US Army Corps of Engineers
Buffalo District
BUILDING STRONG®

Field Investigation Report

Final

Balance of Plant Operable Unit

Investigation to Refine the Extent of Soil Contamination

Niagara Falls Storage Site
Lewiston, New York

Contract No. W912QR-12-D-0023

Delivery Order No. DN02

U.S. Army Corps of Engineers
Buffalo District
Buffalo, New York

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February 2015

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LIST OF ACRONYMS AND ABBREVIATIONS

Ac	actinium
AEC	Atomic Energy Commission
ALARA	as low as reasonably achievable
AOC	area of concern
APP	Accident Protection Plan
ASTM	American Society for Testing and Materials
BAASS	Bayesian Approaches to Adaptive Spatial Sampling
bkgd	background
BOP	Balance of Plant
bgs	below ground surface
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
cm	centimeter(s)
cm/sec	centimeters per second
cpm	counts per minute
COC	chemical of concern
CQC	contractor quality control
Cs	cesium
DCGL	derived concentration guideline level
DOT	Department of Transportation
DQCR	daily quality control report
EM	electromagnetic or engineering manual
EPA	Environmental Protection Agency
ERPIMS	Environmental Resources Program Information Management System
EU	exposure unit
EX	excavation (radiation survey code)
FS	feasibility study
FSP	Field Sampling Plan
ft	feet/foot
FUSRAP	Formerly Utilized Sites Remedial Action Program
GPS	global positioning system
GW	groundwater
GWS	gamma walkover survey
HWP	hazardous or hot work permit
IE	investigative excavation
in	inch(es)
IN	incoming (radiation survey code)
IWCS	Interim Waste Containment Structure
IDW	investigation-derived waste
LOOW	Lake Ontario Ordnance Works
LWBZ	lower water-bearing zone
LWTP	Lockport Wastewater Treatment Plant
m	meter(s)
MARLAP	Multi-Agency Radiological Laboratory Analytical Protocols Manual
MED	Manhattan Engineer District
MH	manhole
MD	matrix duplicate
MDL	method detection limit

LIST OF ACRONYMS AND ABBREVIATIONS (Cont'd)

MS	matrix spike
MSD	matrix spike duplicate
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µR/h	microroentgen per hour
m	meter(s)
m^2	square meter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mm	millimeter(s)
mrem	millirem
mmho/m	millisiemens per meter
mV	millivolt(s)
MW	monitoring well
NAD	North American Datum
NaI	sodium iodide
NGVD	National Geodetic Vertical Datum
NFSS	Niagara Falls Storage Site
NRC	Nuclear Regulatory Commission
NUREG	U. S. Nuclear Regulatory Commission
NYCRR	New York Codes, Rules, and Regulations
OT	outgoing (radiation survey code)
OU	operable unit
Pa	protactinium
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PE	pipeline excavation
PCBs	polychlorinated biphenyls
PAHs	polycyclic aromatic hydrocarbons
PID	photoionization detector
PPE	personal protective equipment
PQL	practical quantitation limit
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
QCP	Quality Control Plan
QAPP	Quality Assurance Project Plan
Ra	radium
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
ROC	radionuclide of concern
RPP	Radiation Protection Plan
RSL	regional screening level
RT	routine (radiation survey code)
RWP	radiation work permit
SCO	soil cleanup objective
SAP	Sampling and Analysis Plan

LIST OF ACRONYMS AND ABBREVIATIONS (Cont'd)

SD	standard deviation
SMS	safety management standard
SOP	standard operating procedure
SOR	sum of the ratios
sq	square
SRSO	site radiation safety officer
SSHO	site safety and health officer
SSHP	site safety and health plan
SVOC	semi-volatile organic compound
TB	test boring
TED	total effective dose
Th	thorium
TN	trench (radiation survey code)
TNT	trinitrotoluene
U	uranium
U-235	uranium-235
U-238	uranium-238
URS	URS Group, Inc.
US	United States
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USDOE	United States Department of Energy
UST	underground storage tank
UWBZ	upper water-bearing zone
VOC	volatile organic compound
WTS	Waste Technology Services, Inc.

1.0 INTRODUCTION

URS Group, Inc. (URS) has prepared this document under Contract 912QR-12-D-0023. As part of this contract, URS conducted an investigation to refine the extent of soil contamination at the balance of plant (BOP) operable unit (OU) at the Niagara Falls Storage Site (NFSS) in October through December 2013 and June and July 2014. This report presents a description of the methods, procedures, and findings of the investigation.

URS performed the investigation in accordance with the following planning documents prepared by URS, dated October 2013:

- *Sampling and Analysis Plan* (SAP)
  - Volume 1 – *Field Sampling Plan* (FSP)
  - Volume 2 – *Quality Assurance Project Plan* (QAPP)
- *Accident Prevention Plan* (APP)
- *Site Safety and Health Plan* (SSHP)
- *Radiation Protection Plan* (RPP)
- *Quality Control Plan* (QCP)

1.1 Site Description

The NFSS is located at 1397 Pletcher Road in the Town of Lewiston (Figure 1). The NFSS, approximately 191 acres in size, represents a portion of the Lake Ontario Ordnance Works (LOOW), a former trinitrotoluene (TNT) production plant which shut down in 1943. Portions of the LOOW site were used by the United States Army Corps of Engineers (USACE) Manhattan Engineer District (MED) and U.S. Atomic Energy Commission (AEC) to store radioactive residues and other materials beginning in 1944. Much of the radioactive residues sent to the NFSS originated from uranium processing activities conducted for MED and AEC at the Linde Air Products facility in Tonawanda, New York, the Mallinckrodt Chemical Works refinery in St. Louis, Missouri, and the Middlesex Sampling Plant in Middlesex, New Jersey.

Radiological constituents of concern at NFSS include isotopic uranium (U), isotopic thorium (Th), and radium (Ra)-226/228. Other constituents that occur on site in lesser amounts include daughter products of the uranium series (uranium-238 [U-238]) and, to some extent, the actinium (Ac) series (uranium-235 [U-235]). Some organic contaminants are also present at the NFSS.

Between 1982 and 1986, the United States Department of Energy (USDOE) consolidated radioactive materials from a portion of the LOOW into a 10-acre Interim Waste Containment Structure (IWCS) on the NFSS (see Figure 2). The IWCS is an engineered landfill designed to retard radon emissions, infiltration from precipitation, and migration of contamination to groundwater. The remainder of the site is referred to as the BOP.

1.2 Site Geology

The geology of the NFSS is presented below, from shallowest to deepest:

- 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 0 to 1.5 meter (m) (0 to 5 feet [ft]), with an average range of 0.3 to 0.6 m (1 to 2 ft). The landscape in some areas of the NFSS is routinely maintained and contains several centimeters (cm) (inches [in]) of loamy topsoil and grass.

- 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 thickness of the unit varies from 1.8 to 7 m (6 to 23 ft). 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 more common in the basal portion of the unit.

  The sand and silt lenses in the basal portion of this unit range from thin partings (i.e., small joints in clay) up to 1.5 m (5 ft) in thickness. 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. 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 5.3 to 6.1 m (17.5 to 20 ft) in thickness occur within the Brown Clay Unit.

- Gray Clay Unit - The Gray Clay Unit, also known as the "Glacio-Lacustrine Clay Unit," is of lacustrine origin. Coarse-grained sand and gravel lenses of the Brown Clay Unit are found intermittently along the top of the Gray Clay Unit and are not representative of a contiguous lithologic unit. The Gray Clay Unit occasionally grades vertically to a silt and sand mixture and lenses of fine to medium-grained sand are dispersed throughout the unit. A "Middle Silt Till Unit" is found occasionally off site where the lower portion of the Gray Clay Unit is absent. 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 1.5 to 9.1 m (5 to 30 ft) and it is the thickest unconsolidated unit at the NFSS.

- 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 glaciofluvial in origin, 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 underlying bedrock.

  The Sand and Gravel Unit is approximately 0.9 to 2.1 m (3 to 7 ft) in thickness and occurs 4.6 to 8.5 m (15 to 28 ft) below ground surface (bgs).

- Red Silt Unit - The Red Silt Unit, referred to as the "Basal Red Till," consists of angular fragments of red shale bedrock in a sandy silt matrix that suggests that this is a 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 0 to 2.1 m (0 to 7 ft). The top of the Red Silt Unit varies across the NFSS from a minimum of 5.1 m (17 ft) bgs to a maximum of 13.7 m (45 ft) bgs. The base varies from 6.7 to 14.9 m (22 to 49 ft) bgs.

- Queenston Formation - The Queenston Formation is the uppermost bedrock unit beneath the NFSS and consists of brownish red shale, siltstone, and mudstone. The top 1.8 to 3.7 m (6 to 12 ft) of the Queenston Formation are moderately weathered, fractured and more permeable than lower portions of the formation. The Queenston Formation is typically encountered 9.75 to 14.9 m (32 to 49 ft) bgs.

1.3 Site Hydrogeology

There are two water-bearing zones identified at the NFSS: 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 common in the Brown Clay Unit. Based on boring logs and recent statistical analysis, these sand seams, pockets, and lenses are intermittent and vertically and horizontally discontinuous. 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, these sand seams, pockets, and lenses are intermittent and vertically and horizontally discontinuous. USACE 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 4.6 to 6.1 m (15 to 20 ft).

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 NFSS and localized flow paths are common within a regional, northwesterly gradient.

The underlying 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 representative of the UWBZ.

The LWBZ extends from the bottom of the Gray Clay Unit to the bottom of the weathered zone of the Queenston Formation and consists of the stratified sands and gravels of the Sand and Gravel Unit, the dense silt and sands of the Red Silt Unit, and the weathered and fractured upper portions of the Queenston Formation. The thickness of the LWBZ varies from about 3.0 to about 11.7 m (10 ft to about 38.5 ft). The LWBZ has significantly higher permeability and more lateral continuity than the UWBZ.

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 to the south and east of the site.

1.4 Project Objectives

During development of a previous remedial investigation (RI), the NFSS was divided into exposure units (EU). An EU is defined as the geographic area in which a future receptor (for purposes of the baseline risk assessment) is assumed to work or live, and where a receptor may be exposed to site-related soil contaminants. Figure 2 presents the overall site layout showing the locations of the EUs.

The objective of the field investigation was to delineate the vertical and horizontal extent of contamination in surface and subsurface soils at locations across NFSS in support of the BOP OU feasibility study (FS). The scope of work for the investigation included:

- Delineate soil contamination at 478 locations across the NFSS,
- Expose and evaluate the former LOOW sanitary sewer in EU10 and EU11,
- Perform a geophysical survey in the area south of the IWCS to identify the presence of buried structures, and
- Manage/sample/dispose of existing investigation-derived waste (IDW) and IDW generated during the field investigation.

1.5 Scope of BOP OU Investigation to Refine the Extent of Soil Contamination

The BOP OU investigation to refine the extent of soil contamination (herein also referred to as the delineation investigation) was performed at locations shown in Figure 3. The scope of the delineation investigation was presented in the FSP prepared by URS dated October 2013. The subsurface portion of the investigation included:

- Advancing soil borings at 380 locations across the NFSS to depths of approximately 0.9 m (3 ft), and
- Retaining soil samples from the 0- to 15-cm (0- to 0.5-ft) interval, 15- to 61-cm (0.5- to 2-ft) interval, and 61- to 91-cm (2- to 3-ft) interval for laboratory analysis of select radionuclides; some samples were also analyzed for polycyclic aromatic hydrocarbons (PAHs).

