Mohawk property or from one environmental medium to another. As discussed in the following section, the presence of SRCs is likely the result of historical operations. Based on sampling conducted in EUs 9 and 10, it appears that contaminated surface soil on the NFSS could be a potential historical source of constituents detected in sediment and surface water in the West Ditch.

5.8.3 Sources and Effects of Past Site Use

Impacted soils and sediments in the West Ditch on the Niagara-Mohawk property were removed during a previous removal action.

- Much of the length of the ditch is impacted by metals and radionuclides at concentrations above background UTLs. This is consistent with the area's proximity to historical operations (i.e. the unprotected R-10 pile and the construction activities conducted at the IWCS in the 1980's).
- Slightly elevated gamma walkover readings were present in only a minimal area of EU 9. One single point location (913) that showed elevated gamma activity also had analytical results that indicated elevated levels of total uranium, radium-226, and thorium-230.

5.9 SITE-WIDE EVALUATION OF TRANSURANIC AND FISSION PRODUCT DATA

5.9.1 Transuranic and Fission Product Data Review

A review of almost 950 surface soil, subsurface soil, and sediment samples was conducted to identify potential fission product or transuranic contamination at the NFSS. The site database contains results for the fission product cesium-137 and the neutron activation product cobalt-60. Both of these radionuclides are produced in nuclear reactors and are commonly present in radioactive wastes. Cesium-137 is also a common radionuclide present in fallout from aboveground nuclear weapons tests. The existence of either of these radionuclides could be an indication that fission-product-contaminated materials were stored at NFSS. The database also contains results for americium-241, a transuranic also typically considered a nuclear reactor byproduct. The existence of americium-241 could be an indication of other transuranics associated with the nuclear industry, such as plutonium. Lastly, the database contains results for isotopic uranium (uranium-234, uranium -235, and uranium-238) that can be used to estimate uranium enrichment, another indicator of the presence of nuclear byproduct material.

5.9.2 Definitions

The following definitions are presented to support method description and the presentation of results:

Background – As presented here, the term background is used in two ways: soil *background* concentrations and detector *background*.

- A soil background concentration is the activity per unit mass (pCi/g) in an area that is not impacted by site activities and contains characteristics similar to site soil.
- Detector background is the detector response to an uncontaminated sample. For radio-analytical data, detector background can be represented as a distribution including both positive and negative values. The soil background concentration may be estimated from this distribution (e.g., as the 95th percentile, mean, or other statistical value).

Detect – As interpreted here, a detect is an analytical result reported above analytical thresholds and is not assigned a rejected (R) or undetected (U) flag, noting that estimated (J-flagged) results are typically accepted as detects.

Histogram – A histogram, as applied here, is a plot that partitions data into bins, where each bin represents a range of pCi/g results.

Qualified – As interpreted here, an analytical result reported with a data qualifier, including the J (estimated) and U (non-detect) qualifiers.

Strip Chart – A strip chart (also known as a run sequence chart) is a plot of the data in the order they are presented in the database. The order number is shown on the x-axis and the parameter of interest (e.g., pCi/g) is presented on the y-axis. Strip charts can be used to quickly identify outliers and data trends.

Probability Plot – A probability plot (can also be shown as a cumulative frequency distribution) presents value of a result within a population of data versus the expected value. Probability plots can be used to quickly identify outliers and can be used to approximate background levels.

5.9.3 Method

Results from six radionuclides were evaluated to determine the existence of fission products and transuranics at NFSS. The general approach was as follows:

- Identify fission product and transuranic radionuclides in the site database;
- Use the isotopic uranium results (from alpha-spec analyses of uranium-234, uranium-235, and uranium-238) to estimate enrichment as an indicator of nuclear materials;
- Use strip charts, probability plots, and histograms to identify outliers from the detector background distribution;
- Upon identification of outliers, use other available data and information to explain, if possible, the existence of outliers.

Results are presented by radionuclide and results reported as numerical values are considered (i.e., results reported as “NA” are excluded). Surface soil, subsurface soil, and sediment results are considered in this evaluation as one population of data. Detects are illustrated as shaded cells on strip charts for ease of identification. The negative (-) 1.45 pCi/g americium-241 result is

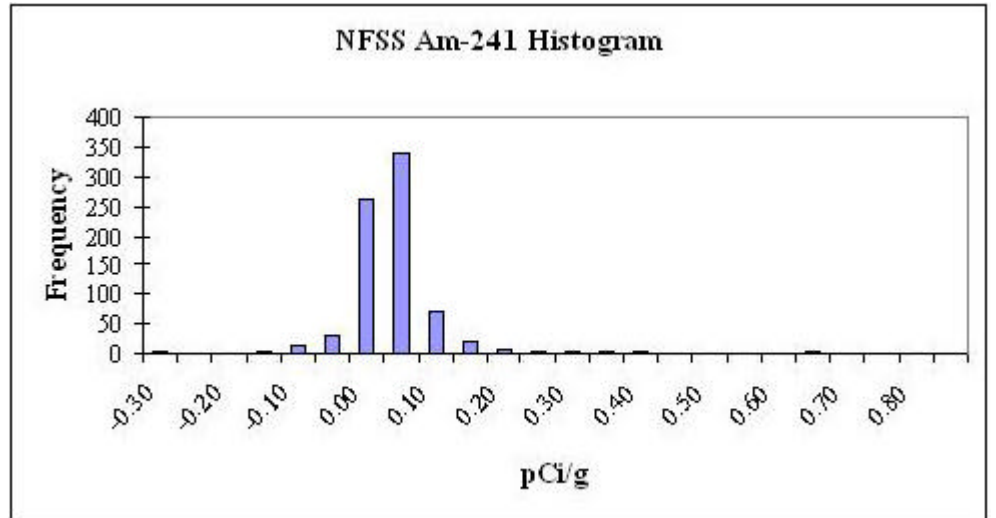
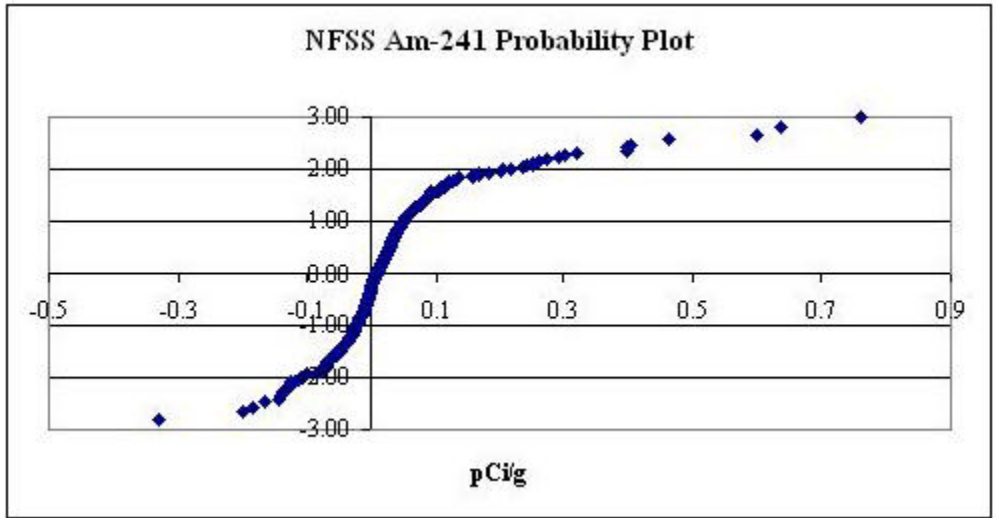
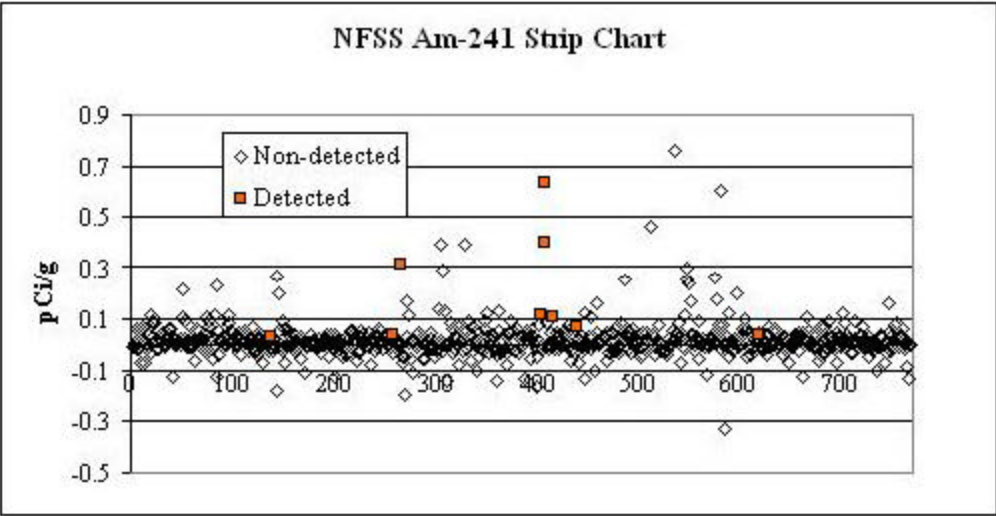
excluded to improve the presentation of other data (scale optimization). Uranium enrichment calculations are only performed using samples with uranium-234 results greater than 2 pCi/g. This truncation was performed given that during the gaseous enrichment process uranium-234 concentrations may be increased relative to uranium-235 and uranium-238 concentrations. A uranium-234 concentration of 2 pCi/g was selected based on the assumption that uranium-234 at 2 pCi/g may be slightly elevated above soil background concentrations and given that enrichment estimates are more reliable with increased concentration. Finally, it is assumed that all the data and associated qualifiers have been reviewed and results accurately represent environmental concentrations.

5.9.4 Results

The following discusses strip charts, probability plots, and histograms for americium-241, cobalt-60, cesium-137, and uranium enrichment, as appropriate. Assumptions concerning the nature of detected results, if any, are also presented.

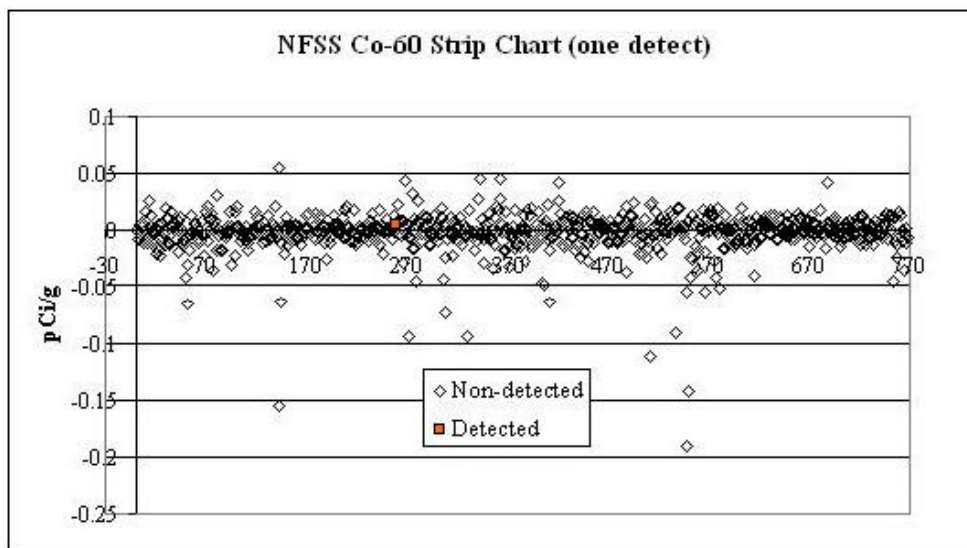
5.9.4.1 Americium-241

A total of 768 americium-241 results are illustrated in the strip chart shown below, only 9 of which are listed as detected (~1%). The maximum result of 0.76 pCi/g is a non-detect (U-flagged) and the detected values fall within the overall range of background concentrations. The probability plot and histogram do seem to indicate the presence of two populations or indicate a lognormal distribution, but do not indicate the presence of contamination. The number of detects (9 of 768) is not unexpected given around 5% false positives (detected when there is actually no activity due to statistical variations) are expected. The conclusion based on available data is that americium-241, which has not been identified as a ROC in the BRA, is not a contaminant, thus, it is unlikely that other transuranics are present at significant concentrations or are widespread in NFSS soils/sediment. This is further supported by a review of transuranic detections at the site. For example, there were only three very low detections of plutonium-239/240 in soil out of 34 samples analyzed. These detections occurred in EU 8, EU 11, and EU 13 at concentrations of 0.322, 0.129, and 0.536 pCi/g, respectively. There were no detections of plutonium-238 in 34 samples analyzed. Likewise, there were no detections of strontium-90 in 31 soil samples analyzed. However, there was one detection of strontium-90 in sediment in EU 16 (pipeline) at a concentration of 0.74 pCi/g.



5.9.4.2 Cobalt-60

At total of 768 cobalt-60 results are evaluated, only one of which is detected at 0.0058 pCi/g. This “detected” value is J-flagged (estimated), falls well within the population of non-detected results, and represents approximately 0.1% of the entire population. The cobalt-60 strip chart clearly shows the absence of outliers and the one detected value can easily be described as a statistical anomaly. It is concluded that cobalt-60, which has not been identified as an ROC in the BRA, is not present as significant concentrations in NFSS soils/sediment.

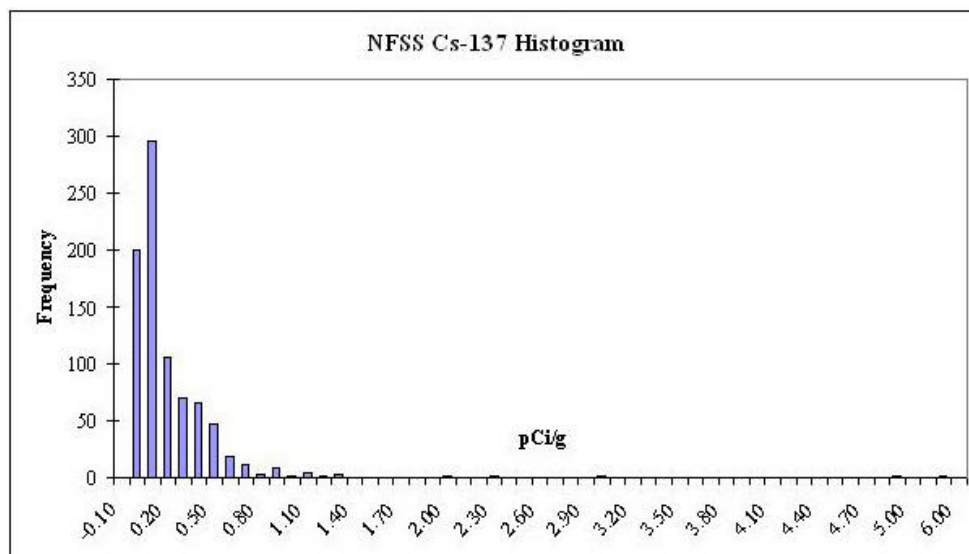
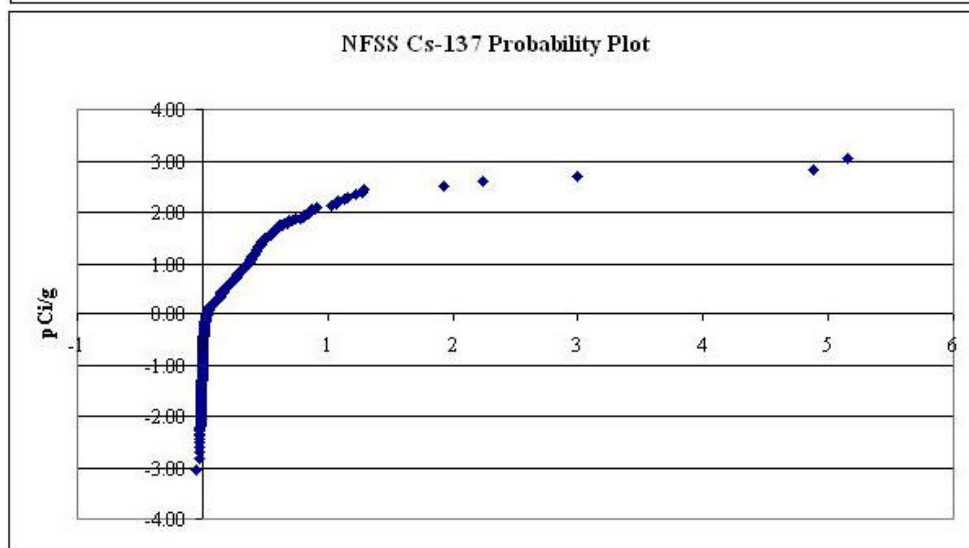
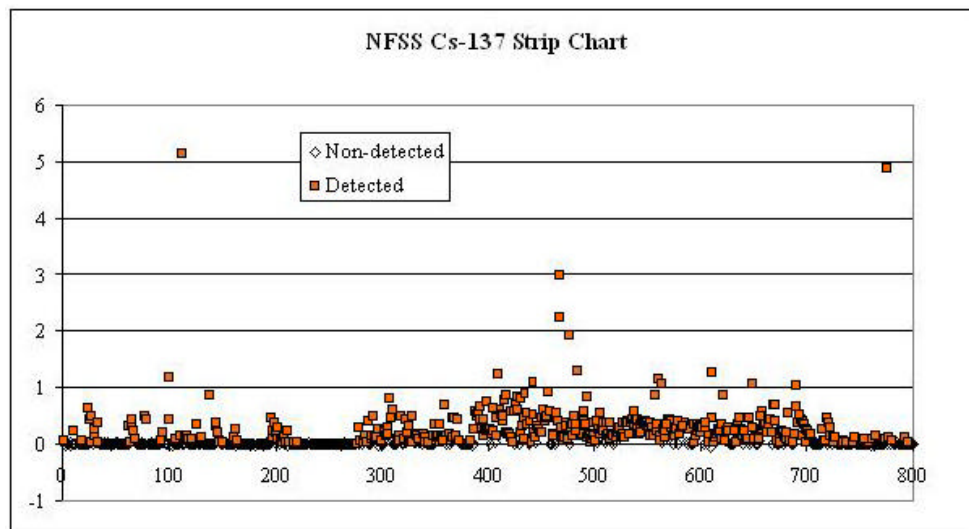


5.9.4.3 Cesium-137

A total of 841 cesium-137 results are evaluated, 433 of which are detects (including 54 J-flagged results). Figure 5-15 shows locations where cesium-137 concentrations exceed the UTL in surface soil, subsurface soil, and sediment. Possible outlier locations, which are further discussed in the following paragraphs, are also noted on the figure. The following additional illustrations show the presence of at least five visual outliers plus suggest the presence of several more. For ease of reference, the maximum five results are presented in the following table. The probability plot and histogram suggest the upper bound of background is approximately 0.8 pCi/g. Twenty-four results (all detects) are reported above 0.8 pCi/g, 23 of which are in the top foot of soil. The maximum result of 5.15 pCi/g is; however, from a subsurface sample from the 1.5 to 2 foot interval. The presence of elevated activity with depth and apparent deviation from the background distribution suggest cesium-137, which has been identified as a ROC in the BRA, is a site-related contaminant and should be evaluated further as part of on-going NFSS activities.

