FINAL REPORT

KAPL Land Disposal Area Focused Corrective Measures Study Report

Knolls Atomic Power Laboratory
Niskayuna, New York

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Prepared for:

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Niskayuna, New York

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LIST OF ACRONYMS AND ABBREVIATIONS

C&D	Construction and Demolition
CAO	Corrective Action Objective
CP	Commissioner's Policy
DER	Division of Environmental Remediation
DOE	Department of Energy
EI	Environmental Indicator
FCMS	Focused Corrective Measures Study
GE Global	General Electric Global Research Center
KAPL	Knolls Atomic Power Laboratory
LDA	Land Disposal Area
MCS	Media-Specific Cleanup Standard
NYCRR	New York Codes, Rules and Regulations
NYSDEC	New York State Department of Environmental Conservation
OM&M	Operation, Maintenance and Monitoring
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
POC	Point of Compliance
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SB	Statement of Basis
SCG	Standards, Criteria and Guidance
SCO	Soil Cleanup Objective
SPRU	Separations Process Research Unit
SV	Sampling Visit
SVOC	Semi-Volatile Organic Compound
SWMU	Solid Waste Management Unit
TCE	Trichloroethylene
TOGS	Technical and Operational Guidance Series
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound

1. INTRODUCTION

This report documents the Focused Corrective Measures Study (FCMS) conducted to evaluate corrective measures to address chemical contamination in soil/waste material, groundwater, and seeps in the Land Disposal Area (LDA) at the Knolls Atomic Power Laboratory (KAPL) – Knolls Laboratory, located in Niskayuna, New York. The FCMS addresses five of the six Solid Waste Management Units (SWMUs) that are located within the LDA and include the Former Landfill, Mercury Disposal Area, Pyrophoric Area, West Field, and Construction and Demolition (C&D) Area No.1. Based on the Resource Conservation and Recovery Act (RCRA) Facility Investigation Report (RFI Report) [Reference (1)], no further action is needed for the North Field, which is therefore not included in the FCMS.

This FCMS Report documents the development and evaluation of a corrective measure based on the nature and extent of chemical releases in the LDA, as presented in the RFI Report. Under the framework of the FCMS, the proposed corrective measure for the LDA incorporates a presumptive remedy with institutional and engineering controls to address Corrective Action Objectives (CAOs). The conceptual components of the corrective measure are also presented herein.

This FCMS was conducted in accordance with the 6 New York Codes, Rules and Regulations (NYCRR) Part 373 Hazardous Waste Management Permit (Part 373 Permit) [Reference (2)] for the Knolls Laboratory [New York State Department of Environmental Conservation (NYSDEC) Permit Number 4-4224-00024/00001]. Guidance and elements were incorporated from 6 NYCRR Part 375 Environmental Remediation Programs [Reference 3)], NYSDEC's Division of Environmental Remediation (DER) Technical Guidance for Site Investigation and Remediation (DER-10) [Reference (4)], NYSDEC's DER Green Remediation Program Policy (DER-31) [Reference (5)], and the RCRA Facilities Investigation Remedy Selection Track, A Toolbox for Corrective Action [Reference (6)].

1.1. SITE DESCRIPTION AND BACKGROUND

As shown on Figure 1, the Knolls Laboratory is located in the Town of Niskayuna, Schenectady County, New York, on the south bank of the Mohawk River. The Knolls Laboratory comprises 170 acres, most of which are located on a bluff approximately 115 to 120 feet above the Mohawk River (referred to as the upper level). Along the northern margin of the Knolls Laboratory, the land surface slopes steeply to a natural bench (referred to as the lower level) approximately 15 to 20 feet above the river surface. The Knolls Laboratory fronts approximately 4,200 feet of the Mohawk River. The Knolls Laboratory is bounded to the north by the Mohawk River; to the east by a mixture of open land, parks, and the closed Town of Niskayuna municipal landfill; to the south by a low-density suburban residential area; and to the west by the General Electric Global Research Center (GE Global). Buildings and support facilities occupy approximately 60 acres of the property. The remainder of the Knolls Laboratory (approximately 110 acres) consists of undeveloped woods and fields.

Construction of the Knolls Laboratory began in 1948, and laboratory operations at the Knolls Laboratory began in 1949. The principal function of the Knolls Laboratory is research and development in the design and operation of Naval nuclear propulsion plants. From the late 1940s through the mid to late 1970s, waste material is known and/or alleged to have been disposed in the LDA SWMUs.

As shown on Figure 2, the six SWMUs that make up the LDA are located in the eastern portion of the Knolls Laboratory, outside the fenced security area. Figure 3 provides a more detailed view of the LDA, including topography and geophysical anomalies mapped in the mid-1990s [Reference (7)], indicating areas containing possible buried metal objects. As indicated by the ground elevation contours on Figure 3, the ground surface in most of the LDA is relatively flat, with steeper slopes adjacent to drainage pathways and along fill faces. The elevations on Figure 3 represent the ground surface prior to the Department of Energy (DOE) Separations Process Research Unit (SPRU) North Field Land Area radiological soil remediation (SPRU North Field Project) [Note that this is a separate designation from the KAPL North Field SWMU]. Although some of the land surface was altered during the SPRU North Field Project, the ground surface was substantially restored to pre-existing conditions and is not materially different from that shown on Figure 3. In addition, clean fill placed between the service roadway and the East Boundary Stream (southwest portion of the map area) has raised ground elevations up to approximately 15 feet from the elevations depicted on Figure 3.

1.1.1. Operational History

The operational history of the six LDA SWMUs is summarized as follows:

- ***Former Landfill*** **-** Disposal operations within the Former Landfill pre-date KAPL operations, when the previous landowner used a former sand and gravel pit for the disposal of scrap metal and household waste. From 1948 to 1974, KAPL used this area for the disposal of what was found to be office and cafeteria waste and C&D debris (*e.g.*, wood, bricks, concrete, asphalt, and wire) based on test pits excavated during the RFI. The buried waste is located on the western portion of the Former Landfill extending over an area of approximately 1.5 acres. The waste is approximately 4 to 10 feet thick and is covered by 1 to 5 feet of sandy soil. Incidental pieces of concrete, asphalt, and metal are present at the surface along the slopes adjacent to the Former Landfill, resulting in an estimated overall size of 2.1 acres.
- ***Mercury Disposal Area*** **-** The Mercury Disposal Area was an unlined earthen pit approximately 2 feet wide by 5 feet long by 4 feet deep in which old batteries were disposed. During inspection of the area in the late 1970s, mercury droplets associated with the batteries were observed in the soil. In the early 1990s, the battery carcasses and soil contaminated with mercury were excavated from the pit and disposed offsite. In addition to the excavated pit, a shallow depression approximately 2 feet wide by 5 feet long by 2 feet deep was located just south of the excavated pit. Three soil piles of unknown source, all approximately 2 feet high, also were present in the immediate vicinity of the pit and the depression.
- ***North Field*** **-** The North Field is located in what was a soil borrow area during construction of the Knolls Laboratory and covers an area of approximately 1.5 acres. A north-south trending hill, approximately 10 to 20 feet high, was removed to provide clean fill. Historical employee accounts and some historical physical evidence (*e.g.,* broken containers, glass shards, bottles, and a protruding drum) indicated that chemicals of an unspecified nature may have been buried in the North Field. Investigation activities did not indicate evidence of buried material in the North Field or releases of chemical constituents.
- ***Pyrophoric Area*** **-** Between the early 1950s and late 1970s, zirconium chips and powder were burned or buried in the Pyrophoric Area, which covers approximately 1.5 acres. A fire accelerant (kerosene or methanol) was used to aid the burning, which took place on a 4-foot-square, ¼-inch-thick steel plate located near the former pyrophoric shed[1]. Approximately 7,100 pounds of scrap zirconium were reportedly burned or buried in this area. Because of the reactive nature of zirconium, unburned zirconium was immersed in oil and buried in approximately 30, 1-gallon and 5-gallon containers in the vicinity of the former pyrophoric shed. Several of the containers were exhumed in the late 1980s. Buried material that consists mostly of C&D debris, was found in the western portion of the Pyrophoric Area. The buried material is 6 to 8 feet thick and is thinly covered with sandy soil, though some debris is visible at the surface. An approximately 6-inch thick layer of pyrophoric burn residue was found on the ground surface in the eastern portion of the Pyrophoric Area.
- ***West Field*** **-** Historical employee interviews indicated that the West Field was a shallow unlined disposal area in which chemical wastes of an unspecified nature were buried more than 40 years ago over a period of about 1 year. Based on historical information, the general area of the West Field is shown on Figure 3, covering approximately 0.5 acres. Buried material consisting of laboratory debris (*e.g.,* glassware and tubing) and C&D debris was identified in the West Field. The waste is 4 to 6 feet thick and is covered with 1 to 2 feet of sandy soil, though soil fill with sporadic wood debris was found as deep as 8 feet in an isolated area. Although not within the defined boundaries of any LDA SWMU, the area between the West Field and the Pyrophoric Area and Former Landfill has been called the West Field Extended, and comprises an area of

[1] The pyrophoric shed and surrounding fence were dismantled in 2017.

approximately 1.3 acres. Waste material in the West Field Extended typically consists of 6 to 8 feet of C&D debris, with some areas comprising 1 to 3 feet of silty sandy fill with sporadic C&D debris.

- ***C&D Area No.1*** **-** The C&D Area No.1 encompasses roughly 0.4 acres in a partial bowl-like feature, with an elevated rim and a lower mostly flat interior. The rim of the bowl comprises an undisturbed ridge of soil to the north and east, a remnant of early site soil borrow-area excavations, and a ridge of merged soil piles to the south, consisting of sand and gravel with large cobbles. Broken asphalt slabs, chunks and slabs of reinforced concrete, small piles of concrete rubble, and vitrified clay pipe are scattered on the ground surface. Occasional pieces of metal and asphalt are also present. An isolated small pile of concrete rubble is located approximately 75 feet southeast of the area. The source of the concrete material is unknown. Investigation activities indicated no evidence of buried material at this location.

1.1.2. LDA Corrective Action History

As part of the Part 373 Permit, several investigations and studies have been previously undertaken at the LDA, including the RCRA Facility Assessment Preliminary Review - Visual Site Inspection Report [Reference (8)], issued by NYSDEC in July 1998, in which NYSDEC identified further action requirements for the six LDA SWMUs. Each SWMU was subject to a Sampling Visit (SV) to evaluate if a release of chemical constituents had occurred in the soil. The Pyrophoric Area carried an additional requirement of a groundwater RFI to evaluate the nature and extent of volatile organic compounds (VOCs) historically detected in a nearby well.

In parallel with the development of the LDA SV Work Plan, a separate SV investigation associated with the Former Slurry Drum Storage Area of the SPRU Project [Reference (9)], was ongoing in portions of the LDA, including areas that overlapped portions of the Former Landfill and Pyrophoric Area. During implementation of the SPRU SV, low concentrations of VOCs were found in the shallow soil in the Former Landfill and Pyrophoric Area. The positive indication of a chemical release to the environment met the objective of the SV, and NYSDEC and KAPL agreed that further characterization of the releases in the Former Landfill and Pyrophoric Area would be performed during the follow-on RFI. Therefore, the LDA SV focused on the Mercury Disposal Area, North Field, West Field and C&D Area No.1; still some investigation was performed in portions of the Former Landfill and Pyrophoric Area.

In accordance with the Part 373 Permit requirements, the LDA SV Work Plan was initially designed to investigate surface and near-surface soils for releases of chemical constituents associated with known or suspected historical shallow burial of solid waste. During development of the LDA SV Work Plan, NYSDEC requested that the schedule for groundwater RFI associated with the Pyrophoric Area be advanced to allow a positive determination to be made by the end of 2005 for the environmental indicator (EI) *Migration of Contaminated Groundwater Under Control* (Groundwater EI). The Groundwater EI milestone was established by the United States Environmental Protection Agency (USEPA) pursuant to the Government Performance Results Act. Consequently, the LDA SV Work Plan was modified to include a groundwater investigation, and the LDA SV Work Plan was approved by NYSDEC in May 2002 [Reference (10)].

Fieldwork for the LDA SV was performed between July 2002 and July 2004. The investigation activities were implemented in several phases in accordance with the approved LDA SV Work Plan [Reference (10)] and supplemental scope of work agreed to by NYSDEC. The supplemental work included shallow soil sampling to address NYSDEC comments on the SPRU SV Report [Reference (11)]. Via Reference (12), KAPL assumed responsibility to further evaluate, under the LDA Corrective Action work, sporadic indications of possible minor releases in shallow soil within an area associated with the Former Slurry Drum Storage Area, for which a link to SPRU could not be definitively determined. Through a cooperative effort with DOE-SPRU, additional shallow soil samples were collected for KAPL by the DOE-SPRU contractor. These samples were collected, handled, and analyzed in accordance with procedures approved by NYSDEC.

Based on the results of the LDA SV, NYSDEC made a positive determination for the Knolls Laboratory for the Groundwater EI [Reference (13)] in October 2004 and the *Current Human Exposures Controlled* EI in August 2005 [Reference (14)]. Addressed in these EI determinations is the LDA, for which the extent and migration of the contaminated groundwater in the LDA was identified to be under control, and human health exposure related to contaminated soil and groundwater in the LDA was identified to be under control.