During the course of the investigation, USACE directed URS to perform additional work consisting of the following:

- Advancing additional soil borings at 98 locations, and
- Collecting additional soil samples from depths down to 2.1 m (7 ft) in select borings to bound the depth of contamination.

As stated in the BOP Operable Unit *Field Investigation Report*, dated August 2013, the groundwater analytical data shows that total uranium-impacted groundwater is present in areas where USDOE remedial activities were known to occur. Historical aerial photographs show land scarring in the OW11B area during the time of USDOE remediation activities. During the BOP OU field investigation, uranium impacts were detected in the groundwater collected from the area between the buried pipes and from along the top of the concrete-encased sanitary sewer in the OW11B area might be associated with those former remediation activities. Part of the scope of work for the current investigation was to further characterize the sanitary sewer in the OW-11B area. Specific activities included:

- Excavating six investigative trenches (referred to as Investigative Excavations 9 through 12 [IEMH06 and IE9 through IE12]), and
- Removing one manhole (MH06).

During the course of the investigation, URS performed additional work consisting of plugging manhole MH09, which is the next downgradient manhole from MH06.

Other activities performed during the investigation included:

- Global positioning system (GPS) gamma walkover surveys (GWSs),

- Soil and trench radiological surveys,
- Radiation support surveys,
- Geophysical survey,
- Investigation location coordinate and elevation surveys,
- Excavation dewatering,
- Health and safety monitoring,
- Laboratory analyses of soil and groundwater samples for radionuclides and some soil samples for PAHs,
- Laboratory analyses of IDW samples for radionuclides, metals, pesticides, herbicides, PAHs, polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs), and semi-volatile organic compounds (SVOCs), and
- IDW management including off-site disposal.

The investigation activities are briefly described below. Details of the field investigation are provided in Section 2.0.

1.6 Strategy for Delineation of Soil Contamination

The purpose of the delineation investigation was to delineate the vertical and horizontal extent of contamination in surface and subsurface soil at the NFSS. The data will support the BOP OU FS effort by reducing the uncertainty of the estimated volume of soil that may require excavation. The delineation investigation focused on radionuclides of concern (ROC) and chemicals of concern (COC).

Radionuclides

The RI and baseline risk assessment performed at the NFSS (USACE, 2007) identified the following ROCs for BOP soil for the construction worker receptor:

- Actinium-227 (Ac-227)
- Protactinium-231 (Pa-231)
- Lead-210 (Pb-210)
- Radium-226 (Ra-226)
- Thorium-230 (Th-230)
- Uranium-234 (U-234)
- Uranium-235 (U-235)
- Uranium-238 (U-238)

Given that multiple ROCs are identified for the BOP, the sampling strategy for the delineation investigation was designed to comply with the requirements in 10 Code of Federal Regulations (CFR) 40 Appendix A Criterion 6(6), which provides a clean-up goal for Ra-226 and a means to derive cleanup goals for radionuclides other than Ra-226.

In accordance with 10 CFR Part 40, Appendix A, Criterion 6(6), the concentration of Ra-226 is limited to 5 picocuries per gram (pCi/g) in the top 15 cm (6 in) of soil. If other radionuclides are present, their cleanup goals are the concentrations of the radionuclides that would produce the same dose as 5 pCi/g of Ra-226 in the top 15 cm (6 in). This dose for Ra-226 is called the ‘benchmark’ dose. The same process is used to establish a benchmark dose for subsurface soil (i.e., below the top 15 cm [6 in]), although the cleanup goals are the concentrations of the radionuclides that would produce the same dose as 15 pCi/g of

Ra-226.

Derived Concentration Guideline Limits

RESRAD is a computer model designed by the USDOE to estimate radiation doses and risks from RESidual RADioactive materials. The RESRAD computer code (version 6.5) is used to convert the benchmark dose to a derived concentration guideline level (DCGL) for each ROC (see Appendix A for details). The DGCLs apply to a 100-m^2 (1,076-ft^2) area. To simplify the presentation of DCGLs, as well as the resulting sampling and analysis plan for the BOP delineation investigation:

- The dose contributions from Ac-227 and Pa-231 were added to their parent radionuclide, U-235, in order to allow these daughter nuclides to be accounted for in the overall benchmark dose and DCGL without necessitating that these radionuclides be measured.
- The DCGL for combined total uranium was calculated from which the U-238 DCGL was determined and used as a surrogate for the total uranium DCGL.
- Although Pb-210 is listed as an ROC, and it could be considered to be present in equilibrium with its parent Ra-226, a separate DCGL for Pb-210 was not developed. This is because laboratory analysis for this radionuclide is not commonly performed. One way to account for its presence would be to add its dose to the dose of its parent Ra-226, however, this was not done because the dose contribution from Pb-210 is orders of magnitude smaller than the dose from Ra-226. Furthermore, adding the Pb-210 dose contribution to the Ra-226 dose would increase the benchmark dose used to calculate cleanup goals under 10 CFR 40 Appendix A Criterion 6(6), which would result in larger DCGLs for other radionuclides (i.e., it would not be conservative).

Therefore, the analytical schedule for radionuclides for the BOP delineation investigation was limited to Ra-226, Th-230, and U-238. The results of RESRAD showed that the DCGLs are as follows:

Parameter	DCGL Surface Soil[1] (top 15 cm [6 in]) (pCi/g)	DCGL Subsurface Soil[1] (below 15 cm [6 in]) (pCi/g)
Ra-226	5	15
Th-230	18	55
U-238	115	346

Notes:
[1] - DCGLs are limits above background concentrations.

Sum of the Ratios Calculations

If one or more residual radionuclide is present in a 100-square meter (m^2) area, the sum of the ratios (SOR) of the ROCs should not exceed "1" (unity); a SOR exceeding 1 indicates that at least one radionuclide is present at a concentration exceeding the benchmark dose. Because many of the ROCs are naturally occurring, the SOR takes background (bkgd) radionuclide concentrations into consideration. The average background concentrations, defined during the 2007 RI, are as follows:

Parameter	Background Concentrations (pCi/g)
Ra-226	0.79
Th-230	0.90
U-238	0.82

Refining the extent of contaminated soil for the BOP delineation investigation was first performed by conducting an office exercise where SOR scores were calculated using existing analytical data from the surface (i.e., top 15 cm) and subsurface (i.e., below the top 15 cm). Since there was typically more than one analytical result at depth (below the top 15 cm) per borehole, a conservative approach was employed whereby the maximum concentration below the top 15 cm from each borehole was chosen for the SOR calculation. SOR scores were calculated using the following equations:

$$SOR_{surface\ soil} = \frac{\text{Ra-226} - \text{bkgd}}{5\ \text{pCi/g}} + \frac{\text{Th-230} - \text{bkgd}}{18\ \text{pCi/g}} + \frac{\text{U-238} - \text{bkgd}}{115\ \text{pCi/g}}$$

$$SOR_{subsurface\ soil} = \frac{\text{Ra-226} - \text{bkgd}}{15\ \text{pCi/g}} + \frac{\text{Th-230} - \text{bkgd}}{55\ \text{pCi/g}} + \frac{\text{U-238} - \text{bkgd}}{346\ \text{pCi/g}}$$

Where:

Ra-226 bkgd = 0.79 pCi/g
Th-230 bkgd = 0.90 pCi/g
U-238 bkgd = 0.82 pCi/g

Delineation of ROC Soil Contamination and Identifying Areas of Concern

The delineation of the extent of soil contamination was performed in two phases. In the first phase, SOR scores were calculated for all existing surface and subsurface soil data. Sample locations that exhibited an SOR score greater than 1 were subject to further investigation, and proposed borings (typically four) were evenly spaced (within 5 to 10 m) around the subject borehole to refine the extent of contamination. Prior to drilling and sampling, all proposed boring locations were staked in the field and a gamma radiation walkover survey covering an approximate 3-m (10-ft) radius around each proposed borehole was performed to identify elevated surface radiation levels in the area. If elevated gamma radiation readings were identified, one or more of the borings was moved to the area of the higher gamma reading and/or additional borings were added, as appropriate. In either case, elevated gamma survey results outside the 100 m^2 area were generally investigated through sampling.

The second phase was initiated by overlaying a random-start 100 m^2 grid over the entire NFSS and re-calculating the average SOR scores for the set of data located within each 100 m^2 area, pursuant to 10 CFR 40 Appendix A Criterion 6(6). If the average SOR score within an area of 100 m^2 was greater than 1, a contaminated soil area of concern (AOC) was identified. The aerial extent of the contaminated soil AOC was estimated using Bayesian Approaches to Adaptive Spatial Sampling (BAASS) software, which is similar to kriging and considers the nearest "clean" data point (i.e., a sample location with an SOR score of less than 1). Following the application of BAASS, each AOC was evaluated to determine if existing data sufficiently delineated the extent of contamination. If not, additional borings were proposed and a second round of drilling and sampling was performed. Similar to the first round of sampling, all proposed boring locations were staked in the field, a gamma radiation walkover survey was performed, and BAASS software incorporated the new data to estimate the extent of the contaminated soil AOC.

A total of 461 borings were completed during this field investigation. Of those, 372 borings were completed during the first phase and 89 borings during the second phase of the investigation.

Chemicals

The RI and Baseline Risk Assessment performed at the NFSS (USACE, 2007) identified COCs in BOP soil for a variety of receptors. For this field investigation, COCs identified in the Baseline Risk

Assessment for the industrial, maintenance, and construction workers were selected and included PAHs and PCBs.

Based on the current and likely future site use, the analytical data for these COCs were compared to Industrial Use soil cleanup objectives (SCOs) presented in Title 6 New York Code of Rules and Regulations (NYCRR) Part 375 (Note: There are no SCOs for maintenance or construction workers). The result of this comparison showed that only PAHs exceeded their respective SCOs, so only PAHs were considered COCs and thus were included in this investigation.

Similar to the ROCs, two rounds of sampling were performed to refine the extent of soil contaminated with PAHs. A total of 34 borings were completed to delineate areas of COC contamination.

1.7 Investigation of Uranium Impacts in the OWB11 Area

Investigative Excavations in EU10 and EU11

Over the past several years, groundwater analytical data for well OW11B in EU10 has shown elevated concentrations of uranium (see OW11B location in insert in Figure 2). Based on USACE's review of soil and groundwater data collected near well OW11B, the source of the uranium has not been determined.

The historical placement of material storage piles appear to be the source of radionuclide and total uranium contamination in the area south of the IWCS. Previous remedial activities in and around the grit chamber, decontamination pad, and OW11B, and historical material storage piles discerned from photographic and video analysis, are likely sources of groundwater impacts in this area. Furthermore, the groundwater concentrations are consistent with the soil detections in the area south of the IWCS and near OW11B.

The water and sewer lines in the OW11B area were identified as possible conduits of uranium contaminated groundwater migration. The water supply and distribution pipelines in the OW11B area were investigated, cut, and plugged during the 2012 BOP investigation and eliminated as potential conduits of contamination. The sanitary sewer in this area was further investigated as part of the current delineation investigation.