Potential NFSS Cesium-137 Outliers (maximum five results)

Sample ID	Start Depth (feet)	End Depth (feet)	Concentration (pCi/g)	Detection Limit (pCi/g)	Error (pCi/g)	Flag
SB 8D016-2231-2.0	1.5	2	5.15	0.0268	0.587	J
SS 3D001-2414	0	0.5	2.23	0.0508	0.221	--
SS 3D002-2415	0	0.5	3	0.0447	0.388	--
SS 414-051	0	0.5	1.92	0.0302	0.057	J
TB301-2811-01.0-029	--	1	4.88	0.0502	0.504	--

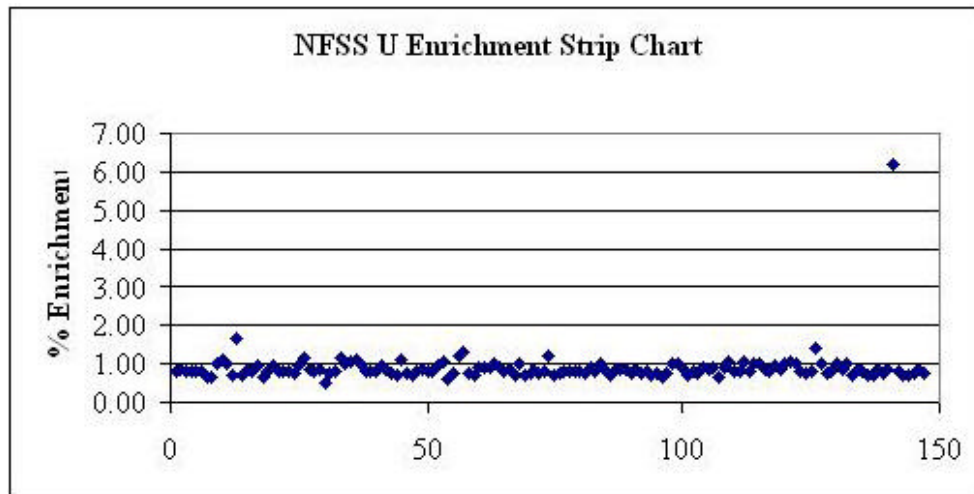


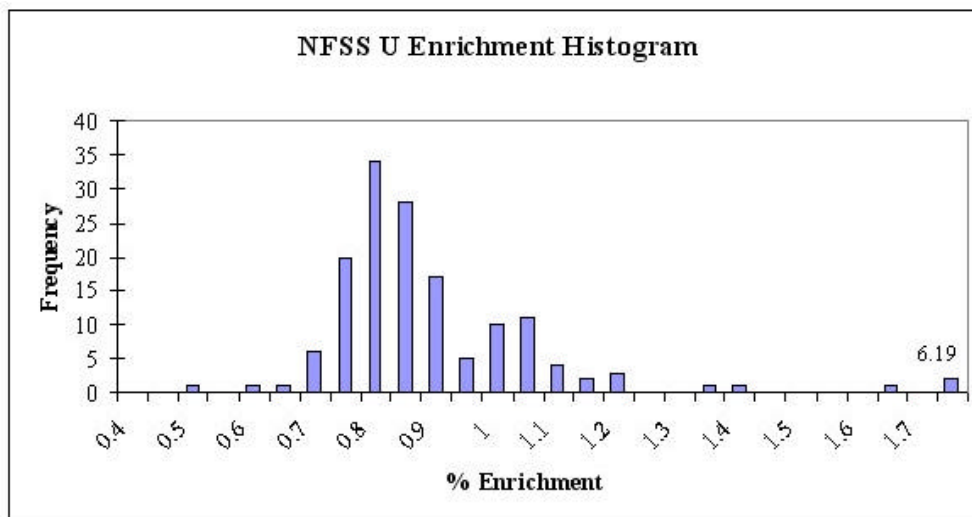
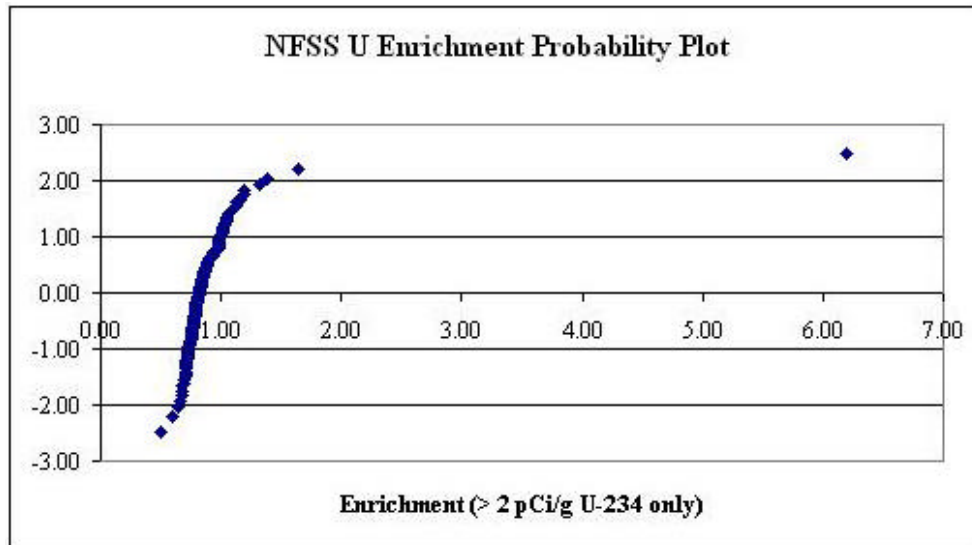
5.9.4.4 Uranium Enrichment

A total of 147 isotopic uranium results are evaluated, all with detected uranium-234 concentrations above 2 pCi/g. The following strip chart shown clearly illustrates one outlier with an estimated enrichment of 6.19 percent (surface sample TB414-2844-05.5-004). Inspection of the uranium enrichment probability plot and histogram show that the remaining results can be interpreted as within the background distribution for enrichment. As with the potential cesium-137 outliers, attempts should be made to tie the potential enrichment outlier with historical activities, or to dispute this result given other information not considered here. It is noted; however, that the total activity is relatively small compared to what might be expected for enriched uranium contamination and the result represents only about 0.7% of the entire dataset. Uranium-234, -235, and -238 have been identified as ROCs in the BRA.

Potential NFSS Enrichment Outlier (TB414-2844-05.5-004)

Uranium Isotope	Concentration (pCi/g)	Detection Limit (pCi/g)	Error (pCi/g)	Flag
Uranium-234	15.2	0.21	2.21	--
Uranium-235	0.64	0.24	0.3	--
Uranium-238	1.26	0.09	0.418	--





5.9.4.5 Other Considerations

The following table presents the 24 maximum cesium-137 results (all above 0.8 pCi/g), and enrichment estimates to determine if higher concentrations/enrichments are collocated across parameters. Radium-226 results are also presented for comparison given radium-226 is the primary NFSS contaminant relative to concentration. Review of the table shows that the single enriched uranium outlier is not collocated with elevated cesium-137 or radium-226 results.

Comparison of Potential Outliers

Sample Number	Cesium-137 (pCi/g)				Radium-226 (pCi/g)				Enrichment
	Result	MDL	ERR	Qual.	Result	MDL	ERR	Qual.	%
Potential Enriched Uranium Outlier									
TB414-2844-05.5-004	0.00	0.00	0.01	U	0.59	0.03	0.09	--	6.19
Potential Cesium-137 Outliers									
SS3A023-2394	0.81	0.04	0.10	--	17.60	0.08	2.09	--	NC
SD734-375	0.81	0.03	0.09	J	1.10	0.06	0.16	--	NC
SS4A007-605	0.82	0.03	0.10	--	3.27	0.06	0.40	--	NC
SS3A021-2392	0.84	0.05	0.10	--	21.00	0.10	2.45	--	NC
SS829-409	0.85	0.12	0.11	--	182.00	0.25	0.79	--	NC
SS3A007-562	0.85	0.05	0.11	--	5.50	0.09	0.70	--	NC
SS504-692	0.86	0.05	0.06	--	6.07	0.09	0.19	--	0.79
SB3D001-2476-1.0	0.87	0.03	0.10	--	5.63	0.06	0.66	--	NC
SS3B003-576	0.89	0.05	0.12	--	7.91	0.09	1.05	--	0.71
SS3C007-590	0.90	0.02	0.13	--	2.50	0.04	0.36	--	0.75
SS-DRUM02-3372	1.02	0.02	0.12	--	2.54	0.04	0.32	--	NC
SS5A004-640	1.07	0.04	0.13	--	1.67	1.67	0.23	U	NC
SS8D003-2190	1.07	0.03	0.12	--	45.50	0.06	5.04	--	NC
SS3B011-2398	1.08	0.05	0.15	--	12.50	0.09	1.66	--	0.90
SS5A001-637	1.13	0.03	0.13	--	2.91	2.91	0.35	U	0.72
SB8D003-2233-0.75	1.16	0.08	0.10	--	44.50	0.15	0.45	--	NC
SS314-404	1.22	0.05	0.06	--	55.40	0.11	0.33	--	0.94
SS817-704	1.27	0.03	0.16	--	2.72	0.06	0.37	--	0.88
SS422-688	1.29	0.05	0.19	--	2.33	0.07	0.34	--	NC
SS414-051	1.92	0.03	0.06	J	1.64	0.05	0.21	--	NC
SS3D001-2414	2.23	0.05	0.22	--	19.30	0.10	2.14	--	0.78
SS3D002-2415	3.00	0.04	0.39	--	2.03	0.07	0.29	--	1.20
TB301-2811-01.0-029	4.88	0.05	0.50	--	17.40	0.10	2.00	--	0.87
SB8D016-2231-2.0	5.15	0.03	0.59	J	19.10	0.05	2.36	J	0.78
ERR = error NC= not calculated because uranium-234 < 2 pCi/g									
MDL = method detection limit Qual. = qualifier									

5.9.5 Conclusions

The graphical presentation of available data indicates that some small fraction of NFSS may be contaminated with fission products and, at one location, low levels of enriched uranium. Specifically, several elevated cesium-137 results were identified and one elevated enrichment estimate was identified. Based on this analysis, the sample locations identified in the table above should be evaluated more fully in the FS.

5.10 SITE-WIDE EXAMINATION OF NATURE AND EXTENT

This section examines the nature and extent of SRCs across the entire site. General trends are noted and described. Aspects of nature and extent that are specific to an EU or portion of the site are described in the sections that follow.

5.10.1 Occurrence and Distribution of SRCs

5.10.1.1 Soil

Over eight hundred surface and subsurface soil samples were collected within the 191-acre NFSS. As described in Tables 3-4, 3-6, and 3-7, most of the samples were collected from locations known or suspected of being impacted by past site activities. Gamma walkover surveys, which identified areas with elevated gamma radiation, guided the selection of the majority of the soil sample locations in order to fully characterize the radiological parameters present at the site. Since the majority of soil samples were collected from areas for which there was a reasonable expectation of finding concentrations of other parameters above background, the sampling scheme was largely biased to that end. General conclusions are:

- The occurrence and distribution of SRCs, and especially radiological SRCs, in soils are very erratic and uneven. Samples containing high concentrations of a given SRC are frequently located very near samples containing concentrations which are near or below background. Field gamma walkover data and analytical data samples support the conclusion that most of the elevated samples were collected from impacted areas that are small and isolated.
- Field screening indicated that the highest concentrations of radiological parameters are not spread through the soil matrix but rather appear to be associated with small individual chips or stones, apparently consisting of original waste residues.
- Radiological parameters and metals were more commonly found at concentrations above the background screening levels than were organic compounds.
- No direct evidence of USTs was found, though organic compounds were detected in some locations in the subsurface at concentrations above the background screening levels. Concrete structures were found in the subsurface near the southeast corner of Building 401 and these structures may have contained USTs. This conjecture was not verified.

5.10.1.2 Surface Water

Over fifty surface water samples were collected on the NFSS. General conclusions are:

- The majority of SRCs found in surface water were metals.
- Surface water samples in EUs 7 and 9 contained uranium isotopes at concentrations that exceeded background UTLs.
- Several samples contained radium-226 concentrations above the background screening level. The maximum concentration of radium-226 was found in sample SW701-292, collected from a small drainage ditch on the west side of the IWCS leading to the West Ditch on the Niagara-Mohawk property. The concentration in this sample was 3.66 pCi/L -- approximately 7.5 times greater than the background screening level. The radium-226 concentrations in the other samples were less than three times the background screening level.

- There is no evidence that radiological SRCs are migrating off-site in the surface water conveyed by the Central and West Ditches. Radionuclide concentrations at sampling locations near the northern border of the property do not exceed background UTLs; however, both dissolved and total metals were detected in surface water samples collected in the Central and West Ditches at the northern property boundary, indicating that metal SRCs are most likely migrating off-site at these two locations. None of the metal concentrations at these locations exceeded the background UTLs by factors greater than 10.
- Most of the surface water samples were collected from ephemeral streams. Only the Central Ditch and the West Ditch carry water off-site throughout the year.

5.10.1.3 Sediment

As previously discussed, over eighty sediment samples were collected on the NFSS; however, 49 of the samples were later reclassified as soil samples because they were collected from locations that are dry for much of the year. General conclusions are:

- Very few organic compounds were found in sediment samples at concentrations above the background UTLs.
- There is evidence that the past remedial action in the West Ditch was incomplete. A sediment sample, later reclassified to be a surface soil sample and collected in the Baker-Smith area from the side wall of the West Ditch, contained 230 pCi/g of thorium-230.
- There is no evidence that SRCs are migrating off-site in the sediment. However, radionuclides are present in sediment above the background UTLs at the northern property boundary in EU 5 at sampling location 735. Metals are also present above the background UTLs in sediment at the northern property boundary in EU 2 at sampling location 710.

5.10.1.4 Groundwater

Over two hundred groundwater samples were collected on the NFSS. Samples were collected from TWPs, permanent wells installed for this RI, and permanent wells previously installed by the DOE in the 1980's. General conclusions are:

- Several groundwater plumes of SRCs were found in the UWBZ. Most of these plumes are geographically associated with past site uses or activities. The areas at which the groundwater was most impacted by past site activities are:
 - Plumes with elevated concentrations of dissolved total uranium, boron, and chlorinated solvents (e.g. TCE and degradation products) were found in the acid area (EU 4).
 - Plumes with elevated concentrations of dissolved total uranium and boron were found around Building 401 (EU 12, 13 and 14).
 - A plume with elevated concentrations of dissolved total uranium was found near the former Baker-Smith area (EU 1 and 2).
 - A plume with elevated concentrations of dissolved total uranium was found along the western boundary of EU 7.

- A dissolved total uranium plume is present in the southwestern portion of EU 8 near former Building 423.
 - A dissolved total uranium groundwater plume is present in the southeastern portion of EU 8 in the area of former storehouse Buildings 420 and 421.
 - A plume of dissolved manganese was found in EU 3.
 - A bis(2-ethylhexyl)phthalate plume was found in EU 10 to the east of the IWCS.
 - Thorium-230 plumes were found to the north and south of the IWCS (EUs 7, 10 and 11) and to the north of the acid area in EU 4. Similar to the uranium plumes in these areas (discussed below), these plumes are likely the result of site activities prior to the construction of the IWCS.
- Plumes of dissolved uranium were found around the northern section of the IWCS and in the area south-southeast of the IWCS (EU 7, 10 and 11). These plumes are likely the result of site activities prior to the construction of the IWCS.

As mentioned in Section 1.5.2, the R-10 residues were stored unprotected on the surface of the soil north of Building 411. In 1980, several wells were installed in the saturated zones in the R-10 residue storage area (Battelle 1981) and groundwater sampled from these wells exhibited an average uranium concentration of 40.8 µg/L. This value is similar to total uranium concentrations presented in Figure 5-4. Although the clay cutoff wall was installed around the R-10 pile in 1982, residual contamination in the saturated zone outside the wall persists to the north and west of the original R-10 pile. In addition, localized areas of elevated activity ranging from 15,000 to 53,000 cpm (see Figure 3-4) were identified north of the IWCS during the gamma walkover survey. Leaching from these surface soils could be affecting wells in this area.

The *Comprehensive Characterization and Hazard Assessment of the DOE-Niagara Falls Storage Site* (Battelle 1981) reported contamination in the fire water reservoir, Building 409. Contamination inside the building was attributed to water seepage through the south wall from the earthen berm surrounding the reservoir. Low-level soil contamination south of Building 409 was listed as the probable source of building contamination. In addition, in 1985 as the K-65 residues were being transferred to Building 411 from the tower, Building 409 was used as a settling tank in the treatment of slurry water. According to unpublished construction reports, treated slurry water from various bays in Building 411 was pumped to Building 409 for additional settling prior to being pumped to Ponds 3 and 4. Building 409 underwent a gross decontamination operation using a high pressure wash in October 1985 after removal of the 'yellow cake' that had accumulated during its use as an intermediate settling basin. This information suggests that there is a strong potential for the residual groundwater contamination present south of the IWCS to be associated with these historical operations.

- The UWBZ has a very erratic piezometric surface. The depth to groundwater across the site varies greatly and to a large degree is a function of the presence or absence of sand lenses in the subsurface. Figure 5-16 shows the piezometric surface of the UWBZ.
- The hydraulic conductivity in the upper water bearing zone varies greatly across the site. In wells that did not intersect large sand lenses, the hydraulic conductivities are on the order of 10^{-7} cm/sec or less. Table 5-1 summarizes the hydraulic conductivities at the site.

- No plumes were identified in the LWBZ; however, their absence does not necessarily mean that no SRCs were identified in the LWBZ. Several dissolved metal SRCs were identified in the LWBZ, with 55% and 85% of the exceedances reported at concentrations less than 2 and 5 times the UTL, respectively. Dissolved radiological SRCs (thorium-228, thorium-230, and radium-228) were identified in four wells at concentrations less than 1.5 times their respective UTLs. For the purposes of this RI, plume maps were generated for those constituents whose dissolved concentrations exceeded the UTLs in two or more spatially adjacent groundwater samples. The exceedances mentioned above were often isolated hits or, in some cases, spatially adjacent hits where one or more of the concentrations were just above the UTL. The occurrence of such sample results did not warrant identification of a groundwater plume.
- Based on current data, there is a potential that a dissolved total uranium plume extends off site north of EU 1.

5.10.1.5 Pipelines and Subsurface Utilities

SRCs were found in water and sediment samples collected from many locations along the pipelines and subsurface utilities at the NFSS. Most of the samples containing elevated concentrations of SRCs were collected in the following areas on the NFSS:

- Acid Area – EU 4. The SRCs were predominately PAHs, VOCs and SVOCs.
- Building 401 – EU 13. A broad spectrum of SRCs was found, chiefly in the floor drains inside Building 401 itself, though elevated SRCs were also found in the sewer systems servicing the building. The SRCs were predominately metals, PCBs, and pesticides.
- East and Southeast of the IWCS - EU 10 and 11. The SRCs were predominately uranium and thorium isotopes.
- Shops Area – EU 8. PAHs were present in sediment samples collected from the sanitary sewers, but not in water samples. Radiological parameters were detected in several sanitary sewer water samples. Uranium isotopes were commonly found in pipeline sediment samples.

5.10.1.6 Railroad Ballast and Pavement Samples

Five samples of railroad ballast were collected, crushed, and submitted for radiological analysis. The ballast at the site appeared to be a slag material. “Slag” is a generic term for rock-like material which is a byproduct of iron smelting and steel manufacturing. In the past, slag was frequently recycled as a construction material and this practice is still common today. No suitable background values were available for comparison with the site samples. Concerning the content of radiological materials in slag, the EPA has stated the following:

It is generally believed by geologists that the level of Naturally Occurring Radioactive Materials (NORM) found in ores (and slag) depends more on the geologic formation or region rather than on the particular type of mineral being mined. These ores often contain many different minerals, and the radionuclide content of one type of ore or mining operation or its wastes will not be representative of other mines or waste types [*Diffuse NORM Waste - Waste Characterization and Preliminary Risk Assessment* (EPA 1993)].

An evaluation of the railroad ballast data leads to the following general conclusions:

- The concentrations of cesium-137 and the thorium isotopes are below the background screening values for soil.
- The concentrations of uranium-234 and uranium-238 exceed the soil background screening values by a factor of two to three which puts them in the 3 to 6 pCi/g range. The total uranium concentrations in the ballast samples are between two and seven times greater than the background screening value for soil. Leaching of railroad ballast affected two background groundwater samples that were subsequently removed from the groundwater background data set (see Section 4.4.1).
- There appears to be a slight spatial correlation between elevated radium-226 concentrations in surface soils and the locations of railroad beds. Four of the five ballast samples had radium-226 concentrations that exceeded the surface soil background screening value for this isotope (maximum detection of 5.13 pCi/g radium-226). Surface soil samples collected from near railroad beds also typically exceeded the background screening value. During the collection of the surface soil samples, large stones (including pieces of slag) were excluded from the samples. This suggests that the radium-226 in the slag may be slightly mobile in the environment. There does not appear to be a similar correlation between railroad beds and isotopic uranium concentrations in surface soils.

Nineteen core samples were collected from roadways on the site. These cores were crushed and homogenized and then submitted for radiological analysis. As with the railroad ballast, no suitable background dataset was available to determine SRCs in this media. An evaluation of the data leads to the following conclusions:

- There is a wide range in reported values for radium-226, thorium-230, uranium-234, and uranium-238 and some of the sample results for these isotopes are much higher than the soil background screening values. The high relative concentrations and the wide reported range of concentrations suggest that the concentrations of some of these isotopes are higher than background as a result of past activities.
- The ranges in reported values for thorium-228, thorium-232, and uranium-235 concentrations are much less (and the values tend to be lower), indicating that these isotopes are less likely to be higher than background as a result of past site activities.
- In samples containing radium-226, thorium-230, uranium-234 or uranium-238, the relative concentrations of these isotopes in each sample varies significantly. For example, sample RC19-2450 has radium-226 and thorium-230 concentrations of 24.1 pCi/g and 25.9 pCi/g, respectively, resulting in a ratio of 0.93. In sample RC17-2448, the concentrations of these two isotopes are 32 pCi/g and 2.52 pCi/g, respectively, resulting in a ratio of 12.7:1. These results suggest that different waste streams have impacted these two samples.
- The samples with the greatest concentrations of radium-226, thorium-230, uranium-234, and uranium-238 are widely scattered on the site, with no apparent geographical correlation. A sample from EU 4 had the highest uranium-238 and 234 activities at 13.6 to 14.4 pCi/g with the thorium-230 activity at 14 pCi/g and radium-226 activity of 11.7 pCi/g. The highest activities occurred in one sample from EU 6 on O Street where

the radium-226 activity was 129 pCi/g and the thorium-230 activity was 34.4 pCi/g. In this same sample the uranium-234 and 238 activities were 8.9 and 9.9 pCi/g, respectively.

5.10.2 Media Interactions

Because of past remedial actions at the site, there is little correlation between the concentrations of SRCs in surface soils as compared to the concentrations found in groundwater. The past remedial activities evidently removed most of the impacted surface soils that were formerly present. However, none of the previous remedial activities addressed groundwater and there is evidence that plumes are still present.

The situation is very different for the interaction between the subsurface pipelines and the groundwater plumes found at the site. Pipelines or sewers are present in the three main areas with impacted groundwater. Analytical results for samples collected from those sewers and pipelines suggest that the sewers themselves may have been contributors to the plumes. In some cases, the sewers and pipelines may still be contributing to the plumes. Also, in some cases the sewers and pipelines may be acting as preferential flow pathways, influencing the movement and shape of the plumes.

Based on sampling conducted on the Niagara-Mohawk property and in EU 10, it appears that contaminated surface soil on the NFSS could be a potential historical source of constituents detected in sediment and surface water in the West Ditch.

5.10.3 Sources and Effects of Past Site Use

Evidence of adverse impacts was found over much of the site. In general, this evidence consists of elevated concentrations of radiological parameters, though organic parameters were also elevated in some locations.

6.0 FATE AND TRANSPORT

6.1 INTRODUCTION

This section discusses the fate and transport of the constituents that have been identified as SRCs in Section 5 and as COCs in the BRA. Constituent transport was assessed using current analytical results in conjunction with a general understanding of site topography, and surface and subsurface features (i.e., ditches, utilities, sand lenses, etc.) Results of SESOIL modeling conducted to support the BRA, and the results of a groundwater model, are also discussed. Both the Groundwater Modeling Report and the BRA are presented under separate cover, but are a component of the NFSS comprehensive RI.