Although the nature and extent of the chemical releases in the LDA were substantially defined in the LDA SV, additional investigation under an RFI was recommended for all six LDA SWMUs to further characterize the nature and extent of the releases and to enhance the understanding of the hydrogeologic conditions influencing the fate and mobility of the releases. For most of the SWMUs, this entailed refinement of the release characterization. A release characterization plan for the six LDA SWMUs was developed and incorporated into the LDA RFI Work Plan [Reference (15)], which was approved by NYSDEC via Reference (16). The results of the LDA RFI are presented in the RFI Report and summarized in Section 2.

2. RCRA FACILITY INVESTIGATION REPORT SUMMARY

2.1. RCRA FACILITY INVESTIGATION

The LDA RFI was implemented in accordance with the LDA RFI Work Plan to further characterize the nature and extent of the chemical releases in the LDA and to enhance the understanding of the hydrogeologic conditions influencing the fate and mobility of the releases. The RFI included two principal investigations - the Soil Release Characterization and a Groundwater Investigation. The RFI was implemented in two phases; Phase 1 was completed in 2009, in accordance with the RFI Work Plan, and Phase 2 was executed in 2010, based on a supplemental NYSDEC-approved scope of work.

In 2010, between Phases 1 and 2 of the RFI, excavation activities were conducted in the Mercury Disposal Area and Pyrophoric Area, as part of the SPRU North Field Project that is documented in the SPRU Radiological Completion Report for North Field Land Area [Reference (17)]. During the SPRU North Field Project, as much as 2 feet of soil from the Mercury Disposal Area was excavated and disposed offsite, though field personnel indicated at the time that removal and off-site disposal of the upper 0.5 to 1 foot of soil from this area was typical. The area was subsequently graded to blend in with the surrounding contours.

Portions of the Pyrophoric Area, including part of the surface pyrophoric burn residue and much of the easternmost portion of the buried waste, were excavated and disposed offsite. In addition to the C&D debris known to be present, several empty crushed drums were found in an area previously suspected to be a source of VOCs found in groundwater (*i.e.,* VOC source area) within and adjacent to the Pyrophoric Area. The SPRU Radiological Completion Report for North Field Land Area indicates that the maximum depth of the excavation in the Pyrophoric Area was approximately 10 feet. Based on pre-excavation and post-excavation elevation contours, approximately 600 cubic yards of debris and soil are estimated to have been excavated from the VOC area and disposed offsite.

2.2. NATURE AND EXTENT OF CONTAMINATION

The RFI Soil Release Characterization was designed to evaluate the nature and extent of chemical constituents in the LDA associated with known or suspected historical shallow burial of solid waste. The SWMUs investigated as part of the Soil Release Characterization included the Former Landfill, the Mercury Disposal Area, the North Field, the Pyrophoric Area, the West Field, and the C&D Area No.1. The Groundwater Investigation was designed to assess the limits of VOCs detected historically in groundwater in the LDA. The data from the groundwater investigation supplemented and corroborated the findings of the soil investigation.

A summary of the RFI Report conclusions is presented below for the five SWMUs addressed in this FCMS and the Groundwater Investigation. With few exceptions associated with localized perched groundwater in the Former Landfill, disposed material is above the water table. In addition, free chemical liquids were not found in environmental media, nor was any substantial residual contaminant source identified. The RFI data indicate the identified releases are mature and stable, and the chemical constituents in the disposed material are typically incidental to the solid and stable fill material and are not readily migrating beyond the immediate disposal area.

For purposes of identifying areas to be addressed in the FCMS, the investigation analytical results for the LDA soil were compared to the respective 6 NYCRR Part 375 Unrestricted Use Soil Cleanup Objectives (SCOs) and the site-specific background concentrations for metals. Figure 4 shows the locations of concern based on that comparison and also shows locations where waste material/debris was observed. RFI analytical results for groundwater, seeps, and surface water were compared to the respective Class GA groundwater standards and Class A surface water standards identified in 6 NYCRR Part 703 [Reference (18)] and Class GA groundwater guidance values and Class A surface water guidance values identified in Technical and Operational Guidance Series (TOGS) No. 1.1.1 [Reference (19)]. Figure 5 summarizes the water data to show the extent of the VOC plume where water concentrations exceed the groundwater and surface water quality criteria.

2.2.1. Former Landfill

The waste in the Former Landfill typically extends to depths of 10 feet or less, but has been found as deep as 12 feet. The waste is above the water table, except at two locations where water is perched on shallow gray till. The waste material consists mostly of office and cafeteria waste, with some C&D debris. Isolated crushed and empty 1-gallon cans of duplicating cleaning solvent and isopropyl alcohol were present sporadically within the waste. A light ballast was found at one location.

An isolated pocket of unique waste exists at the base of the slope on the southwest side of the Former Landfill. A black sand-like material with a tar-like odor was discovered within the remnants of a deteriorated and unidentifiable rusted container found at 3 to 3.5 feet below grade. The black sand-like material extends to approximately 4 feet below grade over an area roughly 2-feet square. The location of the black sand-like material is separate from the main disposal area, with no evidence of lateral continuity of waste between the two areas.

Overall, the VOC, semi-volatile organic compound (SVOC), polychlorinated biphenyl (PCB), and metals results for the Former Landfill are unremarkable, with concentrations exceeding the respective SCO in only a few isolated locations. Markedly high concentrations of gasoline-related VOCs were found at one location within the waste, and notably high concentrations of PCBs and metals were detected in the black sand-like material. However, data from test pits and soil borings indicate the constituents are not migrating substantially from the waste in the Former Landfill into the underlying and adjacent soil.

2.2.2. Mercury Disposal Area

Low and diffuse concentrations of polynuclear aromatic hydrocarbons (PAHs) and PCBs were found throughout the surface soil in the Mercury Disposal Area, with concentrations of PAHs and PCBs exceeding the respective SCOs each in only one sample. The occurrence and distribution of certain metals indicates that the soil has been affected by a source of metals which has since been removed. Mercury concentrations were found exceeding the SCO in one isolated area. As described in Section 2.1, affected soil was removed in 2010 during the SPRU North Field Project, possibly leaving only one location with mercury concentrations greater than the SCO. Low and diffuse concentrations of cyanide were detected throughout the Mercury Disposal Area, principally in the surface soil. The concentrations may represent a subtle effect from a release in this area or possibly a general background concentration of cyanide in the surface soil.