To expose and evaluate the condition of the sanitary sewer, six locations (IETES-01, IEMH06, and IE9 through IE12) were excavated, visually inspected, and scanned for evidence of radioactive contamination. Samples of soil and groundwater were collected for laboratory analyses. Inspection of the sewer revealed that it was 46 cm (18 in) diameter clay tile and encased in concrete, similar construction as other LOOW sewers. The sewer was found to be structurally intact with no cracks or penetrations. The investigation found that the sewer had been previously cut and plugged with concrete just north of South 31 Ditch. The sewer was not encountered in excavation IETES01 on the south side of South 31 Ditch, indicating that previous remedial activities at the NFSS included the removal of the section of sewer extending from the cut and plugged location at IEMH06 to an undetermined point south of South 31 Ditch.

As part of the investigation to determine the possible presence of a uranium source in the OWB11 area, 35 of the delineation borings were sited in a grid system throughout this area. A source term was not identified in these delineation borings or in the investigative excavations.

Manhole MH06 Removal

Manhole MH06 was one of many of the LOOW manholes originally constructed to provide access to the sanitary sewer. Manhole MH06 was located in EU10, just north of South 31 Ditch. The manhole had been plugged with concrete during previous remedial efforts. The manhole was removed as part of the delineation investigation. Inspection of the removed manhole revealed that the previously installed concrete effectively plugged the manhole base and the underlying sewer. As part of the investigation, the sewer downgradient of the manhole was plugged with concrete following the manhole removal.

Geophysical Survey

A combination of geophysical survey methods was used to investigate subsurface utilities and structures in the area immediately south of the IWCS. The methods used were able to detect various metals and variances in the soil conductivity caused by the presence of materials, such as fill, which have properties that differ from naturally occurring materials on site. In addition to identifying known, existing structures, such as monitoring wells, fences, and underground utilities, the geophysical survey identified anomalies that are likely associated with LOOW-era structures including foundations of former freshwater water treatment plant buildings 409, 410, and 413; potable water lines; and a valve pit. Two areas of elevated conductivity on the south side of the IWCS appear to be associated with an access road and ramp installed to provide access into the IWCS during landfill construction, which likely produced a zone of greater compaction and thus a different conductivity signature.

The geophysical methods are not capable of detecting non-metallic materials and therefore, were not effective in identifying the presence of the concrete-encased sanitary sewer lateral, which, according to historical documents, extended northwest from manhole MH08 toward the freshwater treatment plant building 409.

2.0 FIELD INVESTIGATION ACTIVITIES

The BOP OU delineation investigation was conducted during the period of October 30, 2013, through December 23, 2013, and June 17 through July 1, 2014. This section presents a discussion of the specific field investigative activities performed.

All fieldwork was performed under the supervision of a URS geologist who functioned as the Site Supervisor and Contractor Quality Control (CQC) Manager. A copy of the Site Supervisor's field notebook is provided in Appendix B. Appendix C includes copies of the Daily Quality Control Reports. A USACE representative was also present during all field activities.

The URS Site Safety and Health Officer (SSHO) and radiation protection personnel were also present during all field activities. Appendix D contains copies of Tailgate Safety Meeting Minutes and Permits prepared by the SSHO.

2.1 Geophysical Survey

One of the first investigative field activities was the geophysical survey of the area to the south of the IWCS. A crew of two scientists from Hager-Richter Geoscience, Inc. (Hager-Richter) performed the survey on November 6 and 7, 2013. The purpose of the survey was to delineate the presence and extent of several LOOW-era structures (i.e., building foundations, water and sewer lines, etc.) located in the area south of the IWCS. Survey methods included electromagnetic (EM) and magnetometer.

Equipment

Hager-Richter used the following non-intrusive instruments during the survey:

- Geonics EM31
- Geonics EM61-MK2A
- Geometrics G858-G magnetometer

The EM31, EM61, and magnetometer survey methods detect buried metal. However, none of these methods can provide information on the type of objects causing an anomaly. The EM31 and EM61 methods detect all types of metals including copper, brass, and aluminum, while the magnetometer method detects only ferrous metal. The EM31 survey method can also detect variations in ground conductivity. These variations can be caused by different soil types.

EM31

The electromagnetic induction terrain conductivity survey was conducted using a Geonics Model EM31 terrain conductivity meter. This instrument provided measurement of both the quadrature-phase and in-phase components of terrain conductivity without ground electrodes or contact. The quadrature-phase data are useful for detecting the presence of anomalously conductive ground. The in-phase component data identify the presence of metal objects. A digital datalogger recorded data for both components.

The EM31 reads ground conductivity in millisiemens per meter (mmho/m) with a resolution of 2% of full scale and an accuracy of 1 mmho/m. The nominal depth of earth sampled by the EM31 in the vertical dipole mode is approximately 5.5 m (18 ft).

EM61

The EM61 survey was conducted using a Geonics EM61-MK2A time domain electromagnetic induction metal detector. The EM61-MK2A is capable of detecting buried metal objects such as utilities, underground storage tanks (USTs), and drums. A transmitter coil generates a pulsed primary magnetic field in the earth, thereby inducing eddy currents in nearby metal objects. The eddy current produces a secondary magnetic field that is sensed by two receiver coils; one coincident with the transmitter and the other positioned 40 cm (1.3 ft) above the main coil. The instrument responds to the secondary magnetic field produced by metal objects. A digital datalogger recorded the secondary responses in millivolts (mV).

Magnetometer

The magnetic survey was conducted using a Geometrics G858-G cesium (Cs) magnetometer equipped with two sensors. Total magnetic field and vertical magnetic gradient were measured. Data were acquired continuously in walking mode, effectively recording data at about 24-cm (10-in) intervals along each survey line. A base station location recorded the temporal variation of the earth's magnetic field.

Survey Procedures

Hager-Richter established a local survey grid in the area of interest, which was defined as being bound to the north by the top of the south slope of the IWCS, to the west by an imaginary line extending from the western edge of the IWCS, to the east by the Central Drainage Ditch, and to the south by an imaginary line running east-west approximately 12 m (40 ft) south of manhole MH08.

The EM61 data were acquired at approximately 20-cm (8-in) intervals along survey lines spaced 1.5 m (5 ft) apart.

The EM31 data were acquired at approximately 0.3-m (1-ft) intervals along survey lines spaced 3 m (10 ft) apart.

The magnetometer data were acquired at approximately 15-cm (6-in) intervals along survey lines spaced 3 m (10 ft) apart.

Survey Results

The geophysical survey identified anomalies that are likely associated with LOOW-era structures including foundations of freshwater treatment plant buildings 409, 410, and 413, and potable water lines. Two areas of elevated conductivity on the south side of the IWCS appear to be associated with an access road and ramp installed to provide access into the IWCS during landfill construction.

The geophysical methods are not capable of detecting non-metallic materials and therefore, were not effective in identifying the presence of the concrete-encased, clay tile sanitary sewer lateral, which, according to historical documents, extended northwest from manhole MH08 toward the freshwater treatment plant building 409.

2.2 Radiation Surveys

Two approaches were used to investigate potential radiation impacts at the NFSS: field radiation surveys and laboratory analyses of multimedia samples (e.g., soil and water). Radiation protection surveys were also conducted under the site radiation safety program. This section discusses the field radiation surveys and radiation protection surveys that were performed during field activities. Laboratory analytical results of multimedia samples are discussed in Section 3.

Scope

Radiation measurements were collected at the locations of, and during the advancement of, soil borings; the excavation of investigation trenches; and of waste generated during these field activities.

Field radiation (i.e., characterization) measurements included:

- GPS GWS – Prior to sampling, a GWS was conducted at each proposed sample location to identify the highest surface radiation level in the area. This information was provided to the USACE to support field adjustments of the sample locations, if warranted. A GWS was also conducted across the proposed excavation areas to document the pre-excavation radiation levels. After restoring the excavated areas, the GWS was repeated to document the final (post-excavation) radiological condition of the excavation areas.
- Excavation screening –
    - Unshielded gamma radiation measurements were collected on the excavated soils temporarily stockpiled during excavation.
    - Shielded gamma radiation surveys of walls, sides, and bottoms of the excavations were conducted to identify areas of elevated material.
- Alpha, beta, and gamma scanning was performed on soil cores.

Radiation safety measurements included:

- Personnel and equipment alpha, beta, and gamma scans.
- Incoming and outgoing alpha, beta, and gamma surveys.
- Alpha and beta smear counts.
- Waste storage dose rate surveys.
- Bioassay samples.
- Personnel dosimetry.

Personnel

All on-site URS and contractor personnel participated in site-specific radiation safety training and the project bioassay and dosimeter program. The site-specific, four-hour training met the requirements of USACE-accepted Assistant User requirements. URS Buffalo employees assigned to the NFSS underwent an additional four hours of radiation safety training to meet the USACE requirements for Authorized Users.

During the field effort, site visitors included the geophysical team, couriers from TestAmerica, and concrete truck drivers. These visitors were allowed on the NFSS under URS escort.

Instrumentation

Radiological constituents of concern at NFSS include isotopic uranium, isotopic thorium, radium-226/228, and their decay products. Other constituents that occur on NFSS in lesser amounts included daughter products of the uranium series (U-238) and, to some extent, the actinium series (U-235). Table 1 presents a listing of the radiation detection equipment used during this project.

All site instrumentation underwent an annual calibration prior to its arrival on site; Appendix E1 contains copies of the calibration certificates. Daily performance checks were performed to ensure instrumentation was functioning as calibrated. All portable field instruments used underwent a start- and end-of-day check. Stationary instrumentation (smear counter) underwent a start-of-day check. Satisfactory performance tests were conducted using a known radioactive source and results were within ±20% of the expected response. Instruments that did not meet performance test criteria, found to be defective or damaged, were removed from service. Routine maintenance activities, completed at the job site included replacing cables, batteries, and the Mylar faces on the Ludlum model 43-93 probes. Mylar replacement required the probe to dark correct prior to use; detectors sat for least 12 hours, and then underwent an instrument set up check to confirm it was still functioning as calibrated. The performance checks were documented in an electronic daily source check spreadsheet. Copies of the daily source check spreadsheets for each instrument/detector pairing are included in Appendix E2-1.

Routine Radiation Protection Activities

Routine radiation protection activities were performed in accordance with the RPP and were documented on various survey forms, logs, and electronic files. The Radiation Protection Daily Log provides a general summary of radiation protection activities, equipment, and identifies assignments of instruments to each on-site work activity by serial number. Appendix E2-2 contains the Radiation Protection Daily Logs.

All work was conducted under the URS Radiation Work Permit (RWP)/Hazardous Work Permit (HWP) program, as outlined in the RPP, and URS Safety Management Standard 52 (SMS-52AMER). The RWP/HWP permit identified radiological conditions, established worker protection and monitoring requirements, and contained specific approvals for radiological work activities. Radiological or hazardous work permits (RWP/HWP) were assigned a sequential number, and issued for each job task. Workers signed in and out of the job site RWP/HWP indicating that they understood the work requirements, and conducted personal frisks as applicable. Copies of the RWP/HWP issue log and completed permits are provided in Appendix E3.

Radiation surveys were assigned a unique survey number and documented in the Project Radiation Survey Log and on appropriate survey forms. The unique survey number includes a code to indicate the type of survey: Incoming (IN), Outgoing (OT), Routine (RT), and Excavation (EX). A total of 95 radiation safety surveys were conducted during the project as listed in the Survey Log provided in Appendix E4-1.