For the purpose of reporting future impacts to groundwater in this section, 1,000-year model simulations are discussed in most detail, although model simulations were performed for a 10,000-year timeframe. USACE conducted a preliminary evaluation of potential Applicable or Relevant and Appropriate Requirements (ARAR) that may provide the statutory basis for managing the NFSS wastes (SAIC 2003a). ARARs under consideration for NFSS include 10 CFR Part 40 Appendix A and 40 CFR Part 192 Subparts A, B, and C. Both potential ARARs require remedial measures to be effective for up to 1,000 years to the extent reasonably achievable, and in any case, for at least 200 years.

All constituents in soil, sediment, surface water and groundwater are subject to a number of processes that can effect their migration. Many constituents are subject to adsorption onto soil particles which can delay migration by varying amounts depending on the constituent in question and the composition of the soil. Water movement through soil and sediment may leach constituents which then either move to groundwater or are adsorbed further down in the soil column. Organic chemicals may be degraded either chemically or biologically and radioactive decay may impact some short-lived radionuclides within our 1,000 year timeframe. Volatile organics may evaporate and some short-lived radionuclides, such as radon isotopes present at the NFSS, are gases. Both the gases and organic vapors may dissipate in air. The following paragraphs discuss degradation in more detail.

Organic compounds present in the environment will in the long-term reduce to elemental forms (e.g., carbon, hydrogen, and oxygen) with exposure to water, air, bacteria, soil, or sunlight. Persistence of organic constituents in the environment is related to resistance to degradation. The rate of degradation is presented in half-lives, which represent the amount of time necessary to reduce half the quantity of the constituent. The half-lives presented in this report are based on estimated times of degradation from readily available data. Tables 6-1 through 6-3 show available data on half-lives, solubilities, distribution coefficients (K_d), and partitioning coefficients (K_{oc}) for several representative constituents from the NFSS that were reported above screening criteria in this RI report.

Compounds in soil are degraded predominantly by biodegradation and secondarily by hydrolysis. Compounds in groundwater are degraded principally by biodegradation and, to a lesser extent, hydrolysis. Generally, biodegradation in groundwater proceeds at a slower rate compared to surface water, because groundwater microbial populations may be limited in numbers and enzymatic capabilities.

The main transport processes in groundwater include advection and hydrodynamic dispersion. Other reactions that affect constituent mobility and fate include chemical and biological processes. The major categories are acid-base reactions, solution, volatilization, precipitation, complexation, sorption reactions, oxidation-reduction reactions, hydrolysis reactions, and isotopic

reactions. Fate and transport mechanisms are more fully discussed in the document, *Groundwater Flow and Contaminant Transport Modeling, Niagara Falls, Storage Site, Lewiston, New York* (HGL 2007).

VOCs easily dissolve into surface water. Heavier organic compounds, pesticides, SVOCs, PCB, and PAHs tend to adsorb to soil and degrade slowly, and tend not to dissolve into surface water. Typically, metals adhere to soil via physical adsorption, oxidation to hydrous oxide compounds, and formation of insoluble organic complexes. The transport of metal and adsorbed heavier organic constituents (e.g., PAHs, pesticides) adhered to soil and sediment may occur during surface runoff events.

The shallow groundwater in the area of the NFSS has local anaerobic zones that provide the potential for biodegradation of chlorinated compounds. Heavier organic compounds tend to adsorb to soil with slow migration in groundwater. The transport of most of the metal constituents in groundwater is likely to be minimal considering the common aerobic and nearly neutral pH conditions, as well as the high potential for adsorption and precipitation. Specific degradation characteristics of VOCs, SVOCs, PAHs, PCBs, pesticides, and metals are discussed briefly in the following paragraphs.

VOCs

The transport process for VOCs with exposure to the atmosphere is volatilization. VOCs may dissolve in groundwater. Secondary processes may occur, such as biological and chemical degradation. The VOCs detected at the NFSS mainly include acetone, 2-butanone, BTEX, methylene chloride, and chlorinated compounds such as PCE, TCE, cis-1,2-DCE, trans-1,2-DCE and vinyl chloride. VOC groundwater plumes are present in EU 4; however, several VOCs were also commonly detected in other media.

Acetone was widely detected in surface and subsurface soil throughout the NFSS, but is also present in groundwater in EUs 4 and 10, and in sediment and water in pipelines and utilities. 2-Butanone was widely detected in groundwater in several EUs and in surface and subsurface soil throughout the NFSS. It is also present in sediment and water in pipelines and utilities. Both acetone and 2-butanone are soluble in water and have a high vapor pressure. The short half-lives of acetone and 2-butanone are reflective of their tendency to quickly degrade in the atmosphere and to biodegrade easily. It should be noted that acetone and 2-butanone are common laboratory contaminants and detections of these two constituents at the NFSS are generally only slightly above the background UTL. Analytical data indicating the presence of acetone and 2-butanone in various media were reviewed and accepted during the data verification process. Although widely detected, acetone and 2-butanone were not identified as COCs in the BRA and are thus not considered to be a migration concern.

Toluene was the most commonly detected BTEX (benzene, toluene, ethylbenzene, xylenes) parameter detected at the NFSS. These parameters were mainly detected in surface and subsurface soils throughout the NFSS, but were also detected in sediment and water in pipelines and utilities. BTEX parameters have moderate vapor pressures and tend to volatilize. The moderate half-lives of these compounds are reflective of their moderate biodegradation potential, especially under aerobic conditions. BTEX parameters may be present due to the use and storage of fuel at the NFSS. For example, toluene was detected at depth near an area in EU 3 known to once contain fuel storage tanks. This may be indicative of residual soil contamination related to the former tanks or vertical migration of parameters through the soil column.

Chlorinated compounds were mainly detected in groundwater in EUs 4, 8, and 13, but were also detected throughout the NFSS in surface and subsurface soil, and in pipeline sediment and water. Chlorinated compounds (methylene chloride, PCE, TCE, cis-1,2-DCE, trans-1,2-DCE and vinyl chloride) are commonly present in industrial solvents and have a moderate solubility, vapor

pressure, and biodegradation potential. They degrade most efficiently under anaerobic conditions. Methylene chloride and vinyl chloride have the highest vapor pressures and shortest half-lives of these compounds (on the order of weeks to months). Methane, a biodegradation indicator parameter, was detected in groundwater in EU 4 along with TCE/PCE degradation products; therefore, it appears that biodegradation is occurring. Additionally, the presence of VOCs in various media at the NFSS suggests a connection between pipelines, groundwater, and soil.

SVOCs

Bis(2-ethylhexyl)phthalate, 2-methylnaphthalene, carbazole, dibenzofuran, di-n-octylphthalate, and phenol were the most commonly detected SVOCs in various media at the NFSS. Bis(2-ethylhexyl)phthalate was detected in all media in almost every EU. SVOCs generally adsorb more readily to soil and have lower solubilities compared to VOCs, with the exception of the non-chlorinated phenolic compounds. Surface transport of SVOCs bound to soil can occur through soil erosion by runoff or dust generation by wind erosion. However, no SVOCs were detected in surface water at the NFSS; therefore, erosion by surface runoff does not appear to be occurring. Erosion by wind is also not likely because of the presence of vegetation across most of the site.

Based on the SESOIL modeling as presented in Appendix E of the BRA (SAIC 2007), carbazole is the only SVOC identified as a migration chemical of potential concern (mCOPC) in EU 8. However, due to its low concentration and relatively high distribution coefficient, it is not a migration concern.

PAHs

PAHs were commonly detected in surface and subsurface soil throughout the NFSS, and in sediment and water in pipelines and utilities. PAHs were detected far less frequently in groundwater. These compounds are typically persistent in the environment due to low solubilities and high partition and sorption coefficients (Table 6-1). PAH half-lives can be extended by sorption to organic carbon. Consequently, the ultimate fate of these compounds is most likely sorption to soil, followed by slow biodegradation. Surface transport can occur through soil erosion by runoff or dust generation by wind erosion. Analytical data in EU 8 indicate that PAHs present in surface soil may be migrating to surface water. Erosion by wind is not likely because of the presence of vegetation across most of the site.

Based on the SESOIL modeling as presented in Appendix E of the BRA (SAIC 2007), PAHs are identified as mCOPCs in EUs 2, 8, and 11. However, due to their low solubilities and relatively high distribution coefficients, these compounds did not migrate to groundwater based on the modeling results.

Pesticides

Dieldrin, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT were the most commonly detected pesticides in surface soil, subsurface soil, groundwater, and pipeline sediment and water throughout the NFSS. Pesticides are persistent compounds that readily adsorb to soil and tend not to leach to groundwater; however, it is possible that pesticides can eventually leach into groundwater or surface water. Pesticides contain low vapor pressures and low solubilities, relatively high octanol-water partition coefficients, high soil-water partition coefficients, and high soil adsorption coefficients. These compounds strongly partition from water into particulate and organic matter; therefore, there is a low potential for groundwater transport of these pesticides. Consequently, the ultimate fate is most likely sorption to soil, followed by slow biodegradation.

Pesticides were detected in sediment from Building 401 drain samples and in groundwater in EU 13; therefore, a connection between the drains and groundwater appears to exist. Pesticides were also detected in groundwater in EU 10, likely as a result of continued maintenance of the IWCS cap. Runoff from the IWCS cap may have reached groundwater in nearby wells where

sand lenses are present within the clay and silt. Detections of pesticides in wells near the cap are generally less than three times the background UTL.

PCBs

Aroclors-1254 and -1260 were commonly detected in surface soil, subsurface soil, and pipeline sediment across the NFSS. PCBs strongly adsorb to soil with negligible leaching to groundwater. Transport of PCBs may occur through surface erosion of impacted soil by runoff or wind. However, this does not appear to be occurring at the NFSS.

Metals

Due to the complexity of the chemistry of metals in soil and water, considering their various oxidation states and mechanisms for adsorption and precipitation, a complete understanding of the specific metal mobility and chemistry is well beyond the scope of this RI.

In general, the distribution or sorption coefficient of a metal is an indicator of the relative affinity of a metal to solids and, therefore, its immobility. Distribution coefficients for selected metals estimated from laboratory studies (ORNL 2001) are presented in Table 6-2. Factors controlling the metals transport process include the soil-water chemistry and the charge deficiency on adsorbent surfaces (i.e., soil or sediment). Specific factors such as soil texture, soil chemistry, pH, redox potential, and solute and ligand concentrations in pore water further control the mobility of a particular metal species. In general, the solubility of metals tends to increase with increasing acidity, and conversely, lower mobility under neutral and slightly alkaline conditions.

Chemical processes for metals include ion exchange, organic complexation, precipitation and co-precipitation, solid-state diffusion, and isomorphic substitution. Organic compounds can be formed with metals in soil, such as methyl-mercury. Metals may also sorb to sediment via interaction with the organic matter or clay particles to form stable complexes that are relatively insoluble in water. Colloidal transport of metals may also occur.

Many of the metals detected in surface water and sediment at the NFSS are essential nutrients (calcium, magnesium, potassium, and sodium) and metals commonly present in soil (aluminum, iron, and selenium). However, some metals potentially related to site operations (arsenic, barium, boron, lead, and zinc) were detected in surface water. Boron was detected in Building 401 drain samples and is the likely source of the boron plume in EU 13.

Radionuclides

The most common radionuclides that exceeded background UTLs in various media at the NFSS include isotopes of uranium (234, 235, and 238), radium (226 and 228), thorium (228, 230, and 232), and cesium-137. Radionuclides that exceeded background UTLs far less frequently include actinium-227, americium-241, cobalt-60, plutonium-239/240, protactinium-231, and strontium-90. Table 6-3 provides chemical properties for several radionuclides.

Radium-226 is a naturally occurring isotope that is a daughter product in the decay series of uranium-238 to lead-206. The aqueous chemistry of radium is similar to barium, strontium, and calcium (Fetter 1993). It is more soluble than uranium or thorium and can be bioconcentrated by plants. Radium can be strongly exchanged through cation exchange.

Thorium is naturally occurring and typically has a very low solubility. The mobility of thorium increases through complexation with organic compounds. Adsorption of dissolved thorium increases with increasing pH. The sorption of thorium onto clays, oxides and soil organic matter is nearly total at a pH of 6.5 or higher (Fetter 1993). Based on a brief review of well monitoring logs

(Appendix U), typical values of pH for groundwater at the NFSS range from approximately 6 to 8. Therefore, it is likely that thorium has a high sorption rate in the subsurface at the NFSS.

Uranium occurs primarily as uranium-238. The decay series of uranium-238 ends with lead-206, a stable isotope. The chemistry of dissolved uranium is complex. Uranium occurs in three valence states and undergoes oxidation-reduction reactions. It forms soluble complexes with a wide variety of anions, including fluoride, phosphate, carbonate, hydroxide and sulfate. Under reducing conditions, uraninite, a solid uranium oxide compound, may form, which would remove uranium from solution (Fetter 1993). Migration of uranium, one of the principal contaminants at NFSS, is discussed more fully in subsequent sections.

6.2 SOIL

The presence of constituents in soil identified as SRCs is documented in Section 5. These constituents are, as is discussed in the groundwater fate and transport section (Section 6.5), subject to a number of processes that can affect their movement in the environment. The primary processes impacting the movement of constituents in soil are leaching and adsorption.

Large numbers of surface soil samples discussed in Section 5 contain SRCs exceeding their respective background UTLs. Few of these constituents are found in soils below 2 feet; however, in EUs 1, 2, 4, 5, 7, 8, 10, 11, 12 and 13 SRCs above background UTLs are found at depths greater than 10 feet bgs. Due to the nature of historical operations at NFSS, i.e., several previous remedial actions were conducted (see Section 1.5.3), the presence of SRCs at depth cannot solely be attributed to leaching. In fact, contaminants are often found randomly at depth with little or no corresponding surface contamination.

SESOIL modeling was conducted in the BRA (SAIC 2007) to predict the migration of contaminants in the vadose zone to groundwater. The timing of the maximum predicted radionuclide concentration in leachate, at the water table, derived from the SESOIL runs, varies among the EUs. Of the radionuclides modeled, those that migrate most quickly reach their maximum predicted leachate concentrations within 35 to 194 years. These include uranium-234, uranium-235 and uranium-238. Based on the modeling, uranium is predicted to leach to groundwater in all EUs. This leaching is directly dependent on the conservative (i.e., low) K_d value used in the modeling. Some radionuclides including radium-226, radium-228, thorium-230, and actinium-227 do not reach predicted maximum concentrations until well after the 1,000 year modeling timeframe due to soil partitioning. Boron is predicted to move faster than the radionuclides and may have peak leachate concentrations in 20 years while methylene chloride is predicted to migrate even faster and may have peak leachate concentrations in as little as 5 years. The PAH compounds are not predicted to migrate to groundwater.

As mentioned earlier, the organic compounds found in soil are not only subject to leaching but are also subject to degradation by chemical and bacteriological processes in soil. These processes act over many years and the rates depend on the soil conditions. It is documented in Section 5 that organic compounds are present in soil depths greater than 2 feet in EUs 4 and 13. The organics in these EUs are present in the UWBZ. In addition, the methylene chloride present in the vadose zone in EUs 4, 8, and 13 is predicted to continue to leach to the groundwater, based on SESOIL modeling.

Surface soils contain constituents that may be entrained by surface water and moved into the sedimentary media; however, the site is heavily vegetated and erosion in most areas is highly unlikely. The heavy vegetation also makes the airborne dispersal of surface soil constituents

unlikely; however, direct release of gases and resuspension of particulates from surface soil can promote transport of gaseous and organic contaminants via air emissions. Radon-222 is generated by the radioactive decay of radium-226 in the K-65 and metal oxide residues; therefore the IWCS is regularly monitored for radon emissions. The site also has a monitoring program for gamma radiation exposure. Monitoring results are reviewed upon receipt and if any results ever indicate a concern, they will be immediately addressed. The results of this monitoring are reported annually to the public.

Surface soil constituents may be transported by runoff to surface water. The heavy vegetation and the low rates of water infiltration at the site, documented in Section 6.5, may inhibit this process. However, there is evidence that uranium and radium isotopes may have migrated to surface water in the West Ditch, although the timeframe for this migration cannot be determined. The West Ditch was remediated in 1983 (BNI 1990) prior to construction of the IWCS. The sediment and surface water contaminants identified in the West Ditch could be a result of IWCS construction activities rather than current ongoing migration.

6.3 SEDIMENTS

In general, the sediments and their associated SRCs can be expected to move downstream and eventually exit the site to the north due to northerly surface water flow. As the sediments travel, some dilution of the concentrations of these SRCs is to be expected unless there is additional input from surface soil. Some of the sediments are in ponded areas where flow is minimal, and there they can be expected to remain. If the sediments remain in the ponded area there is an increased potential for SRCs to leach to groundwater or to migrate to deeper soils. Volatile organics in sediments have the potential to migrate to soil or groundwater, or to volatilize into the air or be leached by surface water.

Sediments on the site contain metals, radionuclides and VOCs above their respective background UTLs. Some sediments containing SRCs at concentrations slightly above background UTLs could migrate offsite through the ditches, though the RI data show little evidence that this is occurring. The sample closest to the site boundary in the Central Ditch (EU 2) has one metal above its background UTL. A sample in the swale leading north and offsite from EU 5 contained cesium-137 above its background UTL and uranium-238 at its background UTL. Two samples in EU 9 are only slightly above their UTLs for radium-228 and thorium-228.

The BRA (SAIC 2007) indicates that no sediment constituents from the interconnected drainage ways (EU 15) become COCs or ROCs due to the short duration of exposure for individuals who may come in contact with sediment at NFSS. However, because several metals in sediment have the potential to pose ecological risk and the potential for offsite migration exists, further evaluation in the FS of sediment SRCs is recommended. In addition, the site does have an annual monitoring program for sediments (see Section 2) which includes the Central Ditch at the point where it exits the site. Monitoring results are reviewed upon receipt and if any results ever indicate a concern, they will be immediately addressed. The results of this monitoring are reported annually to the public.

6.4 SURFACE WATER

The interconnected drainage ways and ditches contain surface water. The surface water at the site was measured for both total and dissolved metals and radionuclides as well as other constituents. As discussed in Section 5, dissolved metal SRCs are frequently found above their respective background UTLs in surface water. VOCs and SVOCs are also found in surface water.

Those constituents in ponded water may adsorb to soil or eventually infiltrate to groundwater while those in flowing water are more likely to flow downstream than to migrate to soil or sediments. However, if the concentration of a constituent in surface water is fairly consistent it can infiltrate into soil and eventually into groundwater.

As measured in the most northerly surface water sample in the Central Ditch, dissolved metals greater than background UTLs are migrating off site to the north in surface water. Thirteen total metals and 4 dissolved metals exceeding their background UTLs were measured in that sample; however, none of the results except for dissolved silver was more than 5 times the background UTL. The BRA (SAIC 2007) indicates that no surface water constituents from the interconnected drainage ways (EU 15) become COCs or ROCs due to the short duration of exposure for individuals who may come in contact with surface water at NFSS. However, because metals above background concentrations have the potential to migrate offsite, further evaluation in the FS is recommended. In addition, the site does have an annual monitoring program for surface water (see Section 2) which includes the Central Ditch at the point where it exits the site. Monitoring results are reviewed upon receipt and if any results ever indicate a concern, they will be immediately addressed. The results of this monitoring are reported annually to the public.

6.5 UTILITIES AND PIPELINES

Both water and soil/sediment samples were taken from the many pipelines and buried utilities on the site. These samples are unique in a way since there is the chance for water or sediment to migrate along the pipe or in the coarse fill around the pipes. This migration along pipes is evidenced by the presence of a uranium plume along the water line crossing the SE corner of EU 10 (Figure 5-4). The potential exists for SRCs to migrate along the pipelines, particularly the storm sewer lines, until they intersect a drainage ditch or the water table. There is also the possibility that some of these will leach to groundwater. The potential exists for broken pipes, allowing infiltration by groundwater. Many of the pipes are below at least the seasonal high water table making the migration into and out of the pipes possible.

Other areas on site where migration of constituents along the pipelines may be occurring are EU 4 and 13. Boron and VOC groundwater plumes identified in these EUs include water samples from manholes. As explained below, several other constituents were found in pipeline media at concentrations above background.

For the construction worker, the BRA (SAIC 2007) indicates that one PCB (Aroclor-1254) is a COC in pipeline sediment and pipeline water. None of the other SRCs in pipeline sediment and water were determined to pose risks sufficient to be identified as COCs or ROCs. No COCs or ROCs were identified for the subsistence farmer scenario primarily because the risk analysis assumes no exposure to the sediments or water within the pipelines. The construction worker scenario assumes a fairly short (1 day/week for 1 year) exposure to pipeline media and therefore, high levels of contaminants must be present in order to pose significant risk. Even with full-time outdoor occupancy and exposure duration by the construction worker, consistent with assumptions used for LOOW pipeline exposures, risk levels were still within the acceptable risk range and no additional COCs or ROCs were identified.

As seen in Figures 4-22 through 4-24, pipeline surface water and sediment samples consistently exceed background UTLs for most classes of compounds (metals, SVOCs, radionuclides, etc.) in every EU that contains pipelines. In many cases, the exceedances range from 1 to 20 times the background UTL. The following bullets summarize the instances where SRCs are present in

pipeline media at high concentrations and have the potential to migrate or where data suggests a connection between pipelines and groundwater already exists.

- EU 4: PAHs, pesticides, VOCs (especially PCE, TCE, cis-1,2-dichloroethene, and methylene chloride), SVOCs,
- EU 13: Metals (especially boron and mercury), PCBs (aroclor-1254 and -1260), pesticides,
- EUs 10 and 11: Uranium and thorium isotopes, and
- EU 8: PAHs and uranium isotopes.

6.6 GROUNDWATER

The migration of constituents to groundwater and their movement over time is complex and is often evaluated using groundwater models developed to simulate these processes. A computer model was developed as part of the RI process and is described in detail in the *Draft Groundwater Flow and Contaminant Transport Modeling Report* (HGL 2007). Results of the modeling are summarized here. The report should be consulted for greater detail. In addition to the modeling, which addresses the long term fate and transport of constituents in groundwater, the site groundwater is monitored annually (see Section 2) to determine if there are any issues that need to be addressed. The results of this monitoring are reported annually to the public.