2.2.3. Pyrophoric Area

The soil in the Pyrophoric Area has been affected by VOCs, PAHs, PCBs, and metals. The extent of influence from the PAHs, PCBs, and metals is limited to the surface and shallow disposed waste and the soil in immediate contact with the disposed material. An area exhibiting high soil VOC concentrations was found in the eastern portion of the fill area, and VOCs evidently have migrated from this area and have become isolated in thin deep soil zones below the Pyrophoric Area and West Field Extended. This area of high VOC soil concentrations appears to be the principal source area of VOCs detected in groundwater within and downgradient of the Pyrophoric Area (*i.e.,* VOC source area). As described in Section 2.1, a substantial portion of VOC-affected soil in the VOC source area was removed in 2010 as part of the SPRU North Field Project.

High concentrations of VOCs isolated in deeper soil samples collected from the gray till contact indicate that the VOCs have moved vertically through the soil column in the VOC source area and have migrated laterally along the gray till surface. The high VOC concentrations appear to be isolated mostly in the 6 to 12 inches of soil immediately above the gray till. VOCs are present elsewhere in the waste/fill associated with the Pyrophoric Area, but the concentrations are typically low and diffuse and are not indicative of a VOC source area.

Pyrophoric burn residue was identified in the eastern portion of the Pyrophoric Area. The pyrophoric burn residue is recognizable in the field by its black sandy texture, and it appears to be the cause of the geophysical anomaly (Figure 3) in the eastern portion of the Pyrophoric Area. The pyrophoric burn residue exhibits a distinct profile of chromium, cobalt, iron, nickel, and vanadium at concentrations exceeding SCOs. The extent of pyrophoric burn residue is limited to surficial material, which is typically 6 inches thick.

Concentrations of PAHs, PCBs, and metals present in soil are associated with the waste and soil fill material in the Pyrophoric Area. However, data from samples below the waste and fill indicate that the elevated concentrations of PAHs, PCBs, and metals are associated with the solid and stable waste or fill and do not migrate substantially into the underlying soil. With the exception of the VOCs, the chemical constituents are incidental to the solid and stable waste and are not readily migrating beyond the immediate disposal area.

2.2.4. West Field and West Field Extended

The soil in the West Field and West Field Extended has been affected by PAHs, PCBs, and metals associated with the shallow buried waste in these areas. However, the extent of the influence is limited to the soil in immediate contact with the waste. VOCs are not significant in the West Field proper, and overall were found in the West Field Extended at unremarkable concentrations, with the exception of high VOC concentrations discovered below the waste isolated within silt and clay, indicative of migration under the West Field Extended from a nearby source area. The chemical constituents are incidental to the solid and stable waste and are not readily migrating beyond the immediate disposal area. The VOCs found at depth in the West Field Extended appear to be associated with a mature and stable release from a nearby and undefined source area.

2.2.5. C&D Area No.1

Overall, the PAH, PCB, and metals results for the C&D Area No.1 are unremarkable. Low and diffuse concentrations of PAHs and PCBs were found throughout the surface soil in the C&D Area No.1, which is consistent with the presence of C&D debris. Concentrations of PAHs greater than SCOs were detected in one isolated sample. PCB concentrations greater than the unrestricted SCO were detected in two surface soil samples; however, the PCB concentrations in these samples are less than the residential SCO. The occurrence and distribution of certain metals elevated above background may represent a subtle but unremarkable effect on the soil from the C&D debris in this area.

The soil in the southern rim of C&D Area No.1 has been affected by the VOC trichloroethylene (TCE). Concentrations of TCE exceeding the SCO were detected in shallow soil in a small area in the southwest rim of C&D Area No.1. TCE concentrations exceeding the SCO appear to be limited to the upper 1 to 2 feet of the gray till, which is found at depths of 1.5 to 3 feet below ground surface in the area of the release.

TCE concentrations exceeding the SCO were also found in shallow and deep soil in a small area in the southeast rim of C&D Area No.1. TCE concentrations greater than the SCO are present in the soil at or near the surface of the gray till found at 4 to 7 feet deep and extend to a depth of 25 feet in an isolated area. The vertical extent of the TCE is uncharacteristically deep for the gray till and appears to be the result of a concentrated release of TCE directly onto a confined surface of the gray till which enhanced localized vertical migration into the gray till rather than lateral migration and diffusion across the gray till surface.

Groundwater was found in only one boring, located adjacent to the TCE release in the southeast rim, and is limited to a thin seam of fine sand isolated within the gray till. Isolated saturated lenses of fine sand are not uncommon in the gray till and are capable of transmitting small quantities of water. However, these sand lenses are not connected and water is rapidly depleted from these small isolated sand lenses with little or no recharge. TCE was detected in the localized groundwater at a concentration less than the Class GA groundwater standard. The minor groundwater TCE concentration in close proximity to the high soil TCE concentrations indicates that the TCE has become effectively immobilized within the gray till.

2.2.6. Groundwater Investigation

The occurrence and movement of groundwater in the LDA is controlled by the geology, which is dominated by a dense, clay-rich, glacial deposit of gray till. The gray till underlies the entire LDA and ranges in thickness from 25 to 55 feet. Owing to its low permeability, the gray till inhibits vertical movement of groundwater. Consequently, groundwater is found in the sand and gravel above the gray till and also as localized perched groundwater where the shallow porous fill material rests on relatively low permeability deposits of silt and clay. Groundwater flows preferentially into the permeable sand and gravel, which is oriented north-south within a north-south trending trough in the surface of the gray till. Groundwater movement is therefore constrained into an overall north-south flow orientation. Just north of the Former Landfill, an apparent divide exists in the water table, separating northward groundwater flow from southward groundwater flow, which may be the result of increased recharge through the relatively porous fill material and the perching of the groundwater on the underlying silt and clay. This mounding of the groundwater surface occurs beneath the central portion of the fill material located in the Pyrophoric Area and the area to the south and west. Groundwater flows subradially from the central mound of groundwater and is assimilated into the localized flow patterns within the surrounding sand and gravel deposits. The groundwater flow patterns shown on Figure 6 are adapted from RFI Report groundwater contour maps.

VOCs are present in a north-south oriented plume controlled and constrained in movement and extent by the sand and gravel deposits and underlying gray till. A source area of the principal VOCs [perchloroethylene, TCE, cis-1,2-dichloroethylene, and vinyl chloride] present in the groundwater plume was found in the Pyrophoric Area, coincident with the highest VOC concentrations in groundwater. The primary migration pathway from the VOC source area is groundwater flow to the north. However, evidence was found of VOCs having migrated westward from the VOC source area along the top of the westward sloping surface of the gray till, independent of the primary groundwater flow. Soil borings apart from the VOC source area revealed high concentrations of VOCs only in the soil at the contact with the gray till. Outside the VOC source area, similarly high VOC concentrations were found shallower than the gray till surface in one isolated sample within the silt and clay beneath the fill just west of the Pyrophoric Area. The isolation of the high VOC concentrations vertically within the soil column indicates the VOCs have migrated laterally to this location from the VOC source area or possibly from a separate source area in nearby fill. Non-aqueous phase VOC liquids were not found in soil elsewhere in the LDA nor were non-aqueous phase liquids found in the groundwater monitoring wells.