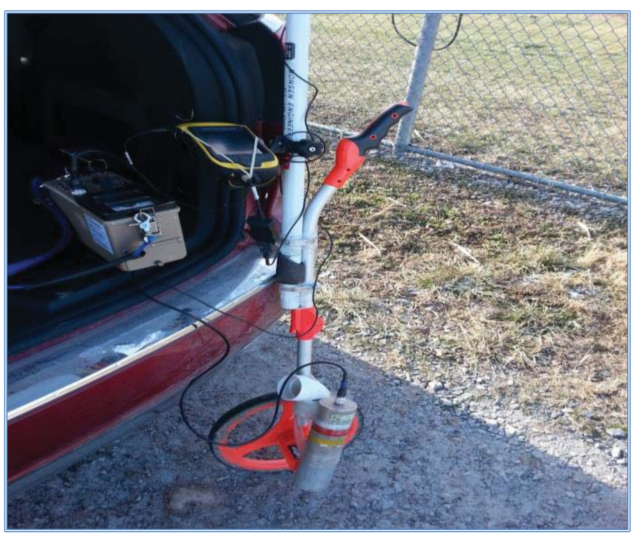
Prior to being brought on site, reusable equipment and items were surveyed for radiological contamination to verify IN conditions. Materials that arrived on site in new and unopened condition were assumed to be free of radioactive contamination and were not surveyed. Surveys included scans and collection of smear samples to identify removable contamination and were recorded on the appropriate survey forms. RT surveys were conducted to identify radiation exposure rates in areas where work occurred, and to support general work activities. Surveys to support the investigative excavation work were documented as EX surveys, while the gamma walkover surveys and soil sample measurements were documented on separate data sheets and not assigned specific survey IDs.

To document compliance with the site release criteria identified in the RPP, and with United States Department of Transportation (DOT) requirements, all sample coolers underwent a survey that included collection of dose rates, along with a fixed and removable contamination survey, before leaving the NFSS (OT).

At the end of a specific work activity and before it left the NFSS, equipment that had the potential to come into contact with contaminated material was decontaminated and surveyed for release (OT). Copies of radiation surveys are provided in Appendix E4-2, and the results of smear samples are included in Appendix E4-3.

Gamma Walkover

The GWS was conducted with a high-efficiency gamma ray scintillation detector (2x2 NaI, Ludlum Model 44-10), coupled to a count rate meter/scaler (Ludlum Model 2221) with serial port (Ludlum 4261-148) that transferred gamma radiation count rates to the GPS unit every two seconds. The survey grade (±1 meter) GPS (Geo6000 XH) and external antenna (Zephyr) recorded the position and associated information at one-second intervals. The GPS units were configured to collect data using North American Datum (NAD) 1983 New York State Plane Coordinates. The GPS external antenna was positioned at a fixed distance above the detector to accurately determine the detector locations throughout the survey. The detector was mounted on a pole or wheel at a distance of 10 cm (4 in) from the ground. This change in detector height from the 30 cm (12 in), detailed in Standard Operating Procedure (SOP) RS-8.0 GPS Gamma Radiation Surveys, was done at the direction of the USACE. The change in the detector height reduces the detector field of view for each measurement from approximately 17000 cm^2 (18 ft^2) to approximately 1900 cm^2 (2 ft^2).



Photograph 1 - Gamma Walkover Survey Configuration

Background gamma radiation data were collected by walking serpentine transects approximately 1 m (3.3 ft) apart at a speed of approximately 0.5 m/sec (1.6 ft/sec), from the right-of-way along Pletcher Road, and the right-of-way and along the road entering the NFSS. Measurements were collected from both grassy/dirt areas and asphalt-paved areas. Initially, the background area was walked with a detector placed at a height of 30 cm (12 in), but a second background survey was repeated at the end of the fieldwork with the detector at a height of 10 cm (4 in).

Prior to sampling, the area around each proposed soil sample location was cleared of large vegetation, debris, and obstructions and each location was flagged or staked. The survey flag/stake functioned as the center point for each GWS area. Documentation supporting the GWS is provided in Appendix E5.

Photograph 2 - Cleared and Flagged Sample Location

At most locations, the GWS area was larger than the minimum area of 9 m^2 (100 ft^2) specified in the FSP. In some areas, the proposed density of sample of locations made it more practical to establish a larger area that covered multiple sample locations. In these situations, the survey area extended 3 m (10 ft) beyond the proposed locations. Within each survey area, the GWS was conducted by walking serpentine transects approximately 1 m (3.3 ft) apart at a speed of approximately 0.5 m/sec (1.6 ft/sec).

Photograph 3 - Gamma Walkover Survey

Survey areas that included surface materials of both grass and asphalt were surveyed separately and assigned a unique file name (Appendix E5-3). A total of 293 data files, containing 74,219 valid measurements were collected during the GWS.

The GPS data files were downloaded to a computer using GPS Pathfinder, and exported to Microsoft Excel. Field posting plots were generated daily using Surfer®, and were routinely reviewed with the USACE's NFSS representative to identify adjustments to the proposed sample locations. Proposed locations that were based on prior GWS data were adjusted in the field to the marked highest gamma location. GWSs were completed at all of the proposed sampling locations with the exception of three locations (8F005) that were inaccessible because they were located inside the main drainage ditch, and two (8D016-8, 8D016-9) added at the end of the work. After consultation with the USACE, 12 locations were not sampled after completion of the GWS.

The final GWS position data were differentially corrected using GPS Pathfinder Office, based on the Lockport and Youngstown base stations. Data files were exported to Microsoft Excel, measurements were converted to microroentgen per hour (µR/h) using Ludlum's standard conversion factor, summary statistics, and Surfer® classed postings plots were generated. Appendix E5-4 is a table of all 74,219 measurements with the GPS positions.

Soil Borings

At each soil boring location, a timed surface gamma radiation measurement was collected prior to sampling. During sampling, the recovered soil core was laid out on a plastic-lined work surface for field screening. The soil was sectioned into the predetermined sample intervals (e.g., 0 to 15 cm (0 to 0.5 ft) below grade, 15 to 61 cm (0.5 to 2 ft) below grade, etc.). Each soil section was then screened, recording a time count with both a Ludlum Model 44-9 Geiger-Mueller pancake probe and a Ludlum Model 43-93 alpha/beta probe and the data recorded on Core Sample Log data sheets (Appendix E6-2).

During sampling, the results of the field screening were reviewed to evaluate the need to advance the sampler to a greater depth. Initially, the anticipated maximum boring depth was 1.5 m (5 ft) below grade; however, a few borings exhibited potential contamination below that depth, so those borings were advanced deeper. The actual maximum boring depth was 2.1 m (7 ft) below grade. For the borings advanced to a depth of 1.5 m (5 ft), the soils below 0.9 m (3 ft) were screened at 31-cm (1-ft) intervals. For the borings advanced to 2.1 m (7 ft), the soils below 0.9 m (3 ft) were screened at 0.61-cm (2-ft) intervals.

Borehole Sample Depth Intervals

Screening Interval	**Total Boring Depth**		
	0.9 m (3 ft)	**1.5 m (5 ft)**	**2.1 m (7 ft)**
1st Interval	0 to 15 cm (0 to 0.5 ft)	0 to 15 cm (0 to 0.5 ft)	0 to 15 cm (0 to 0.5 ft)
2nd Interval	15 to 61 cm (0.5 to 2 ft)	15 to 61 cm (0.5 to 2 ft)	15 to 61 cm (0.5 to 2 ft)
3rd interval	61 to 91 cm (2 to 3 ft)	61 to 91 cm (2 to 3 ft)	61 to 91 cm (2 to 3 ft)
4th Interval	NA	0.9 to 1.2 m (3 to 4 ft)	0.9 to 1.5 m (3 to 5 ft)
5th Interval	NA	1.2 to 1.5 m (4 to 5 ft)	1.5 to 2.1 m (5 to 7 ft)

Investigation Excavations

The Investigative Excavations (IEs) were completed to gather radiation data at depth to identify a possible radiological source term, investigate the presence and condition of the sanitary sewer, and to remove manhole MH06. During excavations, the excavated materials removed from the investigation trench were placed on plastic. The excavated soil was routinely scanned using an unshielded NaI detector to identify elevated material.

Excavations varied in area and/or depth. After completion of an excavation, radiological measurements were collected from the sidewalls and bottom using a shielded sodium iodide (NaI) detector. The detector was positioned to ensure the detector's bottom (i.e., open face) was positioned toward the location being measured. A timed count (30 seconds) was collected while the detector was slowly moved across an area of approximately of 0.46 sq m (5 sq ft) [0.3 m (1 ft) vertical, 1.5 m (5 ft) horizontal]. The presence of standing water in some excavations prevented the collection of data at certain locations. After the gamma data and soil samples were collected, the soil was returned to the excavation. Appendix E7 contains investigation trench data forms.

Investigation-Derived Waste (IDW) Surveys

Because there was a possibility that materials used during performance of the fieldwork could come into contact with potentially contaminated soil, plastic sheeting and other solid materials were placed, as applicable, in large garbage bags and then deposited in the IDW roll-off. Water pumped out of the excavations and generated during decontamination was placed into polyethylene storage tanks. The manhole from MH06 was also deposited in the roll-off. The exterior of the roll-off was surveyed for contamination and documented as part of the routine radiation surveys.

Routine Radiation Safety Activities

Work performed at the NFSS was in accordance with the RPP. No incidents of personal contamination occurred, and all personnel exposures were below the dosimeter detection limits. All equipment and general survey results were within the NFSS ambient radiation levels and met the requirements for release. Appendix E4 contains copies of the surveys.

Gamma Walkover Results

All gamma walkover measurements were collected using a Ludlum 2221 paired with a Ludlum 44-10 probe with the data converted to µR/h. Gamma radiation levels in the background area ranged from 5.9 µR/h to 20.7 µR/h with a mean of 11.9 µR/h and a standard deviation of 2.2 µR/h. The gamma radiation levels seen on site ranged from 4.8 µR/h to 89.5 µR/h. A summary of the GWS statistics by exposure unit is included as Table 2.

Locations with unexpected elevated radiation levels were labeled as SP, and under the direction of the USACE NFSS representative, an additional 13 borings were advanced to characterize those areas. The results of the field GWS surveys were reviewed with the USACE NFSS representative and sample locations were adjusted or added in the field. Five GWS (GWS-1, 10, 16, 17 and 25) locations identified based on the GWS performed during the RI were not sampled because they were in concrete, asphalt, or rock. Appendix E5-1 provides Surfer® count per minute posting plots of the GWS data. Summary statistics were generated for each area surveyed and are included in Appendix E5-2. Appendix E5-3 includes GWS field sheets.

Soil Core Logging Results

Appendix E6 provides tables that detail radiological screening results for each of the 478 soil boring locations.

Investigative Excavation Results

Gamma radiation levels from most of the excavated soils ranged from 11 µR/h to 16 µR/h with an average of 13 µR/h. Elevated readings of 24 µR/h and 34 µR/h were seen during the excavation activities at MH-06 but through further screening, it appeared to be small, less than 0.09 m^2 (1 ft^2), areas without a specifically identifiable source. Table 3 provides a summary of the minimum and maximum scan ranges, in counts per minute (cpm), for the investigative excavations.

Appendix E7 includes figures of each investigation excavation. Generally, the shielded measurements showed normal variations in the radiation count rates, however elevated radiation measurements were recorded along the north wall in IE9, which had a maximum reading of 8,126 cpm; the next highest maximum was 5,014 cpm measured in IE MH06.