A multi-step process was used to simulate source releases and unsaturated zone transport, within the IWCS, and elsewhere on the NFSS. This approach used separate modeling codes to estimate the water flux through the IWCS and to predict vertical transport of contaminants through the unsaturated zone outside of the IWCS. Collectively, the modeling tools were used to predict the long-term rates of contaminant mass-loading to the water table over the entire NFSS site. Predicted mass-loading rates were assigned as time-varying source terms in the NFSS 3-D transport model. The 3-D model was subsequently used to simulate the transport of the contaminants within the saturated zone.

6.6.1 Model Inputs

The inputs to the models included information from a number of sources. The site conceptual model, which is briefly described in Section 2 and in more detail in the modeling report, details the stratigraphy, geology and hydrology of the NFSS site along with information from various reports on the residues and the construction of the IWCS.

Three “source terms” were used to represent initial conditions in the model:

1. The results of Hydrologic Evaluation of Landfill Performance (HELP; Schroeder et al. 1994) and one dimensional (1-D) MODFLOW-SURFACT modeling. The HELP model and 1-D model were applied to the IWCS and estimated vertical transport of contaminants assuming IWCS contents (residues, contaminated soils, and other materials) were unsaturated..

2. The results of SESOIL modeling. The SESOIL model results represent estimated leachate concentrations predicted to reach the UWBZ within the 1,000-year timeframe considered in the RI/FS.
3. The existing plume maps. As presented in Section 5, the plume maps identify limited areas onsite where current concentrations of constituents exist in groundwater above the background UTLs or MCLs, as appropriate.

Water flux through various waste zones in the IWCS was estimated using the HELP model, which is specifically designed to conduct water balance analyses of waste containment facilities like the IWCS. Application of the HELP model provided an estimate of the water flux through the IWCS, based on known waste zone layering, engineering design parameters and pertinent information regarding vegetation, precipitation, cover soils and other variables impacting flow through the system.

Flow rates through the IWCS predicted by the HELP model were input into a MODFLOW-SURFACT 1-D transport model, which was applied to predict the vertical movement of contaminants through the unsaturated zone to the water table. The MODFLOW-SURFACT model accounts for dispersion, sorption, degradation and in the case of radionuclides, radioactive decay and the transport of both radioactive parent and daughter products. The model simulates the release of contaminants from sources within the unsaturated zone and the transport of these contaminants to the water table. Where concentrations were known to be in excess of solubility limits, the MODFLOW-SURFACT solubility-limited simulation option was invoked to account for continuous dissolution of contaminants present in a non-aqueous phase.

The SESOIL (Bonazountas and Wagner 1981 and 1984; Hetrick, Scott, and Barden 1993) model was applied to predict the contaminant flux to the water table from specific areas of soil contamination outside the IWCS. SESOIL is a 1-D vertical transport model for unsaturated soil zones for use in determining solute distribution in soil profiles. The SESOIL model was input with representative soil concentrations for each of the 14 terrestrial EUs on the NFSS. These representative concentrations were developed using an aggregate data set consisting of soil, sediment, and manhole sediment sample results from each EU. Only samples from the vadose zone, which varies across the site, were considered in the SESOIL model. Representative concentrations (i.e., exposure point concentrations) were calculated and compared against a generic soil screening level, which was refined using a dilution attenuation factor of 20. Those constituents with the potential to leach to the water table at unacceptable concentrations were then modeled in SESOIL.

The SESOIL model results provided a time-varying source term for each EU that is representative of concentrations at the water table derived from the leaching of contaminants in soil. Because the SESOIL modeling was done for the BRA, the infiltration rates used in the groundwater model differed from those used in SESOIL; therefore, adjustments were made to the contaminant flux for each constituent before it was input to the groundwater transport model. Only constituents estimated to leach to groundwater within 1,000 years were input as sources to the 3-D transport model.

As previously discussed in Section 5, a groundwater plume was defined to be a group of wells or groundwater samples in proximity to each other which exhibited groundwater concentrations of a given SRC that exceeded the associated background screening level, or MCL, as appropriate. Where appropriate, plume extent also considered water results taken from manholes. For metal and radionuclide SRCs, both total and dissolved concentrations were considered when evaluating

the existence of any given groundwater plume. However, only the dissolved concentrations were used to define isoconcentrations (i.e., the shape and extent of the plumes) used in the groundwater model.

Additional details on the HELP, 1-D MODFLOW-SURFACT and 3-D transport model setup and application are provided in the *Draft Groundwater Flow and Contaminant Transport Modeling Report* (HGL 2007). Details of the SESOIL model approach and methodology are summarized in the NFSS BRA (SAIC 2007).

6.6.2 Model Results

The modeling report describes model results under baseline conditions and four failure scenarios. However, this RI report focuses on the baseline condition only. Table 6.4 summarizes the results of the 3-D groundwater flow and transport model for the uranium (uranium-238) decay series, actinium (uranium-235) decay series, and thorium (thorium-232) decay series. Table 6.5 summarizes results of the 3-D groundwater flow and transport model for metals, VOCs, and SVOCs. These tables provide the site-wide maximum concentration for each radionuclide or chemical constituent for each model layer at three time references: (1) the first time the radionuclide/constituent is detected above the screening level to identify short term concerns, (2) at 1,000 years to correspond to the potential ARAR timeframe to be evaluated in the FS, and (3) at 10,000 years. For chemical constituents, the maximum concentration is also provided for the first time that the constituent's concentration decreases to a level below the screening level, if applicable. Included on the table is a description of the NFSS site locations that correspond to the maximum concentrations for these time references. The model results presented in these tables are discussed in the following sections. The Model Report (HGL 2007) presents graphical representations of model simulations for constituent concentrations over time.

6.6.2.1 Radiological Constituents

Visual interpretations of groundwater fate and transport modeling results appear to indicate that offsite migration of radionuclides may occur at four site areas within a 1,000-year evaluation period. The four locations include the northwest corner of EU 1, the west side of EU 7, the east side of EU 8, and the south side of EU 11. To more accurately evaluate this potential offsite migration, groundwater modeling results using data obtained from the model post-processor were used to predict maximum uranium isotope concentrations at these four boundary locations within 1,000 years. Conclusions are summarized below; however, this data is discussed in detail in the BRA Report (SAIC 2007).

Based on model simulations, uranium isotopes are predicted to migrate offsite within 1,000 years in EUs 1 and 11 at concentrations that exceed screening and risk levels. Offsite migration in EUs 1 and 11 is the result of continued migration of existing groundwater contamination with additional contributions predicted from SESOIL modeling. Uranium isotope concentrations in the UWBZ on the boundaries of EUs 7 and 8 are expected to remain below screening and risk levels within the next 1,000 years. However, the conclusions made regarding the fate and transport of uranium isotopes in site groundwater are somewhat dependant on the conservative K_d value of 3.6 L/kg that was used in the modeling simulations. Use of this K_d value causes the model to predict greater concentrations of radionuclides in groundwater due to increased leaching of site soils.

Within 1,000 years, the maximum concentrations of uranium isotopes are predicted to occur in the Brown Clay Till beneath the IWCS, near Building 411 (see Table 6.4). Additionally, model results indicate that the screening levels for uranium-234 and uranium-235 will be exceeded in

even the deepest of the aquifers (the upper Queenston Formation) within 1,000 years. This is likely the result of potential leaching of residues within Building 411 in the IWCS. Other than the uranium-isotopes, thorium-230 is the only radionuclide that exceeds its screening level in the Brown Clay Till within 1,000 years, likely due to existing groundwater contamination in EU 7. However, thorium-230 is not expected to migrate below the Brown Clay Till within 1,000 years at concentrations that exceed the screening level.

All modeled radionuclides are predicted to exceed screening levels in the Brown Clay Till in 10,000 years. Of these constituents, only uranium isotopes and thorium-230 are predicted to migrate below the Glacio-Lacustrine Clay at concentrations that exceed screening levels, with the maximum concentrations of the isotopes being below the IWCS. Within 10,000 years, uranium isotopes are predicted to exceed screening levels in the Queenston Formation and thorium-230 is predicted to slightly exceed its screening level in the Alluvial Sand and Gravel. The rest of the daughter products do not approach their respective screening levels in any layer below the Glacio-Lacustrine Clay. Concentrations of actinium-227 and protactinium-231 in groundwater increase within each model layer up to 10,000 years due to ingrowth.

6.6.2.2 Metal Constituents

Seven metals (arsenic, barium, boron, iron, lead, molybdenum and manganese) present in residues within the IWCS were modeled using the HELP and 1-D model. For many of these metals, the baseline leachate concentrations are well below the background UTLs at 1,000 years. Groundwater modeling results indicate that there is only minor dispersion of these metals over 1,000 years due to minimal infiltration rates. Modeling predicts that these metals will not migrate offsite in groundwater at concentrations above screening levels in the vicinity of the IWCS.

The groundwater flow and transport model indicates that boron and manganese are the only two metals that exceed screening levels in groundwater within 1,000 years at the NFSS. The existing boron and manganese plumes in EUs 3, 4, and 13 also exhibit little dispersion over 1,000 years, and the maximum concentrations of these metals in groundwater are not expected to increase above the current concentrations of the plumes. Concentrations of boron and manganese that exceed the screening levels are not expected to migrate vertically below the base of the Brown Clay Till (i.e., to a depth of approximately 15 feet in EUs 3, 4, and 13).

Based on SESOIL modeling results, levels of cadmium in groundwater reach peak leachate concentrations in 6,000 years; however, this is beyond the timeframe evaluated in this RI.

6.6.2.3 Organic Constituents

A number of organic compounds are present in the groundwater outside the IWCS, including PCE, TCE, cis-1,2-DCE, vinyl chloride, bis(2-ethylhexyl)phthalate, and methylene chloride. PCE, TCE, cis-1,2-DCE, and vinyl chloride are all present within the same plume in EU 4. Groundwater modeling results indicate that only minor dispersion of this VOC plume occurs due to low infiltration rates. This plume is not predicted to migrate off-site. Concentrations of cis-1,2-DCE and vinyl chloride, degradation products of PCE and TCE, temporarily increase in groundwater during the 1,000 year time period due to biodegradation processes.

As biodegradation occurs, PCE and TCE concentrations gradually decline while degradation products (cis-1,2-DCE and vinyl chloride) increase slightly in the first 50 years. PCE, TCE, cis-1,2-DCE, and vinyl chloride are all expected to degrade to levels less than the screening values

within 300 years in the Brown Clay Till. However, these VOCs continue to migrate downward into the Glacio-Lacustrine Clay. TCE and vinyl chloride further migrate to the Alluvial Sand and Gravel and Queenston Formation in the first 150 years. Vinyl chloride is predicted to degrade to below screening levels by 200 years.

According to groundwater fate and transport modeling results, the bis(2-ethylhexyl)phthalate plume in EU 10 exhibits only minor dispersion and migration within the Brown Clay Till within 1,000 years, and the maximum concentration of this organic compound in groundwater is not expected to increase above the current concentrations of the plume. Vertical migration of this SVOC below the base of the Brown Clay Till at concentrations exceeding the screening level is not expected within 1,000 years or beyond.

SESOIL modeling results indicate that methylene chloride may leach to groundwater within 50 years; however, concentrations never exceed the screening level. Additionally, the groundwater fate and transport model indicates that concentrations of methylene chloride never exceed the screening level in groundwater.

6.6.3 Model Independent Review and Comparison

An independent review of the groundwater modeling results was performed using the RESRAD-OFFSITE computer code. This code is one of the RESRAD family of computer codes (Argonne 2001) that has been used at a number of FUSRAP sites. The hydrologic model in this computer code is not nearly as sophisticated as that developed for the NFSS as presented in the modeling report (HGL 2007), but has been shown to provide reasonable estimates of future radionuclide concentrations in groundwater. In addition, the radionuclide decay and ingrowth algorithms in RESRAD have been extensively reviewed and verified. This review was largely limited to radionuclides in the uranium-235 decay series, i.e., uranium-235, protactinium-231 and actinium-227, in Bay D of Building 411. This review focused on two aspects of the HGL groundwater model, radionuclide decay and ingrowth, and the general shape and magnitude of the radionuclide concentrations in groundwater beneath Bay D.

The HGL model clearly addresses radionuclide ingrowth and decay, as is evident in the predicted concentrations of protactinium-231 and actinium-227 in groundwater beneath Bay D. Since actinium-227 has a very short half-life of about 22 years, the concentration of this radionuclide would be essentially zero in several hundred years without accounting for ingrowth. But this is not what the HGL model indicates. Rather, the HGL groundwater model indicates that the actinium-227 is indeed present in groundwater at the end of the modeling period, i.e., 10,000 years in the future. In addition, the activity profiles through 10,000 years for several radionuclides in the uranium-238 decay series (i.e., radium-226 and lead-210, and thorium-230 and radium-226) as determined by the HGL model, were reviewed. The relative concentrations of these two pairs of radionuclides were consistent with expectations.

In comparing the results for the uranium-235 decay series in Bay D, a fairly close match was obtained between the HGL model and RESRAD-OFFSITE for uranium-235. The breakthrough curves had a similar shape, and the magnitude of the maximum concentrations differed by about a factor of 5. The predicted results by HGL were higher than those estimated by RESRAD-OFFSITE. The results for protactinium-231 were also comparable, with RESRAD-OFFSITE predicting a higher concentration at earlier times than the HGL model through 10,000 years. The maximum concentration predicted by RESRAD was higher than that predicted by the HGL model by less than a factor of 5 through 10,000 years. RESRAD-OFFSITE indicates a maximum concentration occurring at about 5,000 years. The HGL estimates are still increasing at 10,000

years, so the maximum predicted concentrations are likely closer than indicated by this comparison beyond 10,000 years.

The predicted concentrations for actinium-227 show the largest discrepancy between these two models. RESRAD-OFFSITE predicts that the actinium-227 concentration in groundwater beneath Bay D is essentially equal to that of protactinium-231 through the first 5,000 years. After 5,000 years, the actinium-227 concentration exceeds that of protactinium-231. The predicted maximum concentration of actinium-227 is about 10 times greater than the predicted maximum concentration for protactinium-231 through 10,000 years. In contrast, the HGL model predicts that the actinium-227 concentration in groundwater beneath Bay D will be less than that for protactinium-231 by about a factor of 100. The shapes of the breakthrough curves for these two radionuclides are generally the same in the HGL model, indicative of the ingrowth of actinium-227 from protactinium-231 as both radionuclides move downward through Bay D.

There are a number of possible explanations for this difference and for discrepancies in results between other radionuclides described above. One explanation deals with how each model handles differences in infiltration through the system. The HGL model employed a time-varying water flux, based on predictions of flow through the layered system from the HELP model. The flux rate in the HGL model varied temporally through each 10,000 year simulation; however, the water flux for any given time period was constant through all layers, including the underlying concrete floor. The RESRAD-OFFSITE model was assigned a constant infiltration rate (i.e., not time-varying) to the upper most model layer, and the flux rate through each layer was set equal to this infiltration rate.

Another explanation is related to the manner in which the two models account for the coupling effect of transport and ingrowth in the concrete layer at the bottom of Bay D. Because of the large differences in transport speeds among parent and progeny radionuclides (in this case, the K_d s for uranium-235, protactinium-231, and actinium-227 are 3.6, 1500, and 450 mL/g, respectively), ingrowth in the concrete layer could not be accounted for satisfactorily in RESRAD-OFFSITE without further dividing the concrete layer into numerous smaller sublayers. Most of the actinium-227 reaching groundwater is from protactinium-231 (as shown in both models), which in turn comes from uranium-235. Uranium moves quite quickly with groundwater, and the ability of the model to accurately account for radionuclide ingrowth at the very bottom of the concrete layer is very important for accurately predicting future groundwater concentrations for actinium-227 beneath the IWCS. In addition, there are a number of differences in the modeling approaches in these two codes, which could account for this discrepancy.

Once these contaminants reach groundwater there will be considerable dilution from dispersion and differences between the IWCS-based contaminant outflow rate and the ambient groundwater flow rate. The dilution process should minimize any potential future radiation exposures. It has been concluded that the groundwater modeling results (HGL 2007) are reasonable predictions of future groundwater concentrations at the site from releases of radioactive contaminants in the residues and wastes contained in the IWCS.

6.6.4 Uncertainties in Groundwater Modeling Results

This RI report was written using groundwater modeling results assuming a K_d value of 3.6 L/kg the uranium isotopes. A sensitivity analysis was conducted to evaluate the effect of the uranium K_d value on predictions made regarding the fate and transport of uranium isotopes in site soil and groundwater. The sensitivity analysis was done for the uranium-238 isotope only since similar results would be expected for all of the uranium isotopes. Two sensitivity cases were studied;

Sensitivity Case 1 used a K_d value of 8.7 L/kg for uranium-238 and Sensitivity Case 2 used a K_d value of 46 L/kg. The baseline case ($K_d=3.6$ L/kg) included all contaminant sources including groundwater plumes. Cases 1 and 2 included only soil based plumes and IWCS sources. Conclusions predicted by the model include:

- In Case 1, beneath the IWCS where no groundwater plumes are present, an approximate two-fold increase in K_d (i.e. from 3.6 to 8.7 L/kg) resulted in more than a four-fold reduction in the maximum on-site concentration.
- In Case 2, beneath the IWCS where no groundwater plumes are present, an approximate one order of magnitude increase in K_d (i.e. from 3.6 to 46 L/kg) resulted in over a two order of magnitude reduction in the maximum on-site concentration.
- The time predicted for the initial screening level exceedance below the IWCS was extended 150 years (from 200 to 350 years) for Case 1 ($K_d=8.7$ L/kg) relative to the baseline case ($K_d=3.6$ L/kg).
- The time predicted for the initial screening level exceedance below the IWCS was extended 950 years (from 200 to 1,150 years) for Case 2 ($K_d=46$ L/kg) relative to the baseline case ($K_d=3.6$ L/kg).
- No screening level exceedances were predicted at the NFSS property boundary within 1,000 years (assuming no groundwater plumes were considered).

A groundwater modeling simulation was also performed to evaluate the effects of saturation of the IWCS. A water level of 320.09 ft was used for this simulation, which resulted in saturation of approximately 66% of the residues in Buildings 411, 413 and 414. Saturated IWCS simulation results predict an increased lateral extent of the contaminants compared to the Baseline Case (unsaturated conditions). Despite the increased extent, however, there were no IWCS-related screening level exceedances within 1,000 years. Saturated IWCS simulations results also indicate increased vertical migration relative to the Baseline Case. This is attributed to the modeling approach where the constant head is specified only within the IWCS waste zones, creating a mounding condition, and increased vertical gradient.

More detailed descriptions of the K_d sensitivity analysis and the saturated flow simulation are provided in the groundwater modeling report (HGL 2007).

7.0 CONCLUSIONS AND RECOMMENDATIONS

This section provides a logical transition from the extensive list of SRCs discussed in Section 5 to a reduced list of site constituents posing risk to human health (i.e. COCs and ROCs). This section incorporates results from the BRA and the groundwater fate and transport modeling, and provides recommendations for those EUs and media that should be carried forward for further evaluation in the FS. SRCs have previously been identified and discussed in Sections 4 and 5 of this document. Groundwater fate and transport modeling results were presented in Section 6 of this document. COCs and ROC were determined and identified in the BRA.

Table 7-1 provides a comprehensive summary of SRCs identified at the NFSS site for each investigative media within each EU. This table also identifies constituents that are COCs or ROCs as defined by the BRA. To be consistent with the BRA methodology, the “SB” column in Table 7-1 includes both surface soil and subsurface SRCs (i.e., 0-10 foot depth interval). To distinguish the surface soil SRCs from the subsurface SRCs, an open circle was used to represent SRCs from 0-0.5 feet, whereas a solid dot was used for SRCs from 0.5-10 feet. It should be noted that those constituents identified as SRCs in subsurface soil (0.5-10 feet) were identified by screening against the subsurface soil background UTL that defines subsurface soil as 0-10 feet.

7.1 SUMMARY OF RI FINDINGS FOR EACH EU

A separate summary (for each EU) that addresses the following topics with respect to RI findings is presented in Section 7.3.

- SRCs of significance,
- Nature of occurrence of SRCs,
- Relation of SRC occurrence to site history,
- Groundwater fate and transport modeling results,
- Determination of COCs and ROCs from the BRA, and
- Recommendations for further investigation.

A brief description of these topics and the nature of information provided for each are included in the following sections.

7.1.1 SRCs of Significance

SRCs of significance were identified for each media including soil, groundwater, sediment, surface water, and subsurface utility pipelines. Criteria used to determine significance of SRCs may include, but are not limited to:

- High frequency of detection,
- High magnitude of observed concentrations,
- Widespread occurrence,
- Multiple depth occurrences in soil,
- Clustered concentrations,
- Constituent of an identified groundwater plume, and
- High probability of media interaction (i.e. migration of constituents between media).

Although SRCs may have been identified in a particular media within an EU, no SRCs of significance may have been identified in that media if the above criteria were not met for any of

the SRCs. For example, if one or two SRCs were identified in a particular media within an EU, these SRCs may not have been considered SRCs of significance if they exhibited relatively low concentrations and were sporadic in occurrence.

7.1.2 Nature of Occurrence

It is important to note that, for soil samples, the RI soil sampling gamma survey results were used to select locations that exhibited higher radiation levels. As such, the sample results don't really represent "typical" conditions at the site, but rather are indicative of the "worst case" locations defined by biased sampling.

The nature of occurrence for SRCs of significance is briefly summarized for each media, and the descriptions of nature of occurrence expand on the criteria used to determine SRCs of significance. The nature of occurrence may include a description of the frequency of SRC exceedances above the background UTL, how widespread the SRC is within separate media, at what depths the SRC is found, whether or not the SRC is found in multiple media, and the magnitude of SRC Exceedances above background UTLs.

7.1.3 Relation to Site History

An explanation as to the presence of SRCs within the EU is provided based on available knowledge of the EU's operational history as well as investigative findings that may include field observations or results of historical record searches.