The eastern extent of the VOC plume is controlled by the less permeable gray till which is present at or near the ground surface just east of the study area. Groundwater in the sand deposits within and just south of the Pyrophoric Area assumes a northward or southward flow in response to the gray till, the thick silt and clay deposits immediately to the west, and the apparent hydraulic communication with the larger sand and gravel deposit. The surface of the gray till and the sand and gravel deposit also control the western extent of the plume, whereby the northward sloping trough in the surface of the gray till captures and controls westward VOC migration along the gray till surface, and the north-south trending sand and gravel deposit acts as a hydraulic sink for eastward and westward flowing groundwater, thereby providing a hydraulic barrier to westward flow.

The northward moving portion of the groundwater plume comprises three sub-plumes. One sub-plume is associated with the VOC source area found in the Pyrophoric Area and contains the highest concentrations of VOCs. This plume moves northward from the eastern portion of the fill area. A second sub-plume moves within the sand and gravel along the western side of the fill area. A third, smaller sub-plume emerges from beneath the silt and clay just north of the fill area. The three sub-plumes merge north of the Pyrophoric Area. The plume narrows at its northern terminus, moving northward coincident with the sand and gravel deposits within the trough in the gray till. Groundwater converges into this area from the east, west, and south and ultimately discharges into the Midline Stream swale. As shown on Figure 3, the ground surface slopes from the east, west, and south into the swale, which drains northward via Midline Stream and discharges to the Mohawk River. The Midline Stream outfall is sampled quarterly for VOCs as part of the Knolls Laboratory voluntary monitoring program; VOCs have not been detected.

VOC source areas were not found for the VOCs detected in the western and southern portions of the investigation area. Although patterns of detection and migration in the investigation area are identifiable for specific VOCs or groups of VOCs, discrete source areas of these VOCs were not identified.

In the southern end of the investigation area, the VOC plume narrows south of the groundwater divide, where converging groundwater from the Former Landfill and groundwater from the west constrict the width of the plume. Groundwater and the associated plume flows southward through a narrow area adjacent to the western portion of the Former Landfill. Seeps located near the base of the slope in this area are evidence of the convergence and discharge of groundwater. Seepage is less evident along the eastern portion of the slope of the Former Landfill, with only one intermittent seep identified. VOCs associated with the plume have been detected in the western seeps at concentrations greater than water quality criteria. VOCs have not been detected in the seep to the east, and VOCs have not been detected in nearby downgradient surface water samples.

3. IDENTIFICATION AND DEVELOPMENT OF THE CORRECTIVE MEASURE ALTERNATIVE

This section documents the development of the corrective measure alternative for soil/material, groundwater, and seeps at the LDA, consistent with the Part 373 Permit. Guidance and elements were incorporated from 6 NYCRR Part 375 Environmental Remediation Programs [Reference (3)], NYSDEC's DER-10 [Reference (4)] and DER-31 [Reference (5)], and the RCRA Facilities Investigation Remedy Selection Track, A Toolbox for Corrective Action [Reference (6)].

3.1. DEVELOPMENT OF CORRECTIVE ACTION OBJECTIVES

The broad goals of the RCRA Corrective Action Program [References (20) and (21)] include:

- Protect human health and the environment
- Control sources of hazardous constituents
- Achieve media-specific CAOs

CAOs are media-specific goals which form the basis for this FCMS by providing overall goals for site remediation. Soil/material and groundwater CAOs were considered during the identification of appropriate corrective measure technologies and during the development and evaluation of the corrective measures alternative.

The current, intended, and reasonably anticipated future uses of the LDA and its surroundings; the nature and extent of chemical constituents in the LDA soil/material, groundwater, and seeps; and potential chemical-specific Standards, Criteria and Guidance (SCGs) were considered during the development of the CAOs.

3.1.1. Identification of Potential Chemical-Specific Standards, Criteria and Guidance

Chemical-specific SCGs are health- or risk-based numerical values, or methodologies, which when applied to site-specific conditions, result in numerical values. These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment.

The following SCGs will serve as medium-specific cleanup standards (MCSs) for soil:

- 6 NYCRR Part 375-6.8(a) Unrestricted Use SCOs [Reference (3)]
- NYSDEC Commissioner's Policy (CP) Soil Cleanup Guidance (CP-51) [Reference (22)]

In addition, Knolls Laboratory-specific background concentrations (RFI Report Table 6) and USEPA Regional Screening Levels [Reference (23)] were also considered where an SCO was not designated.

The following SCGs will serve as MCSs for groundwater/seeps and surface water (as related to the cross-media transfer CAO) in this FCMS:

- Class GA groundwater standards and Class A surface water standards identified in 6 NYCRR Part 703 [Reference (18)] and Class GA groundwater guidance values and Class A surface water guidance values identified in TOGS No. 1.1.1 [Reference (19)]

3.1.2. Assessment of Land Use

Consistent with 6 NYCRR 375-1.8 (f) and NYSDEC's DER-10 4.2 (i), the current, intended, and reasonably anticipated future uses of a property are considered when selecting SCOs. The Knolls Laboratory, including the LDA, is owned by the Federal Government, and the ownership and use of the Knolls Laboratory and the LDA is anticipated to remain unchanged for the foreseeable future. The Knolls Laboratory is zoned for research and development uses within the Town of Niskayuna [Reference (24)].

The LDA is located in the eastern portion of the Knolls Laboratory, outside the fenced security area. The LDA consists of mixed undeveloped open fields and woods. The Knolls Laboratory Building Q12 (salt shed) is located along the southern border of the LDA. Human access to the LDA is restricted by 24-hour security measures. Normal vehicular and pedestrian access to the Knolls Laboratory is controlled through perimeter security gates.

Trespassing in the LDA is controlled through the Knolls Laboratory access security measures and a combination of routine surveillance and patrol measures and topographic and natural barriers. Other than use of the service roads for routine security patrols, seasonal snow staging and salt shed use, access to the closed landfill, and equipment and material staging/laydown and retrieval, Knolls Laboratory personnel rarely access the LDA.