After the excavation areas were restored a follow-up GWS survey was conducted with the results summarized below:

Summary of Pre- and Post-Excavation GWS Survey Data

GWS	Number of Points	Minimum (cpm)	Maximum (cpm)	Mean (cpm)	Median (cpm)	Standard Deviation (cpm)
Pre excavation	2106	4347	12449	8915	9201	1536
Post excavation	1364	5066	14092	9644	10014	1675

IDW Results

Radiation levels and smear samples from IDW were within the ambient radiation levels seen on the NFSS. Gamma radiation levels taken from the outside of the roll-off ranged from 4 µR/h to 6 µR/h (Appendix E4).

2.3 Drilling

A total of 478 soil borings were completed during the delineation investigation (see Figures 3 through 10 and Table 4). Russo Development, Inc. (Russo) provided drilling services for the delineation investigation. Drilling was performed during the period of November 5 through December 20, 2013, and June 17 through July 1, 2014. In addition to supervising drilling activities, the URS Site Supervisor inspected the soils for evidence of contamination, screened the soils for volatile organic vapors using a photoionization detector (PID), documented investigation activities, and prepared samples for shipment to the laboratory. A Radiation Technician was present during all drilling activities. The Radiation Technician measured radiation readings on the soil cores and assisted the Site Supervisor in preparing samples for shipment to the laboratory.

Borehole Drilling

Drilling was performed using an AMS direct-push drill rig. Soil sampling was accomplished using a 7.6-cm (3-in) diameter by 1.2-m (4-ft) long Macro core sampler with dedicated, per sample, acetate liners. For the borings where the target depth was 0.91 m (3 ft), the borings were advanced the full length of the Macro core sampler (i.e., to a 1.2-m (4-ft) depth). The borings were advanced this additional depth to allow for scanning below the 0.9 m (3 ft) target depth, should elevated readings be observed at the target depth.

Some borings were advanced deeper, to a maximum depth of 2.1 m (7 ft), based on elevated radiation readings or at the request of USACE. For those deeper borings, the boring was advanced to the target depth in the same borehole using a new acetate liner when sampling below the 1.2-m (4-ft) depth. Upon completion, each borehole was backfilled to grade with granular bentonite.

Decontamination

All down-hole equipment was decontaminated at the drill site by initially removing all loose soil followed by an Alconox and water wash and by a potable water rinse. Decontamination fluids were transferred from the drill sites and placed in polyethylene tanks. Miscellaneous solids, such as plastic sheeting, acetate liners, and personnel protective equipment (PPE), were placed in trash bags and subsequently into the on-site roll-off.

URS performed radiological scans of the drill rig and drilling equipment when the equipment first arrived on site, between each drilling location, and at the end of the field investigation (release survey), prior to the equipment leaving the NFSS. All radiological scans showed no indication of contamination.

Photograph 4 - Direct-push drill rig.

Soil Core Screening

Upon recovery, the acetate liner containing the soil core was sliced open lengthwise and the soil core was then divided into the pre-determined sample intervals. The soils were then scanned with the Ludlum Model 44-9 pancake detector (for alpha, beta, and gamma radiation), Ludlum Model 43-93 detector (for alpha and beta radiation), and MiniRae PID for volatile organic vapors.

Sample Selection

The target soil boring depth was 0.9 m (3 ft), unless radiation readings or USACE required deeper sampling. The soil sample selection depths were predetermined in accordance with the work plans. Three soil samples were to be collected from each boring, with each soil sample representing the following intervals:

- 0- to 15-cm (0- to 0.5-ft) below grade,
- 15- to 61-cm (0.5- to 2-ft) below grade, and
- 61- to 91-cm (2- to 3-ft) below grade.

If elevated radiation readings were observed, or as directed by the USACE NFSS representative, the soil boring was advanced to a maximum depth of 2.1 m (7 ft).

Photograph 5 - Screening soil core with PID (left) and radiation meter (right).

Samples were placed in laboratory-provided containers. Field duplicates, and matrix spike/matrix spike duplicate (MS/MSD) samples (for PAH analyses), were collected at frequencies of 10% and 5%, respectively.

The samples were analyzed by TestAmerica Laboratories, Inc. (TestAmerica) for Ra-226, Th-230, U-238, and/or PAHs following the analytical methods identified in Table 5. The TestAmerica Amherst, New York, facility does not perform radiological analyses. However, to facilitate sample tracking and shipment, a TestAmerica courier picked up the samples from the NFSS and transported them to the TestAmerica facility in Amherst, New York. Subsequently, TestAmerica shipped the samples to their facility in Earth City, Missouri. A USACE representative oversaw sample handling, preservation, and chain-of-custody procedures.

A boring log was prepared for each boring. Appendix F provides copies of the logs. Appendix B contains field notes recorded by the Site Supervisor.

2.4 Excavation Activities

Investigative Excavations (IEs) were advanced to remove manhole MH06, evaluate the presence and condition of the sanitary sewer in EU10 and EU11, and to enable the collection of subsurface soil and groundwater samples. Excavation activities were performed between November 19, and December 5, 2013. Six locations were excavated: IETES01, IEMH06, IE09, IE10, IE11, and IE12 (See Figure 11). The excavations were located along the alignment of the sanitary sewer extending from South 31 Ditch on the south to a site service road on the north.

Russo provided excavation services. Equipment used included a Komatsu 200 LC tracked excavator, support truck, flatbed trailer, and front-end loader along with miscellaneous tools and supplies. Russo provided a two-man crew, one of whom functioned as a competent person to inspect and confirm the safety aspects of the excavation.

An aluminum scaffolding stage with a guardrail was placed across the open excavations, as needed, to allow personnel to safely scan/inspect the excavation from grade.

Excavated soils were stockpiled on plastic sheeting next to each excavation, laid out in the order of removal. The excavated soils were routinely scanned for radiation using a sodium iodide (NaI) detector. At the completion of excavation activities, the soils were placed back into the excavations in the reverse order in which they were removed. The soils were placed in approximately 0.3- to 0.6-m (1- to 2-ft) lifts and compacted with the excavator bucket. The corners of each excavation were then staked for subsequent surveying. A final gamma radiation walkover survey was conducted to document the final radiological condition of each area.

The URS Geologist supervising the excavation activities recorded field activities and observations in a bound field logbook (a copy is provided in Appendix G). A log was prepared for each excavation. Information in the logs includes location and survey information, field observations, soil descriptions, radiological survey data, sample collection information, plan and cross-sectional sketches, and excavation photographs. Appendix H contains copies of the excavation logs.

The dimensions of the excavations were to be of sufficient size as to allow the inspection of each side and bottom of the sanitary sewer. However, the final excavation dimensions were adjusted in the field, as needed, to avoid damage to adjacent monitoring wells and active subsurface utilities.

Excavation Sampling

Radiological measurements were collected from the sidewalls and bottom of the trenches using a calibrated NaI detector Ludlum Model 44-10 with a Model 4260-076 shield. The detector was positioned to ensure the bottom open face was positioned toward the location being measured. A timed count (30 seconds) was collected while the detector was slowly moved across an area of approximately of 0.46 sq m (5 sq ft) [0.3 m (1ft) vertical, 1.5m (5 ft) horizontal].

Four soil samples were collected from each excavation with the exception of excavation IETES01 and IE12. One sample was collected from the top 15 cm (6 in), one from the bottom of the excavation, and two samples from the sidewalls of the excavation. The two sidewall samples were collected from the locations with the highest radiological readings – one representing each sidewall. The soil samples were collected using a hand auger or trowel.

In accordance with instructions provided by USACE in the field, no samples were collected from excavation IETES01. Because excavation IE12 was extended twice as long as its' originally intended length, the number of soil samples collected was doubled. Two soil samples were collected from the top 15 cm (6 in), two samples from the bottom of the excavation, and four samples from the sidewalls of the excavation. The four sidewall samples were collected from the locations with the highest radiological readings – two from each sidewall.

Where groundwater was encountered, one filtered groundwater sample was collected from each excavation. A total of four groundwater samples were collected: one each from the following excavations: IE09, IE10, IE11, and IE12. A peristaltic pump and new silicone and polyethylene tubing was used to collect each groundwater sample. The groundwater samples were filtered with new 0.45 micron filters and placed into clean laboratory-provided containers. The soil and groundwater samples were analyzed in accordance with the analytical schedule presented in Table 6.

Standard turnaround time (not to exceed 21 days) was requested for all samples collected from the field investigative activities. URS' subcontract laboratory provided the appropriate sample containers and coolers for the samples. URS prepared the coolers for pickup by a TestAmerica courier under the supervision of the Site Radiation Safety Officer (SRSO). The laboratory then shipped the samples to the TestAmerica – Earth City facility.

Excavation Observations

Soils encountered at the IEs generally consisted of fill/reworked soils composed of a thin layer of surficial brown loamy clay material underlain by brown to reddish brown silty clay with trace to some angular to subangular fine to coarse sand, and gravel (Brown Clay Unit). The deepest excavations encountered a brownish to pinkish gray silty clay (Gray Clay Unit). Observations specific to each investigative excavation are provided in the text below.

Excavation IETES01

Excavation IETES01 was located on the south side of South 31 Ditch. The excavation was performed after excavations IEMH06 and IE09 were completed and was in the same alignment of the sanitary sewer as observed in those two excavations. The dimension of IETES01 was approximately 1.8 m (6 ft) wide, by 2.7 m (9 ft) long, by 3.9 m (13 ft) deep, starting at the top of the bank of South 31 Ditch and advanced southward.

Fill, consisting of crushed stone, sand and silt, was encountered from ground surface to a depth of approximately 0.5 m (1.5 ft). The fill was underlain by reworked brown silty clay with trace fine to coarse gravel and cobbles (Brown Clay Unit) to an approximate depth of 3.7 m (12 ft). This unit was underlain by gray clay of the Gray Clay Unit. No groundwater was encountered in this excavation.

Excavation IEMH06 found that the sanitary sewer was previously cut and plugged on the north side of South 31 Ditch. Excavation IETES01 was performed to determine the absence/presence of the sanitary sewer on the south side of South 31 Ditch. The sewer was not encountered at this location, suggesting that the sewer was cut off at an undetermined location farther to the south.

Excavation IEMH06 and Manhole MH06 Removal

Sanitary sewer line manhole MH06 was located just north of South 31 Ditch. USACE informed URS that the manhole had been previously plugged with concrete, as evidenced by the presence of poured concrete on the ladder rungs in the manhole. Water was present in the manhole at a depth of approximately 1.8 m (6 ft) below grade.

Before beginning the excavation, Russo used sand bags to plug the culverts leading into and out of the section of South 31 Ditch directly south of MH06. A trash pump was then set up to lower the water level in this section of South 31 Ditch and, if needed, divert the flow from the upstream section to the downstream section.

Photograph 6 - View North across South 31 Ditch. MH06 exposed in excavation IEMH06 in background. Future Location of IETES01 delineated by white paint stripes in left foreground.

Excavation IEMH06 began on the northern bank of South 31 Ditch and proceeded in a northeasterly direction to approximately 1.5 m (5 ft) north of the manhole for a total excavation length of approximately 8.5 m (28 ft).