7.1.4 Groundwater Fate and Transport Modeling

The results of groundwater fate and transport modeling are discussed with respect to groundwater SRCs of significance and groundwater plumes identified for the EU.

7.1.5 BRA – Determination of COC and ROCs

The U.S. EPA and USACE guidance used to prepare the BRA relied on modeled risk estimates for representative receptors that may come into contact with chemical and radiological constituents at the site. The risk estimates were not based on observed impacts to actual people, plants, or animals at the site, nor were they based on measured levels of chemicals within the tissues of these potential receptors. The risk estimates were developed using mathematical models as opposed to actual observed or measured effects. Therefore, these risk estimates should be used only within the CERCLA framework for which they are intended and not for any other purpose such as wildlife management or the development of health advisories.

The COCs and ROCs identified in the BRA are discussed in each EU summary and represent the RME cancer risk for the adult/child subsistence farmer scenario. The subsistence farmer land use scenario is overly conservative for the NFSS and is highly unlikely due to proximity of the site to surrounding landfills and poor yield and quality of on-site groundwater resources. The subsistence farming scenario includes the development of a working farm with livestock for meat and dairy products plus cultivated land for grains, fruits, and vegetables. It is assumed that a subsistence farmer could be exposed to contaminated surface soil, surface water/sediment, impacted home-grown produce, impacted meat and dairy products, and upper and lower groundwater while on site. The carcinogenic COCs are constituents that exceed the 10^{-5} risk level. A risk of 10^{-5} is defined as the probability that one additional person in a population of 100,000 people may develop cancer as a result of exposure to contaminants at the NFSS. The non-

carcinogenic COCs are constituents that show risks exceeding a hazard index of one, the level of concern for potential adverse non-carcinogenic health effects (EPA 1989). For ROCs, if total cancer risk exceeds 10^{-4} , only those ROCs exceeding 10^{-5} risk levels are identified. Risk was determined for the following media pathways: surface soil (0-0.5 feet), soil (0-10 feet), sediment, surface water, groundwater, and food. COCs identified for the food pathway correspond to soil samples collected from 0-0.5 feet. COCs and ROCs identified for the food pathway represent a hypothetical future scenario where food is grown on site. No current risk from food is implied. COCs and ROCs identified by the BRA as risk drivers are presented in the EU summaries. The BRA did not evaluate soils greater than 10 feet deep; however, they are presented in the nature of occurrence discussions in this section in order to evaluate SRCs of significance.

No dissolved metals or dissolved radionuclides were identified as COCs or ROCs in groundwater or surface water because the dissolved fractions were not evaluated in the BRA. COCs and ROCs were identified in the BRA with respect to the total fraction in groundwater and surface water samples.

Table 7-1 and the EU summaries presented in this section include ROCs which were not detected in NFSS RI samples or which were not analyzed for in NFSS RI samples, but were identified by the BRA as contributing to human health risk. These ROCs were identified as posing a risk to human health based on the equilibrium of radioactive decay chains.

Most of the radionuclides found at the NFSS are parts of radioactive decay chains. In nature, these chains are assumed to be in equilibrium with all members of a chain existing at the same activity level. Some members of the uranium-235 and uranium-238 chains were either not analyzed from samples collected during the RI or were not detected in the data used for establishing ROCs at the NFSS site. This scenario occurred most commonly for lead-210 and protactinium-231. The long-lived members missing from the uranium-235 and uranium-238 chains, i.e. protactinium-231 in the uranium-235 chain and lead-210 in the uranium-238 chain, were assumed to be in equilibrium with their nearest long-lived chain member. Thus, protactinium-231 was assumed to be in equilibrium with actinium-227 and lead-210 was assumed to be in equilibrium with radium-226. In such cases, lead-210 and protactinium-231 were identified as ROCs, but not as SRCs. This scenario may occur with other radionuclides as well, but less frequently.

For the purpose of this RI document, it is assumed that future land use on the site will be dominated by human use; therefore, COCs and ROCs identified in this document reflect human health concerns. However, surface water drainages may represent a portion of the site for which protection of ecological receptors is more important. Based on the SERA, no radionuclide SRCs had the potential to pose adverse effects to ecological receptors. The SERA did not eliminate the possibility for ecological risk for some chemical SRCs in surface water and sediments; however, further evaluation using a weight-of-evidence (WOE) assessment revealed relatively healthy and functioning terrestrial and aquatic systems. The WOE assessment concluded no further action is necessary for managing ecological resources at NFSS.

7.1.6 Recommendations

A recommendation for further evaluation of COCs and ROCs in the FS, or a determination of no further action is identified for each media.

7.2 GENERAL CONSIDERATIONS

Through the course of evaluating data collected during this RI, it became apparent that residual radionuclide contamination in soil and the presence of various constituents in pipelines and subsurface utilities are conditions that affect a large portion of the NFSS site. Specific considerations concerning both issues are discussed in the following sections.

7.2.1 Evaluation of Pipelines and Subsurface Utilities

SRCs present in sediment and water within pipelines and subsurface utilities may indicate that pipelines and subsurface utilities act as preferred pathways for the migration of constituents. Therefore, SRCs within pipelines and subsurface utilities should be further addressed in the FS with respect to groundwater and subsurface soil contamination.

7.2.2 Residual Radionuclide Contamination

Residual radionuclide contamination in soil could be the result of difficulties encountered during historical cleanup activities. In addition, the soils may have been cleaned up to standards deemed appropriate by DOE at the time; however, technology improvements and the conservative screening criteria used during this RI indicate that further evaluation of the contaminants in soil may be warranted.

During the RI, unexpected, rare occurrences of elevated cesium-137, strontium-190, plutonium-239/240 and enriched uranium were identified. These constituents will be included in the FS evaluation and in remedial design efforts.

7.3 EU SUMMARIES

EU summaries of SRCs, COCs/ROCs, and recommendations for further investigation follow. Additionally, the background data set (EU 18) was discussed previously in this report and therefore is not discussed in this section.

7.3.1 EU 1 (Baker-Smith Area and Vicinity) Summary of SRCs, COCs/ROCs, and Recommendations for Further Investigation

SRCs of Significance

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
Radionuclides	Radionuclides	None Identified	None Identified	Not Applicable
VOCs				
Pesticides				

Nature of Occurrence

Soil

- Actinium-227, radium-226, thorium-230, and uranium isotopes exceeded background UTLs by factors near 100 or more near the former Baker-Smith building foundations and near the West Ditch. Thorium and uranium isotopes exceeded background UTLs at depths greater than 10 feet along the northern boundary of the EU and near the former building foundations. Cesium-137 was present mainly near building foundations and in the southeastern corner of the EU.
- VOCs were detected in the upper 2 feet of soil and at depths greater than 10 feet mainly near former building foundations or roads.
- Pesticides were present at scattered locations within the upper 2 feet of soil.

Groundwater

- A dissolved total uranium plume extends from the west-central portion of EU 2 through the northwest portion of EU 1.

Sediment

- No SRCs of significance were identified in sediment at this EU.

Surface Water

- No SRCs of significance were identified in surface water at this EU.

Relation to Site History

Radionuclides detected in EU 1 may be related to past radioactive waste storage in this area. The slightly elevated levels of cesium-137 in soils may be attributed to the storage of KAPL wastes. The presence of VOCs may be due to the use of chemicals in the pipe shop, machine shop, or welding shop located in the former Baker-Smith area, or related to the use of the former rail line in the area. It is possible that pesticides were used to control insects near the former Baker-Smith buildings.

Groundwater Fate and Transport Modeling

Based on model simulations, uranium isotopes are predicted to migrate offsite within 1,000 years at concentrations that exceed screening and risk levels [MCLs and 10^{-5} PRGs; See Section 5.5 of the BRA (SAIC 2007) for a detailed description of potential risk to offsite groundwater receptors]. This conclusion is consistent with concentrations of uranium isotopes currently

observed in the UWBZ in EU 1. Predicted offsite migration in EU 1 is the result of continued migration of existing groundwater contamination, with minor additional contributions from SESOIL modeling predicting leaching from existing soil contamination. The existing groundwater contamination only slightly exceeds the MCL; however, the contribution from soil leaching indicates that concentrations of uranium will increase with time. It should be noted that the conclusions made regarding the fate and transport of uranium isotopes in site groundwater are somewhat dependant on the conservative K_d value of 3.6 L/kg that was used in the modeling simulations. Use of this K_d value causes the model to predict greater concentrations of radionuclides in groundwater due to increased leaching of site soils. The results of a sensitivity analysis for the uranium K_d value are discussed in Section 6.6.4. A modified K_d value for uranium may be used in the FS for determining cleanup criteria.

BRA – Determination of COCs and ROCs

No COCs were identified for EU 1; only ROCs in soil (0-10 feet) and food were identified for EU 1. ROCs identified by the BRA that pose risk in soil (0-10 feet) include:

Actinium-227	Radium-226	Uranium-234
Cesium-137	Radium-228	Uranium-235
Protactinium-231	Thorium-230	Uranium-238
Lead-210	Thorium-232	

ROCs identified by the BRA that pose risk in food include:

Actinium-227	Radium-226	Thorium-232
Protactinium-231	Radium-228	Uranium-234
Lead-210	Thorium-230	Uranium-238

Of the ROCs, radium-226 was identified as a risk driver contributing 50% or more of the cancer risk in the adult/child subsistence farmer scenario. Recommendations for addressing the ROCs are presented below.

Recommendations

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
The presence of ROCs identified in the RI/BRA should be further evaluated in the FS.	Due to the potential for future risk to offsite groundwater receptors, the presence of radionuclides in groundwater should be further evaluated in the FS.	No Further Action	No Further Action	Not Applicable

7.3.2 EU 2 Summary (Baker-Smith Area and Vicinity) of SRCs, COCs/ROCs, and Recommendations for Further Investigation

SRCs of Significance

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
Radionuclides VOCs PAHs PCBs Pesticides	Radionuclides	None Identified	None Identified	Radionuclides PAHs

Nature of Occurrence

Soil

- The most commonly detected radiological SRCs in both surface and subsurface soil were thorium-230 and radium-226. These two radionuclides were also detected at depths greater than 10 feet bgs. Actinium-227, cesium-137, radium-228, and uranium isotopes were also found in surface and subsurface soils throughout the EU. Radionuclides in EU 2 generally exceeded the background UTLs by factors less than 10.
- VOCs were detected mainly in the eastern portion of the EU in the likely area of the former sellite manufacturing buildings and storage tanks. VOCs were found within surface and subsurface soils including depths greater than 10 feet bgs. PAH compounds were also found in surface and subsurface soils in this area.
- PCBs and pesticides were found within the upper two feet of soil at widespread locations within the EU.

Groundwater

- A dissolved total uranium plume extends from the west-central portion of EU 2 through the northwest portion of EU 1. Dissolved thorium-228 was also detected above the background UTL at one location within the EU.

Sediment

- No SRCs of significance were identified in sediment at this EU.

Surface Water

- No SRCs of significance were identified in surface water at this EU.

Subsurface Utilities

- Uranium isotopes were detected above the background UTLs in sediment in a sanitary sewer line southwest of the intersection of O Street and Campbell Street. Cesium-137 was detected above the background UTL in sediment in a storm sewer line near Campbell Street. Radium-226 was detected above the background UTL in surface water from one manhole location.
- Several PAHs were detected in sediment from two locations on the storm sewer system.

Relation to Site History

Presence of radionuclides at levels above background UTLs in EU 2 are likely due to activities conducted nearby at the former radium storage vault (Building 433) in EU 3 and due to the EU's proximity to neighboring EUs where radioactive wastes were once used or stored. However, historical references indicate that radium sources stored in the radium storage vault were sealed sources and were not a source of radiological contamination (Aerospace Corporation 1982). Historical references also indicate that the radium storage vault was also uncontaminated (Battelle 1981). The presence of VOCs, PAHs, and PCBs may be due to industrial activities and the use or storage of chemicals in the former sellite manufacturing buildings and storage tanks. An abandoned drum investigated in the southeastern corner of EU 2 could be a source of some localized PAH compounds, PCBs, and pesticides. A small portion of the New Naval Waste Area, where construction debris was stored, is located in EU 2 and represents a possible source for some SRCs present in the EU. It is possible that pesticides were used to control insects in areas of the EU. Constituents in the subsurface utility lines may be related to activities within the EU or may have been transported through the sewer or storm systems from neighboring EUs.

Groundwater Fate and Transport Modeling

The dissolved total uranium plume that extends from the west-central portion of EU 2 through the northwest portion of EU 1 is predicted to migrate offsite in EU 1 within 1,000 years at concentrations that exceed screening and risk levels [MCLs and 10^{-5} PRGs; See Section 5.5 of the BRA (SAIC 2007) for a detailed description of potential risk to offsite groundwater receptors]. This offsite migration in EU 1 is the result of continued migration of existing groundwater contamination in EUs 1 and 2, with minor additional contributions from SESOIL modeling predicting leaching from existing soil contamination. The existing groundwater contamination only slightly exceeds the MCL; however, the contribution from soil leaching indicates that concentrations of uranium will increase with time. It should be noted that the conclusions made regarding the fate and transport of uranium isotopes in site groundwater are somewhat dependant on the conservative K_d value of 3.6 L/kg that was used in the modeling simulations. Use of this K_d value causes the model to predict greater concentrations of radionuclides in groundwater due to increased leaching of site soils. The results of a sensitivity analysis for the uranium K_d value are discussed in Section 6.6.4. A modified K_d value for uranium may be used in the FS for determining cleanup criteria.

BRA – Determination of COCs and ROCs

COCs and ROCs identified by the BRA that pose risk in soil (0-10 feet) include:

Benzo(a)anthracene	Actinium-227	Thorium-230
Benzo(a)pyrene	Cesium-137	Thorium-232
Benzo(b)fluoranthene	Protactinium-231	
Dibenz(a,h)anthracene	Lead-210	
Indeno(1,2,3-cd)pyrene	Radium-226	
Boron	Radium-228	

COCs and ROCs identified by the BRA that pose risk in food include:

Benzo(a)anthracene	Dibenz(a,h)anthracene	Actinium-227	Radium-226
Benzo(a)pyrene	Indeno(1,2,3-cd)pyrene	Protactinium-231	Radium-228
Benzo(b)fluoranthene	Boron	Lead-210	Thorium-232
Benzo(k)fluoranthene			

Of the COCs, benzo(a)pyrene was identified as a risk driver in soil (0-10 feet) and in food. Of the ROCs, radium-226 was identified as a risk driver in soil (0-10 feet). These risk drivers contribute 50% or more of the cancer risk in these media in the adult/child subsistence farmer scenario. The following are recommendations for addressing the COCs and ROCs.

Recommendations

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
The presence of COCs and ROCs identified in the RI/BRA should be further evaluated in the FS.	Due to the potential for radionuclide contribution to the dissolved uranium plume that could potentially migrate offsite in EU 1 and pose future risk to offsite groundwater receptors, the presence of radionuclides in groundwater should be further evaluated in the FS.	No Further Action	No Further Action	No Further Action

7.3.3 EU 3 (Acid Area and Vicinity) Summary of SRCs, COCs/ROCs, and Recommendations for Further Investigation

SRCs of Significance

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
Radionuclides	Manganese	Not Applicable	Not Applicable	None Identified
VOCs				
PCBs				
Pesticides				

Nature of Occurrence

Soil

- Actinium-227, radium-226, and thorium and uranium isotopes were detected above the background UTLs in surface and subsurface soils throughout the EU. Actinium-227 and radium-226 exceeded surface soil background UTLs by factors between 10 and 40 in some locations. Most radionuclides detected in surface and subsurface soil exceeded the background UTLs by factors less than 10. No radionuclides were identified as SRCs at depths greater than 10 feet bgs.
- VOCs, PCBs and pesticides were detected most frequently near trenching locations at depths less than 10 feet bgs. All VOCs detected above the background UTLs were found in soils at depths greater than 2 feet bgs, and five VOCs were detected above the background UTLs at depths greater than 10 feet bgs.

Groundwater

- A manganese plume was identified in the central portion of the EU. Manganese exceeded the background UTL in groundwater in both the total and dissolved phases at two wells.

Subsurface Utilities

- No SRCs of significance were identified in subsurface utilities in this EU.

Relation to Site History

Most of the SRCs present in EU 3 may be due to activities conducted and waste stored at the New Naval Waste Area and from activities at the former radium storage vault (Building 433). However, historical references indicate that radium sources stored in the radium storage vault were sealed sources and were not a source of radiological contamination (Aerospace Corporation 1982). Historical references also indicate that the radium storage vault was also uncontaminated (Battelle 1981). Radionuclide SRCs present within the EU may also be related to waste streams that were transported and stored at the NFSS. VOCs, PCBs, and pesticides were detected in Trench 403 where organic matter, bricks, gravel and wood were observed during excavation activities. Cinders and a ballast layer were also found in Trench 413. These materials may account for the organic constituents observed in soil. Dissolved manganese, detected above the background UTL within the manganese plume near Trench 403, could be related to debris observed in the trench. SRCs may also be present due to the proximity of the EU to the former acid area which was located nearby in EU 4. It is possible that pesticides were used to control insects in areas of the EU.

Groundwater Fate and Transport Modeling

The groundwater flow and transport model indicates that manganese will exceed its screening level in groundwater within 1,000 years at the NFSS. However, the existing manganese plume in EU 3 also exhibits little dispersion over 1,000 years, and the maximum concentration of this metal in groundwater is not expected to increase above the current concentrations of the plume. Concentrations of manganese that exceed the screening level are not expected to migrate vertically below the base of the Brown Clay Till (i.e., to a depth of approximately 15 feet).

BRA – Determination of COCs and ROCs

No COCs were identified by the BRA for this EU, only ROCs were identified for soil (0-10 feet) and food. ROCs that pose risk in soil (0-10 feet) and food in EU 3 include:

Actinium-227
Protactinium-231
Lead-210
Radium-226

Of the ROCs, radium-226 was identified as a risk driver, contributing 50% or more of the cancer risk in the adult/child subsistence farmer scenario. The following are recommendations for addressing the ROCs.

Recommendations

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
The presence of ROCs identified in the RI/BRA should be further evaluated in the FS.	No Further Action	Not Applicable	Not Applicable	No Further Action

7.3.4 EU 4 (Acid Area and Vicinity) Summary of SRCs, COCs/ROCs, and Recommendations for Further Investigation

SRCs of Significance

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
Radionuclides Boron PAHs PCBs Pesticides VOCs	Radionuclides Metals SVOCs VOCs	Not Applicable	None Identified	Radionuclides PAHs PCBs Pesticides VOCs

Nature of Occurrence

Soil

- Cesium-137, radium-226, and thorium-230 were widely distributed in surface soils, and also found in subsurface soils. Americium-241, thorium-228, thorium-232, and uranium isotopes were found in surface and subsurface soils; however, as discussed in Section 5.9.3.1, the detections of americium-241 may be false positives. Radium-228, uranium-235, and thorium isotopes were also found in subsurface soils at depths greater than 10 feet bgs. Radionuclides exceeded background UTLs in surface and subsurface soils by factors less than 10.
- Boron was widely detected above the background UTL in surface and subsurface soils including depths greater than 10 feet bgs. Boron exceeded the background UTL by factors greater than 10 in two samples collected at depths less than 10 feet bgs at abandoned drum locations.
- Fourteen PAH compounds were detected above background UTLs in surface and subsurface soils in the central portion of the EU.
- Aroclor-1254 and Aroclor-1260 were frequently detected in surface and subsurface soils.
- Pesticides and several VOCs were detected in surface and subsurface soils including depths greater than 10 feet bgs.

Groundwater

- A dissolved total uranium plume was identified in the north-central portion of the EU near the former nitric acid concentrator. Dissolved thorium-228 and dissolved thorium-230 were also detected in groundwater in the north-central portion of the EU.
- A boron plume was identified in the central portion of EU 4. Detections of aluminum, barium, cobalt, manganese, and nickel were also found in the total and dissolved phases within EU 4.
- Four SVOCs were detected in groundwater; however, bis(2-ethylhexyl)phthalate was the only SVOC detected above the background UTL in multiple locations within the EU.

- Seventeen VOCs were detected in groundwater at multiple locations within the EU. Southeast to northwest trending groundwater plumes were identified for PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride near wells MW415 and MW415A, and manhole MH 32. The plumes are within the UWBZ at a depth of approximately 10 to 15 ft bgs and appear to be located in a topographic low in the GLC near monitoring well 415 (see Figure 2.15 in the Groundwater Flow and Contaminant Transport Modeling Report (HGL 2007)). Sand lenses greater than 5 ft in depth were encountered in borings 415 and 415A in addition to other less extensive lenses encountered in other borings in this EU. Although not confirmed, DNAPL in the topographic low could be dissolving into the groundwater present in the more permeable sand lenses in the area and contributing to the VOC plumes. The possible contribution of VOCs to groundwater from DNAPL is supported by field data which indicates that no correspondingly high VOC contamination was observed in soils above the groundwater table. PID readings used to guide soil sample collection in boring 415 indicated that no organic vapors were detected in the vadose zone between 0 and 5 feet bgs. Detections of organic vapors were first observed at a depth of 5 feet, which corresponds to the depth of groundwater in the boring. PID readings ranged from 1.4 ppm to 165 ppm at depths of 5 feet to approximately 10 feet bgs, respectively. High levels of VOCs were detected in the subsurface soil samples that correspond with the depth of the groundwater.

Surface Water

- No SRCs of significance were identified in surface water at this EU.