Portions of the Former Landfill, Pyrophoric Area, and the West Field (including West Field Extended) are currently utilized as a material and equipment staging area for a SPRU project located in another area of the Knolls Laboratory. The ground surface in the staging area is covered with crushed stone. Temporary office trailers associated with DOE-SPRU work are located southwest of the LDA, with some trailers overlying the western edge of the West Field. Those trailers within the LDA boundary would be removed at the completion of the SPRU project and prior to implementation of the LDA corrective measure.

3.1.3. Corrective Action Objectives for Soil/Material and Groundwater

Potential MCSs, nature and extent of contamination, potentially unacceptable risks, and the current, intended, and reasonably anticipated future use of the LDA and its surroundings, were considered during the development of CAOs for protection of human health and the environment. As described in Section 2, soil contains chemical concentrations above Unrestricted Use SCOs. Although the current restricted land use would continue for the reasonably anticipated future of the LDA, the Unrestricted Use SCOs are being used as the MCSs to conservatively develop the LDA corrective measure. Though groundwater is not used as a drinking water or industrial water supply and is not anticipated to be used as a drinking water or industrial water supply in the future, groundwater exceedances of chemical-specific SCGs were considered. Accordingly, the following CAOs were developed:

Human Health

- Prevent, to the extent practicable, potential current and future exposure to chemical constituents of concern in soil/material, at concentrations in excess of Unrestricted Use SCOs.
- Prevent, to the extent practicable, potential current and future exposure to chemical constituents of concern in groundwater and seeps, at concentrations in excess of Class GA groundwater and Class A surface water standards, respectively.

Ecological Receptors

- Prevent, to the extent practicable, potential impacts to biota from exposure to chemical constituents of concern in soil/material, at concentrations in excess of Unrestricted Use SCOs.
- Prevent, to the extent practicable, potential impacts to biota from exposure to chemical constituents of concern in seeps, at concentrations in excess of Class A surface water standards.

Cross-media Transfer

- Prevent, to the extent practicable, potential future migration of source chemical constituents of concern in soil/material from impacting groundwater and surface water, at concentrations in excess of Class GA groundwater and Class A surface water standards, respectively.
- Prevent, to the extent practicable, chemical constituents of concern in groundwater and seeps from impacting downgradient surface water, at concentrations in excess of Class A surface water standards.

Resource Restoration

- Reduce, to the extent practicable, chemical constituents of concern in groundwater exceeding Class GA groundwater standards downgradient of the waste management/plume area boundary.

3.1.4. Point of Compliance

For this FCMS, the shallow buried solid waste in the Former Landfill, the western Pyrophoric Area, the West Field and the West Field Extended combined with the VOC plume is considered the waste management/plume area. The groundwater point of compliance (POC), for the purpose of meeting SCGs, is anticipated to be downgradient of the waste management/plume area at the Midline and East Boundary Streams. As described in Sections 3.3.3 and 3.4, water-quality monitoring would be conducted both at the POC for the purpose of documenting concentrations of VOCs proximal to surface water, and within and downgradient of the waste management/plume area for the purpose of monitoring plume stability.

As discussed in Section 2, native geologic features have provided for attenuation and limited migration of chemical constituents from the LDA. The VOCs within groundwater appear to be associated with a mature and stable release within the waste material. Considering that the solid waste material and residual areas of VOCs would remain, restoration of groundwater within the waste management/plume area within a reasonable timeframe is not practical.

3.2. IDENTIFICATION OF AREAS AND VOLUMES OF MEDIA

Areas and volumes of media to be addressed in the FCMS have been estimated based on the nature and extent of contamination, CAOs, and MCSs. The estimated area and volume of media provides the basis to support evaluation of technologies and for developing the components of the proposed corrective measure.

The areal and vertical extents of soil/material are based on consideration of the following boundary conditions:

- Surface and subsurface soil MCSs as identified in Section 3.1.1
- Presence of solid waste material/debris observed in SV and RFI soil borings and test pits and visible debris at the surface (C&D Area No.1)

The areas and volumes of media to be evaluated have been grouped into the waste management/plume area and targeted areas of soil/material identified in the RFI Report.

3.2.1. Waste Management/Plume Area

An evaluation of the approximate area of soil/material to be addressed within the waste management/plume area was conducted. The area has been estimated based on the conclusions of the SV and RFI and the boundary conditions described above. Approximately 5.7 acres of soil/material have been estimated to contain concentrations of chemical contaminants greater than MCSs and/or contain solid waste material/debris as described in Section 2.2 and illustrated on Figure 4.

As described in Section 2.2.6 and illustrated on Figure 5, the VOCs in groundwater are present in a north-south oriented plume area controlled and constrained in movement and extent by the sand and gravel deposits and underlying gray till. As illustrated on Figure 6, the three sub-plumes of the northward moving portion of the groundwater plume merge north of the Pyrophoric Area. In the southern end of the investigation area, the VOC plume narrows south of the groundwater divide, where converging groundwater from the Former Landfill and groundwater from the west constrict the width of the plume. Groundwater and the associated plume flows southward through a narrow area adjacent to the western portion of the Former Landfill. Seeps located near the base of the slope in this area are evidence of the convergence and discharge of groundwater.

3.2.2. Targeted Areas of Soil/Material for Evaluation

Based on the RFI, further action was recommended to address targeted areas of soil/material in the LDA. For the purpose of the FCMS, the lateral extent of soil/material described below has been assumed to extend 10 feet beyond the location(s) exhibiting soil concentrations exceeding MCSs and/or containing solid waste material/debris (*i.e.,* soil/material). Additionally, the vertical extent of soil/material described below, has been assumed to extend 1 foot beyond interval(s) exhibiting soil concentrations exceeding MCSs and/or containing solid waste material/debris. Assumptions relative to the area and volume of soil/material to be evaluated are presented as follows and depicted on Figure 7.

Area Southwest of the Former Landfill

An isolated pocket of black sand-like material exists at the base of the slope on the southwest side of the Former Landfill. As described in Section 2.2.1, this location is separate from the main waste disposal area, with soil exhibiting notably high concentrations of PCBs and metals. For the purpose of the FCMS, the affected soil has been assumed to extend to a depth of 5 feet and cover an area of approximately 100 square feet. Twenty cubic yards of soil have been estimated to contain concentrations of chemical contaminants greater than MCSs.

Mercury Disposal Area

As described in Section 2.2.2, affected soil in the Mercury Disposal Area was removed in 2010 during the SPRU North Field Project. An isolated location remains where mercury was detected at concentrations greater than the SCO. For the purpose of the FCMS, the affected soil has been assumed to extend to a depth of 3.5 feet and cover an area of approximately 100 square feet. Fifteen cubic yards of soil have been estimated to contain concentrations of mercury greater than MCSs.