Fill or reworked soils consisting of silty clay with trace fine gravel was encountered from ground surface to a depth of approximately 1.4 m (4 ft) below grade. The fill was underlain by reworked brown silty clay with trace gravel to a depth of approximately 2.9 m (9.5 ft). The silty clay became more red-brown from 2.9 m (9.5 ft) to the bottom of the excavation at 4 m (13 ft).

The excavation revealed that the concrete-encased sanitary sewer had been previously cut and plugged with concrete at a point approximately 4.3 m (14 ft) south of MH06. The elevation of the top of the concrete-encased sewer was above the bottom of South 31 Ditch. Consequently, the absence of the sewer in South 31 Ditch indicated that the section that crossed the ditch had been removed.

The portion of the concrete-encased sewer exposed in IEMH06 was found to be structurally sound with no cracks or penetrations. The concrete-encased sanitary sewer was encountered at an approximate depth of 2.7 m (9 ft) below grade. The concrete encasement measured approximately 1.2 m (4 ft) wide by 0.9 m

(3 ft) deep. The top and sides of the concrete-encased sewer were smooth and squared off, while the bottom was somewhat rough and appeared to be underlain by a thin layer of gravel. Groundwater seeped into the excavation from this gravel layer at a flow rate of less that approximately 1.9 liter (l) (0.5 gallon (gal)) per minute.

Manhole MH06 was approximately 1.5 m (5 ft) in diameter at the base. The manhole was of brick construction with a cement skin several centimeters thick. The manhole was structurally intact. A 20-cm (8-in) opening for a lateral pipe was present on the west side of the manhole at a location approximately 0.9 m (3 ft) above the base. When exposed during the excavation, the opening was found to have been loosely blocked with a couple of bricks; there was no lateral pipe connected to the opening, nor was there evidence of a pipe observed in the excavation.

As the excavation exposed the base of manhole MH06, a breach occurred on the northern side where the manhole connected to the sewer. Water began releasing from the breach into the excavation. Excavated soil was placed on the breached area as a temporary plug and a temporary berm was constructed on the northern bank of South 31 Ditch to contain the water. It was noted that the water level inside the manhole did not fluctuate when the breach occurred.

Water continued to flow into the excavation from the breach until the water reached a static level at approximately 1.2 m (4 ft) below grade. At this point, the manhole was extracted from the excavation. The manhole was removed in one piece and placed in the roll-off container at the IDW temporary storage area.

Note water pouring out of lateral opening

Photograph 7 - View northeast of manhole MH06. Note lateral opening on left side and concrete plug in sewer at base.

Inspection of the manhole indicated that the concrete plug, which extended several tens of centimeters into the sewer, was effective as water remained present in the manhole at a level above the lateral opening as the manhole was being removed.

At this point, further excavation of IEMH06 was temporarily suspended and investigative excavation IE09 was started to expose the sewer at that location. This was done, in part, to enable access to the sewer so that it could be cored and plugged to prevent further flow of sewer water into the IEMH06 excavation. After two attempts, the sewer line was successfully plugged with concrete and the IEMH06 excavation was dewatered and backfilled with concrete. In accordance with the work plan, the IEMH06 excavation was backfilled with concrete to a level approximately 0.6 m (2 ft) above the top of the sewer. The excavation was left open overnight and the absence of water the following day confirmed that the sewer had been effectively plugged. The remainder of the excavation was then backfilled with soil to existing grade.

Plugging Manhole MH09

Manhole MH06 was located in the up-gradient portion of the LOOW sanitary sewer system. Sewage in the system would have flowed from the south to the north where the former LOOW wastewater treatment plant was located, a distance of over 900 m (2,950 ft) north of the MH06 area. Because of its up-gradient location, a pressure head was not expected in this portion of the sewer. To further isolate flow in the sanitary sewer in the EU10 and EU11 area, manhole MH09 (see Figure 3), the next manhole down-gradient of MH06, was plugged with concrete during the field investigation.

Excavation IE09

Excavation IE09 was completed approximately 4 m (13 ft) north of excavation IEMH06. The purpose of excavation IE09 was to expose and inspect the sanitary sewer, to collect soil and groundwater samples, and to cut a hole into the sewer and plug it with concrete in order to stop the flow of water into the IEMH06 excavation.

Excavation IE09 was approximately 7.6 m (25 ft) long by 6.1 m (20 ft) wide by 3.2 m (10.5 ft) deep. Fill, consisting of silt and clay with trace gravel was present from ground surface to a depth of approximately 0.5 m (1.5 ft) below grade. The fill was underlain by reworked brown silty clay with trace fine to coarse gravel and cobbles (Brown Clay Unit) to the bottom of the excavation at 3.2 m (10.5 ft) below grade.

The top of the concrete-encased sewer was found at a depth of approximately 2 m (6.5 ft) below grade. The sewer was observed to be structurally sound with no cracks or penetrations. A groundwater seep, flowing at less than 1.9 l (0.5 gal) per minute, was emanating from a sand layer on top of the sewer at the southern end of the excavation.

A 15-cm (6-in) diameter core drill was advanced in the approximate center of the sewer. Once the sewer was penetrated, a 15-cm (6-in) diameter polyvinyl chloride (PVC) pipe with a rubber gasket was inserted into the core hole to allow the water in the sewer to rise to a static head and enable the placement of concrete into the sewer. After an initial failed attempt, concrete was successfully placed into the sewer and stopped the flow of water to the IEMH06 excavation. Additional concrete was added to the excavation to a level approximately 0.6 m (2 ft) above the top of the sewer. The remainder of the sewer was backfilled with the excavated soil in the reverse order of which it was removed.

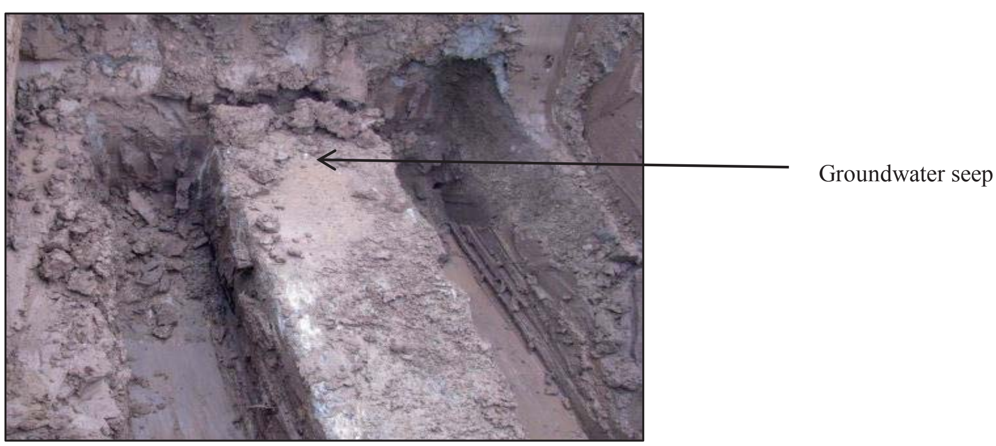
Photograph 8 - Coring concrete-encased sewer in IE-09. Note PVC standpipe in foreground and groundwater seep in background.

Excavation IE10

Excavation IE10 was located approximately 1.5 m (5 ft) north of excavation IE09. Former excavation IE08 was located between IE09 and IE10. The purpose of excavation IE10 was to expose and inspect the sanitary sewer and to collect soil and groundwater samples.

The excavation was approximately 4.9 m (16 ft) long by 4 m (13 ft) wide by 3.2 m (10.5 ft) deep. Fill, consisting of silt and clay with angular gravel, was present from ground surface to a depth of approximately 0.5 m (1.5 ft) below grade. The fill was underlain by red-brown silty clay with trace fine to coarse gravel and cobbles (Brown Clay Unit) to the bottom of the excavation at 3.2 m (10.5 ft) below grade.

The top of the concrete-encased sewer was found at a depth of approximately 2.1 m (7 ft) below grade. The concrete encasement measured approximately 0.9 m (3 ft) wide by 0.9 m (3 ft) deep. The sewer was structurally sound with no cracks or penetrations. A groundwater seep, flowing at less than 1.9 l (0.5 gal) per minute, was emanating from a thin sandy layer on top of the sewer.



Photograph 9 - Concrete-encased sewer in IE-10.

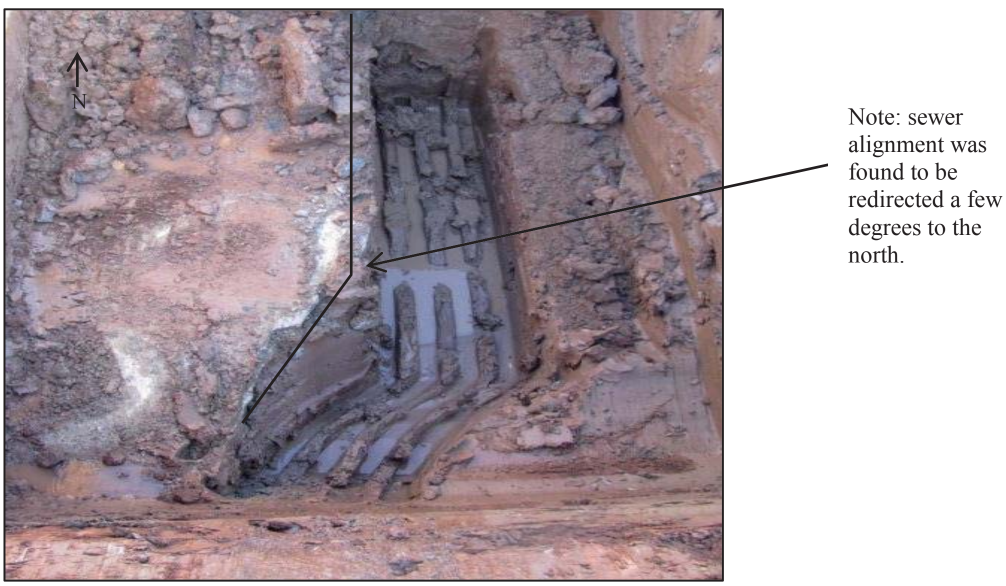
Excavation IE11

Excavation IE11 was located approximately 6.1 m (20 ft) north of excavation IE10. The area between the two excavations contained a buried utility line. The purpose of excavation IE11 was to expose and inspect the sanitary sewer and to collect soil and groundwater samples.

The excavation was approximately 4.6 m (15 ft) long by 3 m (10 ft) wide by 3.2 m (10.5 ft) deep. Fill, consisting of silt and clay with trace gravel, was present from ground surface to a depth of approximately 0.8 m (2.5 ft) below grade. The fill was underlain by reworked red-brown silty clay with trace to little fine to coarse gravel and cobbles (Brown Clay Unit) to the bottom of the excavation at 3.2 m (10.5 ft) below grade.

The top of the concrete-encased sewer was found at a depth of approximately 2 m (6.5 ft) below grade. The concrete encasement measured approximately 0.9 m (3 ft) wide by 0.9 m (3 ft) deep. The western side of the sewer was not exposed due to the presence of monitoring wells MW954 and MW953.

The sewer was observed to be structurally sound with no cracks or penetrations. A groundwater seep, flowing at less than 1.9 l (0.5 gal) per minute, was emanating from the excavation wall at the top of the sewer. It was noted that the sewer alignment diverged a few degrees to the north.