Subsurface Utilities

- Cesium-137, radium-226, and uranium isotopes were detected above the background UTLs in sediment in subsurface utility lines throughout the EU. Cesium-137, radium-226, thorium isotopes, and uranium isotopes were detected above background UTLs in water from the subsurface utilities within the EU. These radionuclides exceeded the background UTLs by factors less than 10 in both sediment and water.
- Aroclor-1260 was detected in sediment at multiple locations in subsurface utilities at concentrations that exceeded the background UTL by a factor of 20 or more.
- Several PAH compounds and pesticides were detected in sediment at multiple locations in subsurface utilities. Most of these detections exceeded the background UTLs by factors less than 10; however, 4,4'-DDE and 4,4'-DDT exceeded background UTLs by factors of 20 or more, while dieldrin exceeded the background UTL by factors over 200. Several PAH compounds and one pesticide were also detected in water from the subsurface utilities within the EU. PAH compounds exceeded the background UTLs in water by factors of 100 or more.
- VOCs were detected in manholes located in close proximity to the PCE/TCE plume. MH-32 is approximately 12 ft bgs which corresponds to the screened interval for MW 415. Thus, a hydraulic connection between the groundwater plume and the subsurface utilities likely occurs in this area. However, there is no evidence of extensive lateral migration of VOC contamination along or within the pipeline. Any remediation of the VOC contamination in EU 4 also should include remediation of the pipelines in the immediate vicinity of the plume.

Relation to Site History

Many SRCs identified in EU 4 were related to abandoned drum locations and trenching locations. Five abandoned drum locations investigated within EU 4 indicated the presence of metals, PAHs, PCBs, pesticides, SVOCs, VOCs, and radionuclides. Organic SRCs, metals, and radionuclides were also identified at several trenching locations where the following items were observed: vitrified clay piping, concrete piping, rebar, steel, PVC, bricks, rubble, ash, oily gravel, and foam. SRCs within the EU may be related to the general industrial operations performed around the former buildings, or may be related to waste streams that were transported and stored at the NFSS. SRCs may also be present in EU 4 due to activities conducted at the former acid area where nitric acid and other materials related to the manufacture of TNT were stored. Radionuclides may also be present in the EU because uranium rods were once stored in former Buildings 431 and 432. Hydraulic connections may exist between groundwater plumes and subsurface utilities.

Groundwater Fate and Transport Modeling

PCE, TCE, cis-1,2-DCE, and vinyl chloride are all present within the same plume in EU 4. Groundwater modeling results indicate that only minor dispersion of this VOC plume occurs due to low infiltration rates. This plume is not predicted to migrate offsite. As biodegradation occurs, PCE and TCE concentrations gradually decline while degradation products (cis-1,2-DCE and vinyl chloride) increase slightly in the first 50 years. PCE, TCE, cis-1,2-DCE, and vinyl chloride are all expected to degrade to levels less than the screening values within 300 years in the Brown Clay Till. However, these VOCs continue to migrate downward into the Glacio-Lacustrine Clay. TCE and vinyl chloride further migrate to the Alluvial Sand and Gravel and Queenston Formation in the first 150 years. Vinyl chloride is predicted to degrade to below screening levels by 200 years.

The groundwater flow and transport model indicates that boron will exceed its screening level in groundwater within 1,000 years at the NFSS. However, the existing boron plume in EU 4 also exhibits little dispersion over 1,000 years, and the maximum concentration of this metal in groundwater is not expected to increase above the current concentrations of the plume. Concentrations of boron that exceed the screening level are not expected to migrate vertically below the base of the Brown Clay Till (i.e., to a depth of approximately 15 feet).

A thorium-230 plume located near the site boundary in EU 4 was evaluated for future risks due to ingrowth because it is feasible that radium concentrations in groundwater could increase in the presence of parent thorium isotopes. It is concluded that existing reported radium concentrations in the EU 4 plume are less than the MCL now (considering both total and dissolved results) and the potential for ingrowth would not result in an exceedance over the next 1,000 years without the introduction of a secondary source of contamination.

BRA – Determination of COCs and ROCs

COCs and ROCs identified by the BRA that pose risk in soil (0-10 feet) include:

Arsenic	Cesium-137
Aroclor-1260	Lead-210
Benzo(a)pyrene	Radium-226

COCs and ROCs identified by the BRA that pose risk in food include:

Arsenic	Benzo(a)pyrene	Lead-210
Boron	Benzo(b)fluoranthene	Radium-226
Aroclor-1254	Indeno(1,2,3-cd)pyrene	
Aroclor-1260	PCE	

COCs and ROCs identified by the BRA that pose risk in groundwater include:

Arsenic	Vanadium	Lead-210
Barium	Bis(2-ethylhexyl)phthalate	Radium-226
Boron	cis-1,2-DCE	Radium-228
Copper	Methylene Chloride	Thorium-228
Lead	PCE	Uranium-234
Manganese	TCE	Uranium-238
Nickel	Vinyl Chloride	

Of the COCs, Aroclor-1260 was identified as a risk driver in soil (0-10 feet) and in food, and PCE was identified as a risk driver in groundwater. Aroclor-1260 and PCE contribute 50% or more of the cancer risk in these media in the adult/child subsistence farmer scenario, as well as 50% or more of the non-cancer risk in the individual scenarios for the adult and child subsistence farmers. Of the ROCs, radium-226 was identified as a risk driver in soil (0-10 feet) and groundwater, contributing 50% or more of the cancer risk in these media in the adult/child subsistence farmer scenario. The following are recommendations for addressing the COCs and ROCs.

Recommendations

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
The presence of COCs and ROCs identified in the RI/BRA should be further evaluated in the FS.	The presence of COCs and ROCs identified in the RI/BRA should be further evaluated in the FS.	Not Applicable	No Further Action	The presence of SRCs should be further evaluated in the FS with respect to the VOC plumes in groundwater.

7.3.5 EU 5 (Panhandle Area) Summary of SRCs, COCs/ROCs, and Recommendations for Further Investigation

SRCs of Significance

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
Radionuclides	None Identified	Radionuclides	None Identified	None Identified
PCBs				
VOCs				

Nature of Occurrence

Soil

- The most commonly detected radiological SRCs in surface soil were cesium-137, radium-226, and thorium-230. Uranium isotopes and actinium-227 were also detected above background UTLs in surface soils. In general, radionuclide SRCs in surface soil exceeded the background UTLs by factors less than 10; however, actinium-227 and radium-226 infrequently exceeded the background UTL by factors greater than 100. All of the surface soil radionuclides were detected above the background UTLs in subsurface soil except actinium-227 and cesium-137. Radium-226 exceeded the background UTL in subsurface soil by factors greater than 60. Only radium-226 and thorium-230 were detected in soils at depths greater than 10 feet bgs; however, these results only slightly exceeded the background UTLs.
- PCBs and VOCs were detected in multiple locations in surface and subsurface soils. Only one VOC was detected at a depth greater than 10 feet bgs.

Groundwater

- Several metals exceeding their background UTLs were found in the groundwater; however, no metal plumes were identified. Silver was consistently found at levels at least 10 times greater than the background UTL in groundwater across the EU; however, all concentrations were less than the secondary MCL of 0.1 mg/L.

Sediment

- Cesium-137 and total uranium exceeded the background UTLs in sediment by factors less than 10.

Surface Water

- Dissolved silver was detected at levels 20 times greater than the background UTL in four samples collected from the O Street North Pond and a pond in the northern portion of the EU; however, metals, in general, are not considered SRCs of significance in surface water.

Subsurface Utilities

- One manhole was sampled in EU 5 for sediment and only a few radionuclides slightly exceeded the background UTL; therefore, no SRCs of significance were identified in subsurface utilities at this EU.

Relation to Site History

Radionuclides may be present in EU 5 due to transportation and storage practices employed at the NFSS prior to the remedial activities in the 1980's. PCBs and VOCs may also be related to the transportation of material along haul roads, activities conducted in the vicinity of the former ammonia plant, or activities conducted at Building 434 in EU 6.

Groundwater Fate and Transport Modeling

No groundwater contaminant plumes were identified in EU 5. Furthermore, groundwater modeling results did not indicate any exceedance of screening or risk levels associated with the fate and transport of contaminants in EU 5.

BRA – Determination of COCs and ROCs

No COCs were identified by the BRA for this EU. ROCs that pose risk in soil (0-10 feet) include:

Actinium-227	Radium-226
Cesium-137	Radium-228
Protactinium-231	Thorium-232
Lead-210	

ROCs that pose risk in food include:

Actinium-227	Radium-226
Protactinium-231	Radium-228
Lead-210	Thorium-232

Of the ROCs, radium-226 was identified as a risk driver in soil (0-10 feet), contributing 50% or more of the cancer risk in the adult/child subsistence farmer scenario. Recommendations for addressing the ROCs are presented below.

Recommendations

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
The presence of ROCs identified in the RI/BRA should be further evaluated in the FS.	No Further Action	No Further Action	No Further Action	No Further Action

7.3.6 EU 6 (Panhandle Area) Summary of SRCs and Recommendations for Further Investigation

SRCs of Significance

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
Radionuclides	None Identified	None Identified	None Identified	Not Applicable
PCBs				
Pesticides				
VOCs				

Nature of Occurrence

Soil

- Radiological SRCs were restricted to the upper 2 feet of soil and occurred in the surface soil at scattered locations across the EU.
- A localized area of elevated radioactivity at the intersection of McArthur Street and O Street in the southeastern corner of the EU contained high concentrations of actinium-227, cesium-137, radium-226, thorium-230, total uranium and uranium isotopes in the surface soil. Concentrations of these radionuclides exceeded their respective background UTL by factors of 20 to 236 times. Protactinium-231, radium-226, thorium-230, total uranium and uranium isotopes exceeded their background UTLs by a factor of 10 to 58 times at depths of up to two feet in this area.
- PCBs were detected in surface soils at five locations with three of the locations either near the northern property boundary with CWM or in a drainage way flowing onto the NFSS from CWM.
- Pesticides are present at scattered locations within the upper 2 feet of soil.
- VOCs were found at three locations in surface soil and two locations in the subsurface soil greater than 10 feet bgs.

Groundwater

- No SRCs of significance were identified in groundwater at this EU.

Sediment

- No SRCs of significance were identified in sediment at this EU.

Surface Water

- No SRCs of significance were identified in surface water at this EU.

Relation to Site History

Radionuclides in the soil in EU 6 may be related to the storage of K-65 residues in Building 434 and the use of N Street, O Street and McArthur Street as haul roads for residues. The PCBs are found near ditches and may be the result of spills during transportation or from PCB containing oil that may have been used for dust control on the adjacent roads. The pesticides appear to also be related to ditches along the haul roads and may be the results of insect control efforts in these

wet areas. The VOCs were found near haul road ditches or near Building 434 and may be a result of activities conducted at or near this building.

Groundwater Fate and Transport Modeling

No groundwater contaminant plumes were identified in EU 6. Furthermore, groundwater modeling results did not indicate any exceedance of screening or risk levels associated with the fate and transport of contaminants in EU 6.

BRA – Determination of COCs and ROCs

No COCs were identified for EU 6; only ROCs in soil (0-10 feet) and food were identified for EU 6. ROCs identified by the BRA that pose risk in soil (0-10 feet) include:

Actinium-227	Lead-210	Uranium-234
Cesium-137	Radium-226	Uranium-235
Protactinium-231	Thorium-230	Uranium-238

ROCs identified by the BRA that pose risk in food include:

Actinium-227	Radium-226	Uranium-234
Protactinium-231	Thorium-230	Uranium-238
Lead-210		

Of the ROCs, radium-226 was identified as a risk driver, contributing 50% or more of the cancer risk in the adult/child subsistence farmer scenario. Recommendations for addressing the ROCs are presented below.

Recommendations

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
The presence of ROCs identified in the RI/BRA should be further evaluated in the FS.	No Further Action	No Further Action	No Further Action	Not Applicable

7.3.7 EU 7 (IWCS and Vicinity) Summary of SRCs, COC/ROCs, and Recommendations for Further Investigation

SRCs of Significance

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
Radionuclides VOCs	Radionuclides	None Identified	Radionuclides	Not Applicable

Nature of Occurrence

Soil

- Radium-226 and thorium-230 are widespread in surface soil with many concentrations exceeding background UTLs by factors of 20 to 400. Uranium isotopes are present in surface soils, but are at low concentrations and at a lower frequency than radium and thorium. Actinium is also present in surface soil at 20 to 300 times the background UTL. The same is true for the aforementioned radionuclides in deeper soils. That is, radium-226 and thorium-230 are most frequently detected and at concentrations 20 to 100 times the background UTL. Actinium is present at 10 to 70 times the background UTL. Uranium isotopes were detected at low concentrations and at a much lower frequency than radium and thorium. Three samples contained elevated concentrations of cesium-137 ranging from 1.07 to 5.15 pCi/g.
- VOCs were detected in several surface soil samples and at depths greater than 10 feet at scattered locations throughout the EU.

Groundwater

- A dissolved thorium-230 plume is present in the southern portion of EU 7. This plume spans the boundary with EU 10 at concentrations that exceed the background UTL by a factor of 2 to 3.
- A small dissolved total uranium plume was noted in the northwest corner of the EU near the West Ditch.

Sediment

- No SRCs of significance were identified in sediment at this EU.

Surface Water

- Thorium-228 and thorium-230 were identified in surface water at this EU at concentrations greater than 40 times their respective background UTLs.

Relation to Site History

Trenching activities conducted in the western portion of EU 7, known as the DOE Organic Burial Area, identified a large volume of wood debris, general demolition debris, an overpack drum containing unused sample containers and sampling equipment, ash-like material, and other miscellaneous debris. Some of the buried materials may be a source of elevated concentrations of radionuclides in soil at EU 7. Approximately 150 field gamma scan results are recorded in the field notes with most of them being consistent with background levels. Also, there were elevated

“hotspots” in the surface soil that may be attributed to contamination not associated with the fill materials. For example, supplementary field investigations of “hotspots” identified in the SAIC Site Wide Gamma Survey, performed during the installation of Trench 808, determined that many of the elevated readings were attributable to small chips in the top few inches of surface soil. These small chips were not found in association with the filled materials. The presence of cesium-137 may be related to the EU’s proximity to EU 1 where KAPL waste was stored or to the buried debris. The elevated concentration of thorium isotopes in surface water can likely be attributed to runoff from surface soil in EU 7. The samples containing VOCs were taken primarily from areas known to contain former settling ponds and water storage pits used during construction of the IWCS.

Groundwater Fate and Transport Modeling

Groundwater modeling results were used to evaluate potential offsite migration on the west side of EU 7 due to continued migration of existing contamination. Modeling results indicate that uranium isotope concentrations in the UWBZ on the boundary of EU 7 are not expected to exceed screening or risk levels within the next 1,000 years.

A thorium-230 plume located near the site boundary in EU 7/10 was evaluated for future risks due to ingrowth because it is feasible that radium concentrations in groundwater could increase in the presence of parent thorium isotopes. It is concluded that existing reported radium concentrations in the EU 7/10 plume are less than the MCL now (considering both total and dissolved results) and the potential for ingrowth would not result in an exceedance over the next 1,000 years without the introduction of a secondary source of contamination. Additionally, thorium-230 is not expected to migrate below the Brown Clay Till within 1,000 years at concentrations that exceed the screening level.

BRA – Determination of COCs and ROCs

No COCs were identified for EU 7. ROCs identified by the BRA that pose risk in soil (0-10 feet) include:

Actinium-227	Radium-226
Cesium-137	Thorium-230
Protactinium-231	
Lead-210	

ROCs identified by the BRA that pose risk in food include:

Actinium-227	Radium-226
Protactinium-231	Thorium-230
Lead-210	

Of the ROCs, radium-226 was identified as a risk driver, contributing 50% or more of the cancer risk in the adult/child subsistence farmer scenario. Recommendations for addressing the ROCs are presented below.

Recommendations

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
The presence of ROCs identified in the RI/BRA should be further evaluated in the FS.	Due to the presence of a thorium-230 plume near the site boundary, the presence of radionuclides in groundwater should be further evaluated in the FS.	No Further Action	No Further Action	Not Applicable

7.3.8 EU 8 (Shops Area) Summary of SRCs and Recommendations for Further Investigation

SRCs of Significance

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
Radionuclides Metals PAHs PCBs Pesticides SVOCs VOCs	Radionuclides	None Identified	None Identified	Radionuclides PAHs VOCs

Nature of Occurrence

Soil

- Radiological SRCs occurred at the highest concentrations in EU 8 in the vicinity of Building 430 near W and X Streets. Several soil samples from this area contained concentrations of actinium-227, radium-226, thorium-230, and various uranium isotopes ranging from approximately 20 to over 100 times the background UTLs. The highest radionuclide SRC concentrations were encountered at the surface, with concentrations decreasing at depth. Cesium-137 was detected above the background UTL in scattered surface soil and subsurface soil locations with concentrations ranging from just above the background UTL to 14 times the background UTL.
- Metals are present in the surface and subsurface soil at several widely scattered locations. Metals occur at depths greater than 10 feet bgs in the vicinity of the shops area and the debris pile.
- Several PAHs were detected at concentrations that greatly exceeded the background UTLs in the upper 3 feet of soil. The majority of these were around the shops area.
- Aroclor-1260, a PCB, is found at several locations across the EU at depths up to 3 feet.
- Pesticides are present at scattered locations across the EU. Most exceedances are less than 3 feet deep; however, three exceedances occur at 8 feet bgs.
- SVOCs occur in the upper 3 feet of soil at several locations around the shops area and in the western portion of the EU.
- VOCs are present in the surface and subsurface soil at several widely scattered locations. Five VOCs occur at depths greater than 10 feet bgs primarily in the vicinity of the shops area and debris pile.

Groundwater

- A dissolved total uranium plume is present in the southeastern portion of the EU near the area of the former storehouse Buildings 420 and 421 and the debris pile.

- A dissolved total uranium plume is present in the southwestern portion of the EU near former Building 423. This plume may be associated with the utility lines in this area.
- Several metals exceeding their background UTLs were found in the groundwater; however, no metal plumes were identified. Silver was consistently found at levels at least 20 times greater than the background UTL in groundwater across the EU; however, all concentrations were less than the secondary MCL of 0.1 mg/L.

Sediment

- No SRCs of significance were identified in sediment at this EU.

Surface Water

- Dissolved silver was detected at levels 20 times greater than the background UTL in three samples taken from small ditches in the north and east portions of the EU.

Subsurface Utilities

- Radiological SRCs were detected above the background UTLs in several pipeline sediment and water samples.
- PAHs were also detected in elevated levels in the pipeline sediment; however, these do not appear to be mobile.
- VOCs were detected above the background UTL at four locations in this EU. Three VOCs exceeded their background UTL by more than 10 times.

Relation to Site History

Radionuclides in the soil, groundwater and subsurface utilities are probably the result of storage of residues in some of the buildings, as well as from their transportation to and from those buildings. The vehicle maintenance and repair shops as well as the machining operations conducted in these buildings may account for the presence of PAHs, metals, SVOCs and VOCs in the soil. These compounds are prevalent in oils, solvents, paints and lubricants that were used at the former building locations. Pesticides may be present in the EU from possible pesticide storage in the buildings or pesticide use in the ditches. PCBs may be present due to the historical use of transformers in the shops area. Constituents in the subsurface utility lines may be related to activities within the shops area buildings or with other activities within the EU.

Groundwater Fate and Transport Modeling

Groundwater modeling results were used to evaluate potential offsite migration on the east side of EU 8 due to leaching from existing soil contamination as predicted by SESOIL modeling. Modeling results indicate that uranium isotope concentrations in the UWBZ on the boundary of EU 8 are not expected to exceed screening or risk levels within the next 1,000 years.

BRA – Determination of COCs and ROCs

COCs and ROCs identified by the BRA that pose risk in soil (0-10 feet) include:

Benzo(a)anthracene	Total Uranium	Radium-226
Benzo(a)pyrene	Actinium-227	Thorium-230
Benzo(b)fluoranthene	Cesium-137	Uranium-234
Dibenz(a,h)anthracene	Protactinium-231	Uranium-235
Indeno(1,2,3-cd)pyrene	Lead-210	Uranium-238

COCs and ROCs identified by the BRA that pose risk in food include:

Aroclor-1260	Carbazole	Radium-226
Heptachlor Epoxide	Dibenz(a,h)anthracene	Thorium-230
Benzo(a)anthracene	Indeno(1,2,3-cd)pyrene	Uranium-234
Benzo(a)pyrene	Actinium-227	Uranium-238
Benzo(b)fluoranthene	Protactinium-231	
Benzo(k)fluoranthene	Lead-210	

Of the COCs, benzo(a)anthracene was identified as a risk driver in soil (0-10 feet), contributing 50% or more of the cancer risk in the adult/child subsistence farmer scenario. Total uranium was identified as a risk driver in soil (0-10 feet) contributing 50% or more of the non-cancer risk in the child subsistence farmer scenario. Of the ROCs, radium-226 was identified as a risk driver in soil (0-10 feet), contributing 50% or more of the cancer risk in the adult/child subsistence farmer scenario. Recommendations for addressing the COCs and ROCs are presented below.

Recommendations

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
The presence of COCs and ROCs identified in the RI/BRA should be further evaluated in the FS.	Due to the potential for leaching of existing soil contamination, the presence of radionuclides in groundwater should be further evaluated in the FS.	No Further Action	No Further Action	The presence of SRCs should be further evaluated in the FS with respect to groundwater plumes and subsurface soils.

7.3.9 EU 9 (Niagara-Mohawk Property) Summary of SRCs and Recommendations for Further Investigation

SRCs of Significance

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
Radionuclides	Not Applicable	None Identified	Radionuclides	Not Applicable

Nature of Occurrence

Soil

- Radiological SRCs were restricted to the upper 2.5 feet of soil with most exceedances less than two times the background UTL. One location on the east bank of the West Ditch contained radium-226 and thorium-230 at concentrations approximately 20 times greater than the background UTL. Another location slightly farther north had a total uranium concentration approximately 4 times greater than the background UTL. Elevated levels of thorium-232 and radium-228 were also found at this location.

Groundwater

- No groundwater samples were taken in this EU.

Sediment

- No SRCs of significance were identified in sediment at this EU.

Surface Water

- Uranium-234, uranium-235 and uranium-238 exceed the background UTL in the dissolved phase at several locations along the West Ditch.

Relation to Site History

The radiological constituents in the soil and surface water near the West Ditch are probably due to the area's proximity to the IWCS and associated construction activities. Although this area was previously remediated, the presence of radionuclides suggests that the remediation was incomplete.