Eastern Pyrophoric Area

Pyrophoric burn residue, recognizable in the field by its black sandy texture, was identified in surface soil in the eastern portion of the Pyrophoric Area. The pyrophoric burn residue exhibits a distinct profile of chromium, cobalt, iron, nickel, and vanadium at concentrations exceeding SCOs. The lateral extent of pyrophoric burn residue has been assumed to encompass the area of the geophysical anomaly described in Section 2.2.3 and adjacent soil containing chemical concentrations exceeding the MCSs. For the purpose of the FCMS, the affected soil has been assumed to extend to a depth of 1.5 feet. The total area and volume estimate of soil/pyrophoric burn residue containing concentrations of chemical contaminants greater than MCSs is estimated to be approximately 10,000 square feet and 555 cubic yards, respectively.

C&D Area No.1

Visible C&D debris at the surface is present throughout C&D Area No.1. For the purpose of the FCMS, the C&D debris and surficial soil has been assumed to be 2-feet thick and cover an area of approximately 0.6 acres, or 25,000 square feet. Although few locations across the C&D Area No.1 contained chemical concentrations exceeding MCSs, approximately 1,830 cubic yards of surficial debris and soil have been estimated. Three isolated areas within C&D Area No.1 contain concentrations of chemical contaminants greater than MCSs and/or material/debris was observed at depths greater than 2 feet.

North C&D Debris Area

A small pile, approximately 3.5-feet thick of C&D debris was identified on the northern edge of the C&D Area No.1. For the purpose of the FCMS, the C&D debris has been estimated to extend to a depth of 4.5 feet and cover an area of approximately 100 square feet. Approximately 20 cubic yards of debris have been estimated to contain C&D debris.

Southwest VOC Area

Concentrations of TCE exceeding the SCO were detected in shallow soil in a small area on the southwest rim of C&D Area No.1. TCE concentrations exceeding the SCO appear to be limited to the upper 1 to 2 feet of the gray till, which is found at depths of 1.5 to 3 feet. For the purpose of the FCMS, the affected soil has been assumed to extend to a depth of 4.5 feet and cover approximately 100 square feet. Twenty cubic yards of soil have been estimated to contain concentrations of chemical contaminants greater than MCSs.

Southeast VOC Area

TCE concentrations exceeding the SCO were also found in shallow and deep soil in a small area in the southeast rim of C&D Area No.1. TCE concentrations greater than the SCO are present at or near the surface of the gray till at depths ranging from 4 to 7 feet deep and extending to a depth of 25 feet in an isolated area. For the purpose of the FCMS, the affected soil in the southeast VOC area has been assumed to extend to a depth of 26 feet and cover an area of approximately 384 square feet. Three hundred seventy cubic yards of soil have been estimated to contain concentrations of chemical contaminants greater than MCSs. Evaluation of technologies for the deeper soil, as related to the soil cross-media transfer corrective action objective, is included in Section 3.3.2.

3.3. IDENTIFICATION OF CORRECTIVE MEASURE TECHNOLOGIES

Based on the results of the RFI and SV, and the streamlined nature of this FCMS, the identification and screening of corrective measure technologies was simplified. As described in the following sections, the identification of the corrective measure technologies to address soil/material relied on presumptive remedy guidance, as appropriate. Furthermore, based on RFI recommendations, a focused identification and evaluation of *in situ* corrective measure technologies was performed for groundwater/seeps and deeper soil in the southeastern portion of C&D Area No.1. Accordingly, the technologies considered for this FCMS are identified below in Table 3-1, and further described below and in Section 3.4.

Table 3-1: Corrective Measure Technologies and Process Options

General Response Actions	Process Option	Corrective Measure Technology
Institutional controls/ limited actions	Use restrictions/ administrative controls	RCRA Post-Remedial Care
	Monitoring	Groundwater, seep and surface water monitoring
Natural recovery	Natural attenuation	Natural attenuation
***Presumptive Remedy:* Containment**	Cover system	Engineered cover
***In situ* treatment/containment**		*To be evaluated (Section 3.3.2)*
Removal	Excavation	Mechanical excavation
Consolidation	On-site placement	Mechanical relocation of material
Disposal	Off-site disposal/treatment	Disposal and/or treatment at a commercial facility

3.3.1. Containment: Presumptive Remedy

USEPA has developed presumptive remedies for certain categories of sites that have similar characteristics, such as types of contamination present, types of disposal practices, or how environmental media are affected. The objective of presumptive remedies is to make use of past experience to streamline the FCMS process. USEPA has conducted an analysis of potentially available technologies for the presumptive remedy site categories and has identified that certain technologies are routinely and appropriately screened out. This analysis serves to substitute for the identification and screening of process options and corrective measure technologies phases of the FCMS [Reference (25)].

The presumptive remedy guidance that is consistent with conditions at the LDA is the Presumptive Remedy for CERCLA Municipal Landfill Sites [Reference (25)]. As stated in the Presumptive Remedy guidance, USEPA expects that "engineering controls, such as containment will be used for waste that poses a relatively low long-term threat where treatment is impracticable." The LDA waste/debris material is considered to be a heterogeneous and stable mass and constitutes a considerable volume to warrant the application of the presumptive remedy.

Accordingly, the following containment action has been identified:

- **Engineered cover system.** A cover for containment of affected soil/material would incorporate layers of soil or gravel to isolate the soil/material, thereby preventing direct contact. The cover system would be finished with vegetation, asphalt and/or gravel surface coverings (based on anticipated future uses) to provide stability and resistance to erosion.

The presumptive engineered cover system would contain the affected soil/material while minimizing changes to the current ground surface and associated groundwater hydrology and VOC plume stability. In consideration of the presence of VOCs in deeper soil below the buried material that is affecting groundwater, the engineered cover system is favored over a low permeability cap, as a low permeability cap would not mitigate the effect on groundwater from the deeper VOC residuals and would have a greater potential to change groundwater flow and plume stability. The buried material and affected soil is underlain by a low permeability glacial till deposit that naturally constrains groundwater flow and contaminant migration vertically and laterally into a defined flow path and readily monitored areas.

3.3.2. Corrective Measure Technology Evaluation

Focused evaluations were completed to identify and screen corrective measure technologies for LDA groundwater/seeps and deep soil in the C&D Area No.1. The following subsections provide discussions relative to these media.