Photograph 10 - Excavation IE11

Excavation IE12

Excavation IE12 was located just south of a site service road. The excavation was separated from the IE11 excavation by approximately 8 m (26 ft). The area between IE11 and IE12 was the former IE07 excavation. The purpose of excavation IE12 was to expose and inspect the sanitary sewer and to collect soil and groundwater samples.

The excavation was approximately 7.6 m (25 ft) long by 4.9 m (16 ft) wide by 3.5 m (11.5 ft) deep. Fill, consisting of silt and clay with trace gravel, was present from ground surface to a depth of approximately 0.8 m (2.5 ft) below grade. The fill was underlain by reworked red-brown silty clay with trace fine to coarse gravel and cobbles (Brown Clay Unit) to a depth of approximately 3.2 m (10.5 ft) below grade.

This unit was underlain by gray clay (Gray Clay Unit). The walls of the excavation frequently sloughed along silt-filled desiccation cracks.

The top of the concrete-encased sewer was found at a depth of approximately 2.3 m (7.5 ft) below grade. The concrete encasement measured approximately 0.9 m (3 ft) wide by 0.9 m (3 ft) deep.

The sewer was structurally sound with no cracks or penetrations. A groundwater seep, flowing at less than 1.9 l (0.5 gal) per minute, was emanating from along the top of the sewer.

Photograph 11 – Excavation IE12. Note sidewall sloughing along silt-filled desiccation cracks.

2.5 Investigation-Derived Waste Management

Waste Streams

IDW includes waste solids and liquids generated during field investigation activities (e.g., drilling, excavation, decontamination, and sampling). URS coordinated the characterization, transportation, and disposal of all IDW. The following waste streams were generated during the investigation:

1. Decontamination liquids.
2. Excavation dewatering water.
3. PPE, plastic, and other disposable materials.
4. Manhole MH06.

Liquids from decontamination and excavation dewatering were placed in polyethylene tanks and a 21,000-gallon Baker tank. Materials such as PPE, plastic sheeting, disposable materials, and non-indigenous waste were placed in trash bags at the point of generation. The bags were then transferred to the IDW storage area and placed into the roll-off.

URS also coordinated the disposal of a scissor lift previously used at the site.

Waste Characterization

The solid IDW waste stream generated during the delineation investigation consisted of manhole MH06 and bagged PPE, plastic, etc. Representative samples of these materials were analyzed for parameters based on the requirements of the US Ecology, Inc. (US Ecology), Grandview, Idaho facility (see Table 7). URS retained Waste Technology Services, Inc. (WTS) of Lewiston, New York, to provide transportation and disposal services for the solid IDW. WTS is a certified waste shipping broker. Services provided by WTS included the preparation of waste profiles and coordination of transportation and disposal of the solid IDW.

The USACE surveyed the scissor lift for radiation levels and URS collected a sample of the lift's hydraulic fluid for PCB analysis and paint chip samples for lead analysis. The results were provided to WTS and included in the waste profile.

Because the groundwater in well OW11B has historically elevated uranium concentrations, the potential existed that the liquid IDW generated during excavation dewatering activities would require treatment at an appropriate radiation waste treatment facility. Therefore, the liquid IDW analytical parameter list was based on the requirements of the PermaFix Environmental Services facility in Knoxville, Tennessee. Table 7 presents the complete list of analytical parameters.

Waste Transportation and Disposal

Solid IDW

The solid IDW was disposed of at the US Ecology, Inc. facility in Grandview, Idaho. Appendix I contains copies of the waste profiles and waste manifests.

Liquid IDW

The analytical results for the liquid IDW was provided to the City of Lockport Wastewater Treatment Plant (LWTP) for their evaluation. LWTP issued URS a letter stating that they would accept the liquid IDW. URS retained Western New York Septic of Wilson, New York, to transport the liquid IDW from the NFSS to the LWTP. Appendix I contains copies of the LWTP acceptance letter and waste manifests.

2.6 Land Surveying

USACE surveyed the soil borings and the staked corners of each investigative excavation for location and ground elevation. The survey coordinates were geo-referenced to North American Datum (NAD) 1983 New York State Plane Coordinates and National Geodetic Vertical Datum (NGVD) 88 Datum. Appendix J contains a copy of the survey data.

3.0 ANALYTICAL RESULTS

3.1 Analytical Procedures

The analytical procedures performed on soil samples from the delineation borings are presented in Table 5. Table 6 presents the analytical procedures performed on the investigative excavation soils and groundwater. The samples were analyzed for radionuclides and PAHs by the TestAmerica Earth City facility and samples for total uranium were analyzed by the TestAmerica Richland, Washington facility. A copy of the laboratory analytical results is provided in Appendix K.

3.2 Data Validation/Qualification

In accordance with the QAPP, full deliverable data packages (Contract Laboratory Program (CLP)-like or equivalent) and Environmental Resources Program Information Management System (ERPIMS) electronic data deliverables were sent to USACE for validation. The USACE performed data validation (EPA Level IV or 100%) in accordance with the guidelines presented in the following documents:

- *USACE Kansas City and St. Louis District Radionuclide Data Quality Evaluation Guidance for Alpha and Gamma Spectroscopy,* 2002;
- U.S. Nuclear Regulatory Commission (NUREG), *Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP), NUREG-1576,* July 2004;
- USEPA, *National Functional Guidelines for Organic Data Review*, EPA 540-R-08-01, June 2008; and
- USEPA, *National Functional Guidelines for Inorganic Data Review*, EPA 540-R-10-011, January 2010.

The quality control (QC) indicator parameters reviewed during the data validation included holding times, field and lab blanks, laboratory control sample/MS/MSD accuracy and precision, field duplicate precision, surrogate/tracer accuracy, and raw data. The results of these indicator parameters were compared to their respective QC limits, whereupon, sample results associated with outliers were qualified accordingly. The qualifiers applied to the data during the validation included “J” (estimated value), and “U” (non-detect), and “R” (rejected).

3.3 Presentation of Analytical Data

Tables 8 through 21 present the delineation soil boring analytical results for radionuclides by EU and Tables 22 through 27 present the PAH analytical results by EU. Tables 28 through 36 present the soil and groundwater analytical results for the Investigative Excavation samples.

The soil analytical results are compared to the following criteria:

- Radionuclide results are compared to the DCGLs for Ra-226, Th-230, and U-238, and
- PAH results are compared to Industrial Use soil cleanup criteria presented in 6 NYCRR Part 375 and CP-51. Note that there are too many Industrial Use soil cleanup criteria values to present within the text of this report. The values are provided along with the analytical results in Tables 22 through 27.

The excavation soil analytical results for U-234, U-235, Th-228, and total U are presented in Appendix K. As explained in Section 1.6, DCGLs are calculated for site ROCs, which have been identified as Ra-226, Th-230, and U-238. The excavation water analytical results are compared to the following criteria:

- For organics and inorganics: 6 NYCRR Part 703: Surface Water and Groundwater Quality Standards and Groundwater Effluent Limitations, February 16, 2008, Class GA. For the radionuclides, the Part 703 criterion for Ra-226 is 3 picocuries per liter (pCi/L); there are no Part 703 criteria for the other ROCs.

- For radionuclides: USEPA National Primary Drinking Water Regulations, EPA 816-F-09-004, May 2009.
  - Ra-226/228 (5 pCi/L),Total Uranium (30 micrograms per liter (µg/L)),
  - Thorium isotopes (15 pCi/L): (Note: USEPA has established a Maximum Contaminant Level (MCL) of 15 pCi/L for alpha particle activity, excluding radon and uranium, in drinking water; thorium would be covered under this MCL), and
  - Uranium isotopes (30 µg/L x 0.9 pCi/µg = 27 pCi/L).

3.4 Delineation Borehole Soil Analytical Results

A total of 1,569 samples were analyzed for radionuclides and 110 samples were analyzed for PAHs. The majority of delineation borehole soil samples were collected from the following intervals:

- 0 to 15 cm (0 to 0.5ft),
- 15 to 61cm (0.5 to 2 ft), and
- 61 to 91cm (2 to 3ft).

Select locations included samples down to the 2.1-m (7-ft) depth.

Tables 8 through 21 present the radionuclide analytical results per EU. A summary of the number of borings completed and the number of radionuclide samples per EU is presented below. The table below identifies the number of surface soil (0 to 15 cm [0 to 0.5 ft]) samples and subsurface soil (>15 cm [0.5 ft]) samples that exceeded the respective radionuclide DCGLs.

Summary of Delineation Soil Boring Samples Analyzed for Radionuclides

Radionuclides									
Exposure Unit	Areas*	Borings	Samples**	Exceedences					
				Surface Soil			Subsurface Soils		
				Ra-226	Th-230	U-238	Ra-226	Th-230	U-238
EU1	6	28	93	2		1			1
EU2	14	39	122	3					
EU3	9	33	107	3			1		
EU4	2	5	12						
EU5	2	10	34	1			2		
EU6	13	40	138	7			3		
EU7	12	59	224	7			20	2	
EU8	30	106	340	16		1	1		2
EU9	1	3	10						
EU10	1	4	13						
EU11	17	92***	294	9	1				
EU12	8	31	88	8					
EU13	4	13	41						
EU14	3	15	53	3			1		
Total:	122	478	1,569	59	1	2	28	2	3

Notes:
* An investigation "area" is where additional delineation was warranted based on radiation survey data or analytical results for a previous soil sample.
** Number of samples includes parent and field duplicates.
*** 35 of the 92 borings were set in a grid pattern in the MH06 area.

The analytical results are briefly discussed below.

Ra-226

A total of 59 surface soil samples and 28 subsurface soils had radionuclide concentrations above the DCGLs. In the EU7 area, 20 samples exceeded the subsurface DCGL criteria but did not exceed the surface DCGL criterion (i.e., Ra-226 impacts were present at depth).

Th-230

Only one surface soil sample, from EU11, contained Th-230 at a level above the DCGL. Two subsurface soil samples, both from EU7, contained Th-230 at levels above the DCGL.

U-238

Only two borings, SP-13 in EU1 and GWS-26 in EU8, contained U-238 at levels exceeding the DCGLs for both the surface and subsurface soils. In both borings, the DCGLs were not exceeded in the bottom samples (i.e., 61 to 91cm [2 to 3 ft] sample).

SOR Calculations

Since multiple radionuclides are present at the site, SOR calculations are performed to identify contaminated soil AOC. As explained in Section 1.6, an average SOR score is calculated for the set of data located within each 100 m^2 area, pursuant to 10 CFR 40 Appendix A Criterion 6(6). If the average SOR score within an area of 100 m^2 was greater than 1, a contaminated soil AOC was identified and BAASS software was used to define the aerial extent of the contamination by estimating the distance between the contamination and the nearest “clean” data point (i.e., a sample location with an SOR score of less than 1). Table 21A presents the results of the SOR calculations for each individual data point.

Tables 22 through 27 present the PAH analytical results per EU. A summary of the number of borings completed and the number PAH samples per EU is presented below. The table below identifies the number of surface soil (0 to 15 cm [0 to 0.5 ft]) samples and subsurface soil (>15 cm [0.5 ft]) samples that contained at least one PAH detected at a concentration above the Part 375 Industrial Use criteria.