Groundwater Fate and Transport Modeling

No groundwater samples were taken in this EU; therefore, no plumes were identified.

BRA – Determination of COCs and ROCs

ROCs in soil (0-10 feet) and food were identified for EU 9. ROCs identified by the BRA that pose risk in soil (0-10 feet) include:

Lead-210	Thorium-230
Radium-226	Thorium-232
Radium-228	

ROCs identified by the BRA that pose risk in food include:

Lead-210
Radium-226
Thorium-232

Of the ROCs, radium-226 was identified as a risk driver, contributing 50% or more of the cancer risk in the adult/child subsistence farmer scenario. Recommendations for addressing the ROCs are presented below.

Recommendations

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
The presence of ROCs identified in the RI/BRA should be further evaluated in the FS.	Not Applicable	No Further Action	No Further Action	Not Applicable

7.3.10 EU 10 (IWCS and Vicinity) Summary of SRCs and Recommendations for Further Investigation

SRCs of Significance

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
Radionuclides	Radionuclides	None Identified	None Identified	Radionuclides
Metals	Metals			
PAHs	SVOCs			
Pesticides				
VOCs				

Nature of Occurrence

Soil

- Almost two thirds of all soil samples collected from depths of two feet or less exceeded the background UTLs for one or more radiological SRC. Radium-226, thorium-230 and uranium isotopes were the most commonly detected radionuclides in surface and subsurface soil. The exceedances were scattered across the EU surrounding the IWCS.
- Metals and two VOCs (1,1-DCE and acetone) occurred at depths greater than 10 feet in the majority of locations. These locations were primarily south and east of the IWCS.
- Several PAH compounds exceeded their background UTLs on the east side of the IWCS, just beyond the subsurface cutoff wall and west of the Central Ditch. Elevated levels of PAHs were also found to the south of the IWCS.
- Pesticides (4,4'-DDE, and 4,4'-DDT) were present at several locations in the soil at depths of one foot or less and at depths greater than 10 feet. The majority of these exceedances were to the south and east of the IWCS.

Groundwater

- Several dissolved total uranium groundwater plumes exist in the UWBZ on all sides of the IWCS in EU 10. The large plume to the south of the IWCS has concentrations reaching approximately 70 times the background UTL.
- A possible thorium-230 plume extends from EU 11 into EU 10 in the UWBZ in the area south of the IWCS. A second possible thorium-230 plume spans the boundary between EUs 7 and EU 10. This plume has thorium-230 concentrations exceeding the background UTL by 2 to 3 times.
- Several groundwater samples contained concentrations of both total and dissolved metals that exceeded background UTLs by a factor of more than ten; however, no groundwater plumes were identified.
- Bis(2-ethylhexyl)phthalate, an SVOC, exceeds the background UTL at several locations primarily along the east side of the IWCS. A small groundwater plume was identified in this area.

- Although no plumes were identified in the LWBZ, several metals, radionuclides, SVOCs and VOCs were detected above the background UTL.

Sediment

- No SRCs of significance were identified in sediment at this EU.

Surface Water

- No SRCs of significance were identified in surface water at this EU

Subsurface Utilities

- Elevated concentrations of uranium isotopes in both the dissolved and total phases were observed in water samples collected from two sanitary sewer manholes located southeast of the IWCS. One manhole had concentrations of uranium isotopes that exceeded the background UTLs by a factor of 20 to 130 times. This manhole is located to the east of the IWCS along the sewer line that partly defines a dissolved total uranium groundwater plume (see Figure 5-4). Sediment samples collected from these two manholes had elevated levels of thorium and uranium isotopes that were approximately 2 times the background UTL.

Relation to Site History

The radionuclide, PAH, pesticide, VOC and metal constituents in the soil could be the result of construction activities that took place prior to the construction of the IWCS. The metals in groundwater appear to be isolated and may be the result of a past release which was spatially limited or has not migrated. The uranium and thorium-230 plumes may be associated with past AEC construction activities or with the slurry ponds that were used during dewatering of the residues. The large uranium plume to the south of the IWCS appears to be associated with the sanitary sewer and water lines in the area. This plume may also be associated with Building 409 which was formerly used for the storage of uranium scrap. The SVOC exceedances in the groundwater and the bis(2-ethylhexyl)phthalate plume may be associated with the settling ponds and past construction activities involving equipment crossing the Central Ditch in the approximate location of the plume. The radiological constituents in the subsurface sewer lines may be related to activities within the EU or may were transported through the sewer pipes or surrounding fill-gravel from neighboring EUs.

Groundwater Fate and Transport Modeling

Unsaturated flow groundwater modeling results indicate that leaching of contaminants from within the IWCS over the next 1,000 years is a concern. Within 1,000 years, the maximum concentrations of uranium isotopes are predicted to occur in the Brown Clay Till beneath the IWCS, near Building 411 (see Table 6.4). Additionally, model results indicate that the screening levels for uranium-234 and uranium-235 will be exceeded in even the deepest of the aquifers (the upper Queenston Formation) within 1,000 years. This is likely the result of potential leaching of residues within Building 411 in the IWCS. The results of a sensitivity analysis for the uranium K_d value are discussed in Section 6.6.4. A modified K_d value for uranium may be used in the FS for determining cleanup criteria.

Little lateral movement of the leached contaminants is predicted. Moreover, the leached contaminants do not reach the site boundary within the 1,000-year modeling period. Specifically, the seven modeled metals (arsenic, barium, boron, iron, lead, molybdenum and manganese)

present in residues within the IWCS will not migrate offsite in groundwater at concentrations above screening levels in the vicinity of the IWCS. Similarly, lateral movement of radionuclides towards the site boundary does not occur to any appreciable extent. Because minimal dispersion of the existing groundwater plumes in the area adjacent to the IWCS is predicted, no additional risk beyond what is present due to current groundwater contamination is expected in this area.

According to groundwater fate and transport modeling results, the bis(2-ethylhexyl)phthalate plume in EU 10 exhibits only minor dispersion within the Brown Clay Till within 1,000 years, and the maximum concentration of this organic compound in groundwater is not expected to increase above the current concentrations of the plume.

BRA – Determination of COCs and ROCs

No COCs or ROCs were identified for EU 10 in the BRA because the subsistence farmer will not be exposed to the constituents in or around the IWCS.

Exposure to the IWCS source term was assumed to present unacceptable risk in the BRA and will be forwarded to the FS. Soil contamination occurring outside the IWCS but within the boundary of EU 10 should be screened against the soil cleanup levels developed in the FS. Recommendations for addressing the SRCs in EU 10 are presented below.

Recommendations

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
The presence of soil SRCs should be further evaluated in the FS.	Due to the potential for leaching of contaminants from the IWCS, the presence of radionuclides and metals in groundwater should be further evaluated in the FS.	No Further Action	No Further Action	The presence of SRCs should be further evaluated in the FS with respect to groundwater plumes.

7.3.11 EU 11 (IWCS and Vicinity) Summary of SRCs and Recommendations for Further Investigation

SRCs of Significance

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
Radionuclides SVOCs PAHs	Radionuclides Metals	None Identified	None Identified	Radionuclides

Nature of Occurrence

Soil

- Essentially all the surface soil samples in this EU have one or more radionuclides exceeding a background UTL. About a third have one or more metals exceeding a background UTL, and significant numbers of samples also have SVOCs that exceed their respective background UTLs.
- Cesium-137, radium-226, thorium-230 and all three uranium isotopes as well as total uranium all exceed their respective background UTLs by factors above 100 and in one location were 10,000 times the background UTL.
- The highest uranium activities were found in the southeastern portion of the EU in a parking area. An exploratory trench in the area showed activities below the asphalt were at normal levels.
- All the above radionuclides and protactinium-231, lead-210, radium-228, total uranium, and thorium-232 are total soil ROCs in the BRA.
- A number of PAHs and other SVOCs are present as SRCs. All but one occurrence are in the surface soils. These occur predominantly near roads.

Groundwater

- All of the groundwater samples from the UWBZ in this EU exceed one or more of their respective background UTLs for total radionuclides and most for one or more total metals.
- Quite a few metals in groundwater exceed the background UTL for total concentration; however, most of these do not exceed the background UTLs for dissolved metals.
- There are two dissolved total uranium plumes in groundwater in EU 11. One is fairly small and in the vicinity of some former dewatering ponds west of EU 12 and crosses over the border with EU 10. The other is very extensive and covers portions of EU 10 as well as EU 11. It is at the south end of EU 11 along the boundary of EU 10 and includes a plume along the water line that cuts diagonally across the southeastern corner of EU 10.
- In addition to the dissolved total uranium plume, there is a thorium-230 plume in the same area along the southern boundary of EU 10 and the western leg of EU 11. Most of the plume is in EU 10.

Sediment

- No SRCs of significance were identified in sediment at this EU.

Surface Water

- No SRCs of significance were identified in surface water at this EU.

Subsurface Utilities

- Two metals (lead and mercury) in utilities sediments exceed their respective background UTLs by more than a factor of 10. However, there is only one sample of each that exceeds the background UTL.
- A number of PAHs in utilities sediments exceeded their background UTLs by factors of up to 23.
- Several metals in water samples from the utilities lines exceed their respective background UTLs by factors of up to 27. The same is true of radionuclides (uranium-234, uranium-235 and uranium-238) in the water samples.

Relation to Site History

Radionuclides may be present in EU 11 because of its proximity to drainage ditches, Building 401 (EU 13) and the IWCS as well as its use for dewatering the slurried residues. SVOCs and PAHs are likely due to nearby roads and the use of EU 11 in construction activities. Metals in groundwater and metals, radionuclides and PAHs in utilities lines are likely due to the presence of broken utility lines and construction activities.

Groundwater Fate and Transport Modeling

Groundwater modeling results indicate that uranium isotopes will migrate offsite on the south side of EU 11 at concentrations that exceed screening and risk levels [MCLs and 10^{-5} PRGs; See Section 5.5 of the BRA (SAIC 2007) for a detailed description of potential risk to offsite groundwater receptors]. This offsite migration is due to continued migration of an existing groundwater plume and a source term derived from the SESOIL modeling which predicts leaching to groundwater from contaminated site soils. However, the conclusions made regarding the fate and transport of uranium isotopes in site groundwater are somewhat dependant on the conservative K_d value of 3.6 L/kg that was used in the modeling simulations. Use of this K_d value causes the model to predict greater concentrations of radionuclides in groundwater due to increased leaching of site soils. The results of a sensitivity analysis for the uranium K_d value are discussed in Section 6.6.4. A modified K_d value for uranium may be used in the FS for determining cleanup criteria.

BRA – Determination of COCs and ROCs

COCs and ROCs identified by the BRA that pose risk in soil (0-10 feet) include:

Total Uranium	Radium-226	Uranium-234
Actinium-227	Radium-228	Uranium-235
Protactinium-231	Thorium-230	Uranium-238
Lead-210	Thorium-232	

COCs and ROCs identified by the BRA that pose risk in food include:

Benzo(a)pyrene	Protactinium-231	Thorium-232
Benzo(b)fluoranthene	Lead-210	Uranium-234
Indeno(1,2,3-cd)pyrene	Radium-226	Uranium-235
Actinium-227	Thorium-230	Uranium-238

Of the ROCs, radium-226 was identified as a risk driver in soil (0-10 feet), contributing 50% or more of the cancer risk in the adult/child subsistence farmer scenario. Benzo(a)pyrene was identified as a risk driver in food, contributing 50% or more of the cancer risk in the adult/child subsistence farmer scenario. Uranium toxicity is identified as a risk driver in soil (0-10 feet), contributing 50% or more of the non-cancer risk in the child subsistence farmer scenario. Recommendations for addressing the COCs and ROCs are presented below.

Recommendations

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
The presence of COCs and ROCs identified in the RI/BRA should be further evaluated in the FS.	Due to the potential for offsite migration of an existing plume and for leaching of contaminants from the IWCS and from site soils, the presence of radionuclides and metals in groundwater should be further evaluated in the FS.	No Further Action	No Further Action	The presence of SRCs should be further evaluated in the FS with respect to groundwater plumes.

7.3.12 EU 12 (Building 401 and Vicinity) Summary of SRCs and Recommendations for Further Investigation

SRCs of Significance

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
Radionuclides PAHs Metals VOCs	Radionuclides Metals	None Identified	None Identified	None

Nature of Occurrence

Soil

- All samples collected from 0-0.5 feet exceeded the background UTL for at least one radiological SRC.
- Thorium-230, exceeds its background UTL by a factor of 44, in surface soil, just north of where EUs 11, 12 and 13 meet north of building 401. Radium and uranium isotopes exceeded background UTLs by factors of up to 32 in surface soils but barely at all in soils deeper than 6 inches. Cesium-137 is present in surface soil samples at up to 2.5 times the background UTL and not above the background UTL in subsurface soil.
- Metals were detected throughout the soil column with slightly more than half the background UTL exceedances at depths of more than 2 feet.
- Most metals identified as SRCs are less than 3 times their respective background UTLs.
- A few PAHs occur in both surface and subsurface soil. The two samples where these occur are located along either the rail spur or Castle Garden Road.
- VOCs are present primarily below 5 feet and are clustered north of building 401 or occur along Castle Garden road or the former rail spur into building 401. Concentrations are generally less than 90 µg/kg.

Groundwater

- Dissolved uranium occurs in a number of wells and forms a distinct plume oriented northwest to southeast just north of Building 401 in EU 13 and across the northwest corner of EU 12. Portions of this plume are not only above the background UTL but also well above the MCL.
- Several metals in groundwater exceed the background UTL for total concentration; however, most of these do not exceed the background UTLs for dissolved metals.

Sediment

- No SRCs of significance were identified in sediment at this EU.

Surface Water

- No SRCs of significance were identified in surface water at this EU.

Subsurface Utilities

- No SRCs of significance were identified in the subsurface utilities at this EU.

Relation to Site History

Radionuclides and metals may be present in EU 12 because of its proximity to drainage ditches, and Building 401 (EU 13). The presence of VOCs may be due to the use of chemicals in Building 401, or related to the use of the former rail line in the area. The PAHs are likely due to the presence of the road and rail spur.

Groundwater Fate and Transport Modeling

Groundwater modeling results indicate that the dissolved uranium plume located in the northwest corner of EU 12 exhibits little dispersion over the next 1,000 years. Uranium isotope concentrations are also not expected to greatly increase over time in this plume.

BRA – Determination of COCs and ROCs

ROCs and COCs identified by the BRA that pose risk in soil (0-10 feet) include:

Arsenic	Protactinium-231	Thorium-230
Benzo(a)pyrene	Lead-210	Thorium-232
Actinium-227	Radium-226	Uranium-238
Cesium-137	Radium-228	

COCs and ROCs identified by the BRA that pose risk in food include:

Arsenic	Actinium-227	Thorium-230
Benzo(a)pyrene	Protactinium-231	Thorium-232
Benzo(b)fluoranthene	Lead-210	Uranium-238
Indeno(1,2,3-cd)pyrene	Radium-226	

Of the ROCs, radium-226 was identified as a risk driver in soil (0-10 feet), contributing 50% or more of the cancer risk in the adult/child subsistence farmer scenario. Arsenic was identified as a risk driver in soil (0-10 feet), contributing 50% or more of the cancer risk in the adult/child subsistence farmer scenario, as well as 50% or more of the non-cancer risk in the child subsistence farmer scenario. None of the ROCs or COCs contribute 50% or more of the risk in food. Recommendations for addressing the COCs and ROCs are presented below.

Recommendations

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
The presence of COCs and ROCs identified in the RI/BRA should be further evaluated in the FS.	The presence of the uranium plume extending from EU 13 should be further evaluated in the FS.	No Further Action	No Further Action	No Further Action

7.3.13 EU 13 (Building 401 and Vicinity) Summary of SRCs and Recommendations for Further Investigation

SRCs of Significance

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
Radionuclides Metals VOCS	Radionuclides Metals SVOCS VOCs	None Identified	None Identified	Radionuclides Metals Pesticides PCBs PAHs SVOCs VOCs

Nature of Occurrence

Soil

- A majority of the surface soil samples in this EU had one or more radionuclides exceeding a background UTL. About a half had one or more metals exceeding a background UTL, and significant numbers of samples also had VOCs or SVOCs that exceed their respective background UTLs.
- Actinium-227, radium-226, thorium-230 and all three uranium isotopes as well as total uranium all exceeded their respective background UTLs by factors above 10 and reach 1200 times the background UTL for one radium-226 sample.
- The highest uranium activities were found in three areas: south of Building 401, southeast of Building 401 near a former structure, and near the intersection of Campbell Street and the north drive of Building 401.
- Only a few of the metals in this EU exceeded their respective background UTLs by more than a factor of 10.
- Metals were detected throughout the soil column with more than two thirds the samples from greater than 10 feet having metals exceeding their background UTLs. All the samples taken from beneath the building had one or more metals exceeding a background UTL.
- VOCs were present as SRCs in all depth ranges including two thirds of the samples deeper than 10 feet. In general concentrations were less than 50 µg/kg; however, in deeper soils, near 10 feet, high concentrations of TCE and cis-1,2-DCE were present in one sample. All but one sample collected from the soil column immediately beneath the building floor contain VOCs as SRCs.

Groundwater

- All of the groundwater samples from the UWBZ in this EU exceeded one or more of their respective background UTLs for either total activity for a radionuclide or total concentration of a metal.

- One groundwater sample from the LWBZ exceeded one or more dissolved background UTLs for a metal and a radionuclide.
- Quite a few metals in groundwater exceeded the background UTL for total concentration; however, only barium, boron, cobalt, manganese, nickel and thallium exceeded the background UTLs for dissolved metals. These dissolved metals exceedances were all less than a factor of 10 above the background UTL.
- One SVOC, bis(2-ethylhexyl)phthalate, was found with concentrations exceeding the background UTL in groundwater.
- There are two dissolved total uranium plumes in groundwater in EU 13. One is north of the north drive of Building 401 and extends northwest into EU 12. The other is extensive and covers the entire southwestern portion of EU 13 from Building 401 to the EU boundary.
- A boron plume is in the east central portion of the EU. This plume extends from the northern boundary of the EU south across the eastern portion of Building 401, and south of the driveway on the south side of the building.

Sediment

- No SRCs of significance were identified in sediment at this EU.

Surface Water

- No SRCs of significance were identified in surface water at this EU.

Subsurface Utilities

- Three metals (boron, cadmium and mercury) in utilities sediments exceed their respective background UTLs by more than a factor of 100 and a number of others exceed their respective background UTLs by a factor of 10 to 100.
- Pesticides and PCBs in utilities sediment exceed their background UTLs by factors as much as 10,000 or more.
- Several PAHs, VOCs, and SVOCs exceed background UTLs in sediment.
- Uranium isotopes frequently exceed background UTLs in sediment by factors less than 10, and radium-226, thorium isotopes, and uranium isotopes exceeded background UTLs in water by factors generally less than 10.

Relation to Site History

Radionuclides may be present in EU 13 because of the use of Building 401 as a storage area. The wide spread presence of metals and VOCs is likely related to their use in Building 401. The non-radioactive isotope boron-10 was produced in Building 401. Boron was widely found in this EU and its presence in soil and groundwater is likely a result of the boron-10 processes performed in Building 401. The presence of bis(2-ethylhexyl)phthalate is like due to normal construction and industrial operations.

Groundwater Fate and Transport Modeling

The groundwater flow and transport model indicates that the existing boron plume in EU 13 exhibits little dispersion over 1,000 years, and the maximum concentration of this metal in groundwater is not expected to increase above the current concentration of the plume. Concentrations of boron that exceed the screening level are not expected to migrate vertically below the base of the Brown Clay Till (i.e., to a depth of approximately 15 feet in EU 13).

Groundwater modeling results indicate that the dissolved uranium plume located in the southern portion of EU 13 exhibits little dispersion over the next 1,000 years, and uranium isotope concentrations are not expected to greatly increase over time in this plume.

BRA – Determination of COCs and ROCs

ROCs identified by the BRA that pose a risk in soil (0-10 feet) include:

Actinium-227	Radium-226
Protactinium-231	Thorium-230
Lead-210	Uranium-238

COCs and ROCs identified by the BRA that pose a risk in food include:

Aroclor-1254	Zinc	Lead-210
Boron	Actinium-227	Radium-226
Copper	Protactinium-231	Thorium-230

COCs and ROCs identified by the BRA that pose a risk in groundwater include:

Arsenic	Manganese	Lead-210
Boron	Lead	Radium-226
Bis(2-ethylhexyl)phthalate	TCE	Uranium-234
Cis-1,2-DCE	Vanadium	Uranium-238
Copper	Cesium-137	

Of the ROCs, radium-226 was identified as a risk driver in soil (0-10 feet), contributing 50% or more of the cancer risk in the adult/child subsistence farmer scenario. Arsenic was identified as a risk driver in groundwater, contributing 50% or more of the cancer risk in the adult/child subsistence farmer scenario. Recommendations for addressing the COCs and ROCs are presented below.

Recommendations

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
The presence of COCs and ROCs identified in the RI/BRA should be further evaluated in the FS.	The presence of COCs and ROCs identified in the RI/BRA should be further evaluated in the FS.	No Further Action	No Further Action	The presence of pesticides, PCBs and metals in the drains should be further evaluated in the FS. See also Section 7.3.16 (EU 16).

7.3.14 EU 14 (Building 401 and Vicinity) Summary of SRCs and Recommendations for Further Investigation

SRCs of Significance

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
Radionuclides	Radionuclides	None Identified	None Identified	None Identified
Metals				
VOCs				

Nature of Occurrence

Soil

- The majority of SRC exceedances of the radionuclide background UTLs were present within the upper 6 inches of soil.
- Radium-226 exceeded its background UTLs by a factor of 300, in surface soil, in the southeastern most corner of the EU. Thorium and uranium isotopes exceeded background UTLs by factors of 1 to 3 in soils up to 8 feet deep along the boundary with EU 13 and 12. Cesium-137 was present in surface soil samples at up to 4 times the background UTL and also was found in a sample at 7 feet below grade in the middle of the EU.
- Metals were detected throughout the soil column with slightly more than half the background UTL exceedances at depths of more than 2 feet.
- Most metals identified as SRCs were only 2 to 5 times their respective background UTLs; however, at least one (boron) is 150 times the background UTL.
- VOCs were present primarily below 2 feet and are clustered in the area between the southern boundary of EU 13 and the former rail spur.

Groundwater

- Total uranium occurs in several wells although not in the form of a defined plume.

Sediment

- No SRCs of significance were identified in sediment at this EU.

Surface Water

- No SRCs of significance were identified in surface water at this EU.

Subsurface Utilities

- No SRCs of significance were identified in the subsurface utilities at this EU.

Relation to Site History

Radionuclides may be present in EU 14 because of its proximity to transportation routes and Building 401 (EU 13). The slightly elevated levels of cesium-137 in soils may be attributed to the transportation or storage of KAPL wastes in EU 13. The presence of VOCs and metals may be due to the use of chemicals in Building 401, or related to the use of the former rail line in the

area. The VOCs may also be related to the former AEC sludge pit that was located in the northwest portion of the EU.

Groundwater Fate and Transport Modeling

No groundwater contaminant plumes were identified in EU 14. Furthermore, groundwater modeling results do not indicate any exceedance of screening or risk levels associated with the fate and transport of contaminants in EU 14.

BRA – Determination of COCs and ROCs

COCs and ROCs identified by the BRA that pose risk in food include:

Boron	Actinium-227	Lead-210
Di-n-octylphthalate	Protactinium-231	Radium-226

ROCs identified by the BRA that pose risk in soil (0-10 feet) include:

Actinium-227	Lead-210
Cesium-137	Radium-226
Protactinium-231	

Radium-226 was identified as a risk driver in soil (0-10 feet), contributing 50% or more of the cancer risk in the adult/child subsistence farmer scenario. Boron was identified as a risk driver in food, contributing 50% or more of the non-cancer risk in the individual scenarios for the adult and child subsistence farmers. Recommendations for addressing the COCs and ROCs are presented below.

Recommendations

Soil	Groundwater	Sediment	Surface Water	Subsurface Utilities
The presence of COCs and ROCs identified in the RI/BRA should be further evaluated in the FS.	No Further Action	No Further Action	No Further Action	Not Applicable

7.3.15 EU 15 (Interconnected Drainageways) Summary of SRCs and Recommendations for Further Investigation

SRCs of Significance

Sediment	Surface Water
None Identified	Metals Radionuclides VOCs

Nature of Occurrence

Sediment

- No SRCs of significance were identified in sediment at this EU. However, metals were detected in the sediment at levels slightly exceeding the background UTL at several locations in the interconnected drainageways. A VOC, methylene chloride, was detected at one sediment sample in the South 16 Ditch in EU 8.

Surface Water

- Several metals were found in the Central Drainage Ditch at levels approximately 2 times the background UTL. Dissolved silver was detected at levels approximately 20 times the background UTL at one location just inside the site boundary in the Modern Ditch and at the next three samples downstream from it in the South 31 Ditch. The three samples taken from the South 16 Ditch also exhibited dissolved silver at these levels.
- Thorium-232 was detected at five locations, three in the Central Ditch and two in the South 31 Ditch. Radium-226 was also detected at levels slightly above the background UTL at two of these locations. However, the fact that radionuclide concentrations do not exceed background UTLs at sampling locations near the northern boundary of the property suggests that radiological SRCs are not migrating off-site.
- Two VOCs, 4-methyl-2-pentanone and benzene, were detected in an isolated sample collected at the conjunction of the South 31 Ditch and the Modern Ditch.

Relation to Site History

Metals and radionuclides in the interconnected drainageways may be the result of past activities including the construction and filling of the IWCS, as well as runoff from currently contaminated surface soil. Metals, specifically dissolved silver, may also be entering the site from surface water to the east and south. The VOCs are likely a result of the nearby AEC sludge pit as surface and subsurface soil samples near this location also exhibited concentrations of VOCs above the background UTL.

Groundwater Fate and Transport Modeling

EU 15 interconnected waterway sediments and water were not addressed in the groundwater fate and transport modeling; however, SRCs in surface water and sediment within the interconnected drainageways are likely migrating offsite at concentrations above background levels. SRCs in groundwater could migrate to surface water and sediment in drainageways where the groundwater table is above the elevation of the bottom of the drainageway. This likely occurs in the Central

Ditch which appears to be hydraulically connected to the UWBZ. SRCs in surface water have the potential to migrate to groundwater only when surface water in the drainageways is flowing above the elevation of the groundwater table.

BRA – Determination of COCs and ROCs

No human health COCs or ROCs were identified for sediment or surface water at any of the 14 physical EUs or in interconnected drainageways (EU 15) due to the short duration of exposure for individuals who may come in contact with surface water or sediment at NFSS. Based on the SERA, no radionuclide SRCs in the surface water or sediment had the potential to pose adverse effects to ecological receptors. The SERA did not eliminate the possibility for ecological risk for some chemical SRCs in surface water and sediments; however, further evaluation using a WOE assessment revealed relatively healthy and functioning terrestrial and aquatic systems. The WOE assessment concluded no further action is necessary for managing ecological resources at NFSS.

Recommendations for addressing EU 15 sediments and water are addressed below.

Recommendations

Sediment	Surface Water
No Further Action	No Further Action

7.3.16 EU 16 (Pipelines and Subsurface Utilities) Summary of SRCs and Recommendations for Further Investigation

SRCs of Significance

Subsurface Utilities- Sediment	Subsurface Utilities- Surface Water
Radionuclides	Radionuclides
PAHs	PAHs
Metals	Metals
VOCs	VOCs
Pesticides	
PCBs	

Nature of Occurrence

Sediment

- Uranium isotopes were detected above the background UTLs in sediment in a sanitary sewer line southwest of the intersection of O Street and Campbell Street in EU 2. Cesium-137 was also detected above the background UTL in sediment in a storm sewer line near Campbell Street. Cesium-137, radium-226, and uranium isotopes were detected above the background UTLs in sediment throughout EU 4. Radiological SRCs were also detected above the background UTLs in several pipeline sediment samples in EU 8 with the uranium isotopes exceeding the background UTL by as many as 29 times. Sediment samples collected from two sanitary sewer manholes located southeast of the IWCS in EU 10 had elevated levels of thorium and uranium isotopes that were approximately 2 times the background UTL.
- Seven PAHs were detected in sediment from two locations on the storm sewer system in EU 2. Several PAHs were also detected in sediment from multiple locations in subsurface utilities in EU 4. PAHs exceeding the background UTL by approximately 2 to 3 times were found in the pipeline sediment at EU 8. Ten PAHs exceeded their background UTLs by a factor of 10 or more in EU 11 sediment. Several PAHs also appeared in the sediment drain samples in EU 13.
- VOCs were detected in multiple locations in sediment from the drain samples in Building 401 within EU 13 with two locations exceeding the background UTL by 20 times or greater. VOCs were also detected above the background UTL at four locations in the EU 8 subsurface utilities. Three of the VOCs exceeded their background UTL by more than 10 times.
- Three metals (boron, cadmium and mercury) in subsurface utility sediments from EU 13 exceeded their respective background UTLs by more than a factor of 100. A number of others metals exceeded their respective background UTLs by a factor of 10 to 100 in EU 13.
- Several pesticides were found in six subsurface utility samples in EU 4 with concentrations exceeding the background UTL by as many as 600 times. Pesticides were also found in the drains in Building 401 at concentrations up to approximately 27,000 times the background UTL.

- PCBs in sediment from the drains in Building 401 in EU 13 exceeded their background UTLs by factors ranging from 14 to approximately 1,400. Aroclor-1260 concentrations exceeded the background UTL in 5 locations in EU 4 by factors ranging from 14 to 100 times.

Water

- Cesium-137, radium-226, thorium isotopes, and uranium isotopes were detected above background UTLs in water from the subsurface utilities within EU 4. Radiological SRCs were detected above the background UTLs in several pipeline water samples in EU 8. Elevated concentrations of uranium isotopes in both the dissolved and total phases were observed in water samples collected from two sanitary sewer manholes located southeast of the IWCS in EU 10. One manhole had concentrations of uranium isotopes that exceeded the background UTLs by a factor of 20 to 130 times. Several radionuclides occurred at concentrations exceeding the background UTL in EU 13, with uranium-234 and uranium-238 more than 10 times the background UTL in one drain sample in Building 401.
- Several PAHs were detected in water from the subsurface utilities within EU 4 at concentrations up to approximately 280 times the background UTL.
- Several metals in water samples from the subsurface utility lines in EU 11 exceeded their respective background UTLs by factors of up to 27. The same was true of radionuclides (uranium-234, uranium-235 and uranium-238) in the water samples. Numerous metals exceeded the background UTL in both the dissolved and total phase in four drain samples from Building 401 and two samples outside the building in EU 13.
- VOCs were detected in multiple locations in water from the subsurface utilities within EU 4; two locations have concentrations of PCE greater than 20 times the background UTL. Two VOCs were also found at concentrations exceeding the background UTL in three of the drain samples in Building 401.

Relation to Site History

Radionuclides may exist in the pipeline sediments and water as a result of residues being stored and staged in various buildings onsite, primarily in EUs 4, 10, and 13. Constituents found in subsurface utilities in the EU 8 shops area, including metals, SVOC, VOCs, PCBs and PAHs, are likely from historical operations conducted in these buildings. These compounds are prevalent in oils, solvents, paints and lubricants that would have been used at the former building locations. Pesticides may be present in the subsurface utilities as a result of a possible spill in a storage area or surface drainage into manholes. It is possible that the pipelines and surrounding gravel-fill provide a pathway for SRCs to travel between EUs and may explain the existence of constituents in many of the areas. Some of the results, especially in EU 4, are very high but not wide-spread. This may be an indication of intentional, though improper, past disposal practices. Also, many manholes are damaged and allow surface water to enter the sewer system. Finally, given the age and generally poor repair of the system, infiltration and exfiltration are likely occurring.

Groundwater Fate and Transport Modeling

EU 16 subsurface utilities sediments and water were not addressed in the groundwater fate and transport modeling.

BRA – Determination of COCs and ROCs

No COCs or ROCs were identified for EU 16 because the BRA assumes that the subsistence farmer will not be exposed to the subsurface utilities. However, the high concentrations of constituents found in both the sediment and water in these utilities could remain a potential risk for construction workers exposed to the pipeline contents and a potential source for groundwater migration. Because of this, EU 16 pipeline sediments should be screened against the soil cleanup levels developed in the FS.

To be consistent with the LOOW BRA, the NFSS BRA considered increased exposure duration to contaminated sediment and surface water for the construction worker. Increasing construction worker exposure duration to sediment and surface water at the NFSS results in additional COCs. These COCs should be considered for the construction worker during development of the FS.

Recommendations

Subsurface Utilities- Sediment	Subsurface Utilities- Water
The presence of SRCs should be further evaluated in the FS with respect to groundwater plumes and soil contamination.	The presence of SRCs should be further evaluated in the FS with respect to groundwater plumes and soil contamination.

7.3.17 EU 17 (Sitewide Media) Summary of SRCs, COCs/ROCs, and Recommendations for Further Investigation

SRCs of Significance

Sitewide Groundwater

Radionuclides

Metals

SVOCs

VOCs

Over 200 groundwater samples were collected on the NFSS. These samples were analyzed for dissolved and total metals and radionuclides, semi-volatile and VOCs, pesticides and PCBs. Many of the samples were taken from TWPs in addition to the 85 permanent wells installed on the site.

Nature of Occurrence

- The UWBZ has a very erratic piezometric surface as shown in Figure 5-16. The depth to groundwater across the site varies greatly and, to a large degree, is a function of the presence or absence of sand lenses in the subsurface.
- The hydraulic conductivity in the UWBZ varies greatly across the site. In wells that did not intersect large sand lenses, the hydraulic conductivities are on the order of 10^{-7} cm/sec or less. Table 5-1 summarizes the hydraulic conductivities at the site.
- Groundwater plumes containing radionuclides, metals and organic compounds were identified in the UWBZ; however, no groundwater plumes were identified in the LWBZ.

Radionuclide groundwater plumes found in the UWBZ are shown on Figures 5-4 and 5-7. Most of these plumes are geographically associated with past site uses or activities.

- A dissolved total uranium groundwater plume was found to extend from the west-central portion of EU 2 through the northwest portion of EU 1. Based on current data, there is a potential that the plume extends off site north of EU 1.
- A dissolved total uranium groundwater plume is present in the north-central portion of EU 4 near the former nitric acid concentrator. The concentrations of dissolved total uranium in this plume are approximately twice the background UTL of 16.7 µg/L.
- A dissolved total uranium groundwater plume is present in the southeastern portion of EU 8. The plume appears to be approximately centered beneath a large debris pile located west of Castle Garden Road and south of Z Street. A second dissolved total uranium plume is present in the southwestern portion of the EU near former Building 423. This plume may be associated with the utility lines in this area.
- Several dissolved total uranium groundwater plumes were identified around the IWCS. Groundwater near the north and west sides of the IWCS is impacted with uranium. There are also minor isolated plumes east of the IWCS and in the western portion of EU 7. A

dissolved total uranium plume, located south of the IWCS in EUs 10 and 11, appears to be associated with the sanitary sewer and water lines in this area.

- A dissolved total uranium groundwater plume was identified northwest of Building 401, in EU 12. Concentrations of dissolved total uranium in this plume were approximately 2 to 3 times the background UTL of 16.7 µg/L.
- A dissolved total uranium groundwater plume was also identified in the area south of Building 401. Concentrations of dissolved total uranium in this plume were up to 3 times the background UTL of 16.7 µg/L.
- Two dissolved thorium-230 groundwater plumes are situated at the boundaries of EU 10. One extends south into EU 11, south of the IWCS, and one extends north into EU 7 near the organic burial area.
- Groundwater plumes for uranium-234 and uranium-238 were identified in the south-central portion of EU 14, in an area not previously known to be impacted by past site activities. However, these plumes are based on groundwater results from two widely separated wells. The large distance between the two wells, over 400 feet, decreases the certainty associated with the plume determination.

Groundwater plumes containing metals and organic compounds were identified in the UWBZ. Most of these plumes are geographically associated with past site uses or activities.

- The data indicate that there is a boron plume in the central portion of EU 4 as shown on Figure 5-6.
- A north-south trending boron plume was found within the central portion of EU 13 as shown on Figure 5-14. Some of the water samples collected from the Building 401 floor drains also exhibited concentrations of dissolved boron that were high relative to the background UTL.
- Seventeen VOCs and four SVOCs were detected in EU 4 groundwater samples at concentrations above background UTLs. Several of these compounds were found in several wells. Figures 5-8 through 5-12 show the extent of these plumes. Concentrations of these VOCs within these plumes greatly exceed the MCLs. Groundwater plumes containing the following compounds are present in EU 4:
 - PCE
 - TCE
 - Cis-1,2-DCE
 - Trans-1,2-DCE
 - Vinyl Chloride

Relation to Site History

All of the delineated groundwater plumes are located in areas where site history indicates that activities occurred involving the constituents identified in the plumes. Section 3 of this report indicates that many of the wells were placed specifically to investigate the impact of these site activities on groundwater. Many groundwater plumes occur near former buildings where

materials were used or stored. There are some site areas where materials were buried or where drums were found that may have contained the constituents identified in groundwater plumes. In some cases, there appears to be a relationship between buried utilities and groundwater concentrations of SRCs.

The plumes to the north-northwest and to the south-southeast of the IWCS are likely remnants of contamination present before construction of the IWCS or contamination generated during construction of the IWCS. Groundwater contamination resulting from the unprotected storage of the R-10 residues was identified in 1980 (Battelle 1981) at concentrations similar to levels detected in groundwater samples taken during this RI. Although the clay cutoff wall was installed around the R-10 pile in 1982, residual contamination in the saturated zone outside the wall persists to the north and west of the original R-10 pile. In addition, localized areas of elevated activity ranging from 15,000 to 53,000 cpm (see Figure 3-4) were identified north of the IWCS during the gamma walkover survey. Leaching from these surface soils could be affecting wells in this area.

In addition, in 1985 as the K-65 residues were transferred to Building 411 from the tower, Building 409 was used as a settling tank in the treatment of slurry water. According to construction reports (BNI 1984b, BNI 1985), treated slurry water from various bays in Building 411 was pumped to Building 409 for additional settling prior to its transfer to Ponds 3 and 4. Building 409 underwent a gross decontamination operation using a high pressure wash in October 1985 after removal of the 'yellow cake' that had accumulated during its use as an intermediate settling basin. The building, which is outside the IWCS cutoff wall, was then demolished, filled with concrete and covered with soil. This information suggests that there is a strong potential for the residual groundwater contamination present south of the IWCS to be associated with these historical operations.

Groundwater Fate and Transport Modeling

Groundwater modeling results indicate that only minor dispersion of the VOC plume in EU 4 occurs due to low infiltration rates. This plume is not predicted to migrate offsite. As biodegradation occurs, PCE and TCE concentrations gradually decline while degradation products increase slightly in the first 50 years. PCE, TCE, cis-1,2-DCE, and vinyl chloride are all expected to degrade to levels less than the screening values within 300 years in the Brown Clay Till. Modeling results also predict that the bis(2-ethylhexyl)phthalate plume in EU 10 will exhibit only minor dispersion within the Brown Clay Till within 1,000 years. SESOIL modeling results indicate that methylene chloride may leach to groundwater within 50 years; however, concentrations never exceed the screening level. Additionally, the groundwater fate and transport model indicates that concentrations of methylene chloride never exceed the screening level in groundwater.

Several metals are predicted to leach from the IWCS within 1,000 years. Groundwater modeling results predicts only minor dispersion of these metals due to minimal infiltration rates. Modeling also predicts that these metals will not migrate offsite in groundwater at concentrations above screening levels in the vicinity of the IWCS.

The groundwater flow and transport model indicates that boron and manganese are the only two metals that exceed screening levels in groundwater within 1,000 years at the NFSS. The existing boron and manganese plumes in EUs 3, 4, and 13 also exhibit little dispersion over 1,000 years, and the maximum concentrations of these metals in groundwater are not expected to increase above the current concentrations of the plumes. Concentrations of boron and manganese that

exceed the screening levels are not expected to migrate vertically below the base of the Brown Clay Till (i.e., to a depth of approximately 15 feet in EUs 3, 4, and 13).

Based on model simulations, uranium isotopes are predicted to migrate offsite within 1,000 years at concentrations that exceed the screening levels. This offsite migration is predicted to occur in EUs 1, 7 and 8. Potential offsite migration of radionuclide concentrations on the east side of EU 8 is a primary concern. Within 1,000 years, U-234 and U-238 are predicted to migrate offsite at concentrations that exceed risk levels by a factor of approximately 10. These concentrations are due to a source term derived from the SESOIL modeling which predicts leaching to groundwater from contaminated site soils. Existing dissolved uranium plumes in EUs 1 and 7 are predicted to migrate offsite within 1,000 years at concentrations that only slightly exceed risk levels. However, conclusions made regarding the fate and transport of radionuclides in site groundwater are somewhat dependant on the conservative K_d value of 3.6 L/kg that was used in the modeling simulations. Use of this K_d value causes the model to predict greater concentrations of radionuclides in groundwater due to increased leaching of site soils. The results of a sensitivity analysis for the uranium K_d value are discussed in Section 6.6.4. A modified K_d value for uranium may be used in the FS for determining cleanup criteria.

Within 1,000 years, the maximum concentrations of uranium isotopes are predicted to occur in the Brown Clay Till beneath the IWCS, near Building 411 (see Table 6.4). Additionally, model results indicate that the screening levels for uranium-234 and uranium-235 will be exceeded in even the deepest of the aquifers (the upper Queenston Formation) within 1,000 years. This is likely the result of potential leaching of residues within Building 411 in the IWCS. Other than the uranium-isotopes, thorium-230 is the only radionuclide that exceeds its screening level in the Brown Clay Till within 1,000 years, likely due to existing groundwater contamination in EU 7. However, thorium-230 is not expected to migrate below the Brown Clay Till within 1,000 years at concentrations that exceed the screening level.

All modeled radionuclides are predicted to exceed screening levels in the Brown Clay Till in 10,000 years. Of these constituents, only uranium isotopes and thorium-230 are predicted to migrate below the Glacio-Lacustrine Clay at concentrations that exceed screening levels, with the maximum concentrations of the isotopes being below the IWCS. Within 10,000 years, uranium isotopes are predicted to exceed screening levels in the Queenston Formation and thorium-230 is predicted to slightly exceed its screening level in the Alluvial Sand and Gravel. The rest of the daughter products do not approach their respective screening levels in any layer below the Glacio-Lacustrine Clay. Concentrations of actinium-227 and protactinium-231 in groundwater increase within each model layer up to 10,000 years due to ingrowth.

Two thorium-230 plumes located near the site boundary (one in EU 4 and one in EU 7/10) were evaluated for future risks due to ingrowth because it is feasible that radium concentrations in groundwater could increase in the presence of parent thorium isotopes: Th-230 for Ra-226 and Th-232 for Ra-228. It is concluded that existing reported radium concentrations in the EU 4 and EU 7/10 plumes are less than the MCL now (considering both total and dissolved results) and the potential for ingrowth would not result in an exceedance over the next 1,000 years without the introduction of a secondary source of contamination.

BRA – Determination of COCs and ROCs

The following ROCs and COCs were identified for EU 17 in the BRA.

Arsenic	Methylene chloride
Boron	Lead-210
Lead	Radium-226
Manganese	Radium-228
Vanadium	Uranium-234
Bis(2-ethylhexyl)phthalate	Uranium-238
PCE	

PCE was identified as a COC risk driver. Radium-226 was identified as an ROC risk driver.

Recommendations

Sitewide Groundwater

The presence of COCs and ROCs identified in the RI/BRA should be further evaluated in the FS.

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