Summary of Delineation Soil Boring Samples Analyzed for PAHs

PAHs					
Exposure Unit	Areas*	Borings	Samples**	Exceedences	
				Surface Soil (# of exceedences)	Subsurface Soils (# of exceedences)
EU2	4	7	24	1 (1)	
EU3	1	1	3		
EU4	1	1	3		
EU8	8	16	52	7 (11)	4 (12)
EU11	1	5	16	4 (13)	1 (1)
EU12	1	4	12		
Total:	16	34	110	12 (25)	5 (13)

Notes:
* An investigation "area" is where additional delineation was warranted based on analytical results for a previous soil sample.
** Number of samples includes parent and field duplicates.

The analytical results are briefly discussed below.

PAHs

A total of 110 soil samples from six exposure units were analyzed for PAHs. Review of the results indicates that 12 surface soil samples contained PAHs at levels exceeding the Industrial Use criteria and five subsurface soil samples contained PAHs at levels exceeding the Industrial Use criteria. The PAH exceedences were all limited to the 0 to 15 cm (0 to 0.5 ft) and/or 15 to 61 cm (0.5 to 2 ft) sample intervals; there were no exceedences below 61 cm (2 ft). The highest concentrations of PAHs were detected in borings 3C007 and 3D006 in EU8, and 2A003 in EU11.

3.5 Investigative Excavation Analytical Results

3.5.1 Investigative Excavation Soil Analytical Results

The soil samples collected from the five Investigative Excavations were analyzed for radionuclides. Filtered groundwater samples were analyzed for radionuclides (Ra-226, uranium isotopes, and thorium isotopes) and total uranium. Unfiltered groundwater samples were analyzed for anions, alkalinity, and total dissolved solids. The IE soil and groundwater analytical results are presented in Figures 12 and 13 and Tables 28 through 36. The figure and tables identify those parameters that were detected at concentrations above their respective criterion. The table below identifies the number of surface soil (0 to 15 cm [0 to 0.5 ft]) samples and subsurface soil (>15 cm [0.5 ft]) samples that exceeded the respective radionuclide DCGLs.

Summary of Investigative Excavation Soil Samples Analyzed for Radionuclides

Radionuclides in Soil									
IE Area	Samples*	Exceedences							
		Surface Soil				Subsurface Soils			
		Ra-226	Th-230	U-238	Total U	Ra-226	Th-230	U-238	Total U
IEMH06	7								
IE9	4								
IE10	4			1				1	
IE11	4							1	
IE12	8							1	
Total:	27	0	0	1	0	0	0	3	0

Notes:
* Number of samples includes parent and field duplicates.

Review of the soil analytical data indicates the following:

IEMH06

Five soil samples and two duplicate soil samples were collected from IEMH06. None of the soil samples contained radionuclides or total uranium at concentrations above the respective criteria (see Table 28).

IE9

Four soil samples were collected from IE9. None of the radionuclides were detected at concentrations exceeding their respective criteria (see Table 29).

IE10

Four soil samples were collected from IE10. U-234 was detected in the surface soil sample at 15.2 pCi/g and in the west wall soil sample at 15 pCi/g, compared to the criterion of 13 pCi/g (see Table 31). U-238 was detected at 14.9 pCi/g in the surface sample and at 15.1 pCi/g in the west wall sample compared to the criterion of 14 pCi/g.

IE11

Four soil samples were collected from IE11. U-234 and U-238 were present at concentrations above the respective criterion in the sample from the north wall. U-234 was detected at 16.7 pCi/g, compared to the criterion of 13 pCi/g and U-238 was detected at 17 pCi/g, compared to the criterion of 14 pCi/g (see Table 33).

IE12

Eight soil samples were collected from IE12. Only the sample from the southeast corner of the south wall contained radionuclides at concentrations above the criteria (see Table 35). U-234 was detected at 15.1 pCi/g, compared to the criterion of 13 pCi/g and U-238 was detected at 14.6 pCi/g, compared to the criterion of 14 pCi/g.

3.5.2 Investigative Excavation Groundwater Analytical Results

The table below identifies the number of groundwater samples that exceeded the respective radionuclide criteria.

Summary of Investigative Excavation Groundwater Samples Analyzed for Radionuclides and Water Quality Parameters

Radionuclides in Groundwater									
IE Area	Filtered Samples*	Exceedences				Unfiltered Samples*	Exceedences		
		Filtered Radionuclides					Unfiltered Water Quality Parameters		
		Ra-226	Th-230	U-238	Total U		Alkalinity	Anions	TDS
IE9	1			1	1	1			
IE10	2			2	2	2			
IE11	1			1	1	1			
IE12	1			1	1	1		1	
Total:	5	0	0	5	5	5	0	1	0

Notes:
* Number of samples includes parent and field duplicates.

Review of the groundwater analytical data indicates the following:

IEMH06

A groundwater sample was not collected from excavation IEMH06.

IE9

In the filtered groundwater sample, U-234 and U-238 were both present at 77.7 pCi/L, compared the criterion of 27 pCi/L for total uranium. Total uranium was detected at 1,240 µg/L compared to the criterion of 30 µg/L.

IE10

In the filtered groundwater sample and duplicate sample from IE10, U-234, U-238 and total uranium were detected at concentrations above their respective criteria (see Table 32). The primary sample contained U-234 at 379 pCi/L and U-238 at 369 pCi/L, compared to the criterion of 27 pCi/L for total uranium; and total uranium at 1,560 µg/L, compared to the criterion of 30 µg/L. The concentrations of these analytes were slightly lower in the duplicate sample.

IE11

In the filtered groundwater sample from IE11, U-234, U-235/236, U-238, and total uranium were detected at concentrations above their respective criteria (see Table 34). U-234 was detected at 888 pCi/L, U-235/236 at 42.6 pCi/L and U-238 was present at 901 pCi/L, compared to the criterion of 27 pCi/L for total uranium. Total uranium was detected at 2,180 µg/L compared to the criterion of 30 µg/L.

IE12

In the filtered groundwater sample from IE12, U-234, U-235/236, U-238, and total uranium were detected at concentrations above their respective criteria. U-234 was detected at 1,060 pCi/L, U-235/236 at 57.8 pCi/L and U-238 was present at 1,070 pCi/L. The criterion for these analytes is 27 pCi/L. Total uranium was detected at 3,050 µg/L compared to the criterion of 30 µg/L.

In the unfiltered groundwater from IE12, sulfate was detected at 290 milligrams per liter (mg/L) compared to the criterion of 250 mg/L (see Table 36).

3.6 Investigation-Derived Waste Analytical Results

Liquid IDW Analytical Results

Representative samples of the liquid IDW were analyzed for the parameters listed in Table 7. The analytical results are presented in Table 37. The results were provided to the LWTP, which provided URS a letter stating their acceptance of the material. A copy of the LWTP letter is provided in Appendix I.

Solid IDW Analytical Results

Representative samples of solid IDW waste streams were analyzed for the parameters listed in Table 7. The analytical results for the contents of the roll-off are presented in Table 38. Table 39 presents the analytical results for the scissor lift. The results and completed waste profiles were provided to US Ecology. Copies of the waste profiles are provided in Appendix I.

4.0 SUMMARY AND CONCLUSIONS

4.1 Radiation Surveys

Gamma Walkover Surveys

Background gamma radiation levels ranged from 5.9 µR/h to 20.7 µR/h with a mean of 11.9 µR/h and a standard deviation of 2.2 µR/h. The on-site gamma walkover radiation levels ranged from 4.8 µR/h to 89.5 µR/h. The highest gamma radiation level of 89.5 µR/h was recorded at boring GWS-11 located in EU11. The impacts at GWS-11 were delineated through other borings advanced in that area.

Soil Borings

The majority of soil boring locations were selected to delineate areas of previously identified radionuclide impacts. Therefore, it was anticipated that elevated radiation levels would be encountered during the radiation surveys in some of those areas. Locations with unexpected elevated radiation levels were found and an additional 13 borings, identified with the "SP" prefix, were advanced to characterize those locations.

Investigative Excavation Results

Gamma radiation levels from most of the excavated soils ranged from 11 µR/h to 16 µR/h with an average of 13 µR/h. Some slightly elevated readings (i.e., 24 µR/h and 34 µR/h) were recorded but through further screening it was determined that those readings were in areas without a specifically identifiable source.

Generally, the shielded measurements of the excavation sidewalls and bottoms showed normal variations in the radiation count rates, however slightly elevated radiation measurements were observed in IE9 along the north wall.

All equipment and general survey results were within the site ambient radiation levels and met the requirements for equipment/materials release.

4.2 Delineation Soil Borings

A significant amount of soil data has been collected at the NFSS, beginning with the initiation of the remedial investigation in 1999 through the end of this field investigation in 2014. All of this data is captured in the effort to estimate the extent of soil contamination, which is depicted in Figures 14 through 20. The results of this delineation will be used to support the BOP OU FS by reducing the uncertainty of the estimated volume of soil that may require excavation. Details of this field investigation are presented below.

A total of 478 borings were advanced during the investigation with 461 borings advanced to better delineate radionuclide areas of concern and 34 borings to better define PAH areas of concern; some borings were used to delineate both radionuclide and PAH areas of concern. Of the 1,569 samples analyzed for radionuclides, 87 samples contained Ra-226 at concentrations above the DCGLs, three samples contained Th-230 at concentrations above the DCGLs, and five samples contained U-238 at concentrations above the DCGLs. While many of the radionuclide levels decreased with depth, some locations contained elevated radionuclide concentrations at depth but not at the surface.

A total of 110 soil samples were collected from 34 borings in six exposure units to further delineate PAH impacts. The results show that 12 surface soil samples contained PAHs at levels exceeding the Industrial Use criteria and five subsurface soil samples contained PAHs at levels exceeding the Industrial Use criteria. The highest concentrations of PAHs were detected in borings 3C007 and 3D006 in EU8, and 2A003 in EU11.

Based on the findings of this investigation, sufficient data is now available to reduce the uncertainty of the estimated volume uncertainty of soil requiring excavation.

4.3 Investigative Excavations

Observations and analytical results for the investigative excavations indicate that the interior of the sewer does not appear to be a conduit for contaminant migration. This is evidenced by the fact that the sewer had been previously cut and plugged just upgradient of manhole MH06; the manhole itself appeared to have been effectively plugged; and the sewer was found to be intact with no cracks or penetrations. Minor groundwater flow was found along the exterior of the concrete encasement.

Although some of the groundwater samples contained elevated levels of total uranium and uranium isotopes, a source term was not identified in the excavations.

The groundwater analytical data from the 2013 BOP Operable Unit *Field Investigation Report* and previous investigations and sampling events show that total uranium-impacted groundwater is present in areas where USDOE remedial activities were known to occur. Historical aerial photographs show land scarring in the OW11B area during the time of USDOE remediation activities. Also, video footage taken during IWCS construction show extensive activities, such as equipment decontamination and materials unloading, storage, and loading, occurred in this area. The uranium impacts detected in the groundwater collected from the area between the buried water supply pipes in excavation IE7 and from along the top of the concrete-encased sanitary sewer, as observed in excavation IE8 and during the current investigation, might be associated with those former remediation activities. In addition to advancing five investigative excavations along the sanitary sewer line, 35 delineation soil borings were advanced in the OW11B area. The fact that none of these investigation activities identified a source term in this area indicates that the source term, if previously present, had been removed and the current groundwater contamination is the result of the historical movement of residue material in this area. Although a source term was not identified, the USACE may perform addition investigations in the OW11B vicinity to obtain additional information on the hydraulic conductivity and groundwater flow in this area.

5.0 REFERENCES

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