3.3.2.1. Groundwater and Seeps

Potential corrective measure technologies to reduce VOCs in groundwater and seeps were identified, including *in situ* treatment and containment response actions. A brief description of these corrective measure technologies and preliminary screening that considers implementability and effectiveness is provided below:

- ***In situ* enhanced bioremediation:** Enhanced bioremediation of groundwater could use bioaugmentation and/or biostimulation to enhance anaerobic conditions in groundwater to promote contaminant biodegradation, subsequently minimizing potential contaminant migration and accelerating contaminant mass removal. Electron donors and nutrients (biostimulation) and/or beneficial microbial populations (bioaugmentation) could be added to the subsurface via injection points to facilitate the anaerobic dechlorination of VOCs. The basic requirements for successful enhanced bioremediation implementation would include: appropriate subsurface geochemical conditions, sufficient nutrient dose, a capable microbial population and the effectiveness of delivering electron donors, nutrients, and/or beneficial microorganisms to the affected groundwater. The effectiveness of *in situ* enhanced bioremediation is dependent upon subsurface hydrogeologic, geochemical, and microbial conditions and effective delivery of bioremediation amendments to the treatment zone.
- ***In situ* chemical oxidation:** *In situ* chemical oxidation would be accomplished by treatment of groundwater using oxidants such as ozone, hydrogen peroxide, hypochlorites, permanganate, and/or sodium persulfide. Oxidation reactions chemically convert constituents to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert. Chemical oxidants can be applied to groundwater via injection points. The effectiveness of *in situ* chemical oxidation is limited by subsurface hydrogeologic and geochemical conditions and ability to effectively deliver oxidants to the treatment zone.
- **Permeable reactive barrier:** Construction of a reactive material wall, air sparging zone, or biobarrier would treat groundwater that flows through the treatment zone. Permeable reactive barrier walls can be installed as a "funnel and gate"; funneling the groundwater toward the reactive media. Periodic replacement of reactive material would potentially be required due to fouling and reduced treatment effectiveness.
- **Phytoremediation**: Trees, including hybrid poplars, willows, evergreens or cottonwood trees could be planted in the vicinity of surface seeps for the purpose of phytodegradation and hydraulic control of VOC-containing seeps. Phytoremediation utilizes fast-growing trees and plants to degrade, transfer, remove, or stabilize contaminants. The effectiveness of phytoremediation is limited as a result of seasonal climate fluctuations. Routine monitoring and periodic replacement of trees would be necessary to evaluate and maintain effectiveness.

Corrective measure technologies were screened and selected for further evaluation based on their potential implementability and effectiveness in addressing VOCs in groundwater and seeps at the LDA. *In situ* enhanced bioremediation and chemical oxidation would be effective in reducing VOC concentrations in groundwater when applied to source areas; however, discrete source areas were not determined for all VOCs detected in the plume, which would result in areas of untreated contaminants. Further, the heterogeneity of the shallow buried waste and the underlying geologic deposits including the underlying low permeability gray till could limit effective distribution of treatment amendments, resulting in areas of untreated contaminants. Multiple injections would potentially be required in conjunction with groundwater performance monitoring.

A permeable reactive barrier would be effective in reducing VOC concentrations in groundwater downgradient of the barrier. A pre-design/treatability study would be required to evaluate barrier wall placement and selection of reactive media.

Phytoremediation would provide a passive means for addressing potential exposure to and migration of VOCs in seeps. Field studies would be required to evaluate seep flow, soil conditions, and potentially effective tree/plant species.

As described in the RFI Report and Section 2.2.6, VOCs are present in a north-south oriented plume controlled and constrained in movement and extent by the sand and gravel deposits and underlying gray till. Additionally, potential sources of groundwater contamination, including chemical constituents in shallow buried material, appear to be coincident with the solid and stable fill material and not readily migrating.

Based on RFI recommendations, the focused identification and evaluation of *in situ* treatment and containment actions was conducted and identified the above potential corrective measure technologies. The RFI documented that the hydrogeologic conditions and the stable nature of the soil/material have resulted in stable groundwater conditions. In consideration of the stability of the groundwater plume and the limitations and uncertainty regarding the effectiveness of *in situ* corrective measures, active groundwater treatment will not be considered at this time. Rather, implementation of a presumptive engineered cover system remedy is recommended in conjunction with an adaptive groundwater, seep and surface water monitoring program. The adaptive monitoring approach and proposed corrective measure are described below in Sections 3.3.3 and 3.4, respectively.

Supplemental treatability monitoring, including monitoring for additional parameters (*e.g.,* chemical, geochemical, and physical) would also be conducted to provide additional data for any warranted future evaluation of potential *in situ* corrective measure technologies. In the event that groundwater or surface water VOC concentrations exhibit an increasing trend in constituent concentrations, compared to the results of baseline monitoring, implementation of corrective measure technologies would be considered and would be supported by the supplemental treatability monitoring results. Further evaluation of potential *in situ* corrective measure technologies, such as bench and pilot-scale treatability studies, may be necessary to further verify effectiveness and implementability.

3.3.2.2. C&D Area No.1 Subsurface Soil

As described in Sections 2.2.5 and 3.2.2, TCE is present in soil to a depth of 25 feet within an isolated area on the southeast portion of the C&D Area No.1. TCE in the soil appears to be concentrated and contained laterally within the low permeability gray till. Additionally, the potential for migration of TCE to groundwater is limited, as groundwater in the gray till is isolated in intermittent lenses of fine sand within the gray till. Based on the RFI, these sand lenses are not connected and water is rapidly depleted from these small isolated sand lenses with little or no recharge.

Potential corrective measure technologies were identified to address deep soil in C&D Area No.1, including *in situ* treatment and removal response actions. A brief description of these corrective measure technologies and preliminary screening that considers implementability and effectiveness is provided below:

- ***In situ enhanced bioremediation***: Enhanced bioremediation could use bioaugmentation and/or biostimulation to enhance conditions in the soil to promote contaminant biodegradation, subsequently minimizing potential contaminant migration and accelerating contaminant mass removal. Electron donors and nutrients (biostimulation) and/or beneficial microbial populations (bioaugmentation) could be added to the subsurface to facilitate the biodegradation of VOCs. Bioremediation amendments could be applied to the subsurface via hydrofracturing, injection points, or mixing of the soil. The effectiveness of *in situ* enhanced bioremediation is dependent upon subsurface geochemical and microbial conditions and effective delivery of bioremediation amendments to the targeted treatment zone.

- ***In situ chemical oxidation***: *In situ* chemical oxidation would be accomplished by treatment of soil using oxidants such as ozone, hydrogen peroxide, hypochlorites, permanganate, and/or sodium persulfide. Oxidation reactions chemically convert constituents to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert. Similar to *in situ* enhanced bioremediation, chemical oxidants can be applied to the subsurface via hydrofracturing, injection points, or mixing of the soil. The effectiveness of *in situ* chemical oxidation is dependent upon subsurface hydrogeologic and geochemical conditions and effective delivery of oxidants to the treatment zone.
- ***In situ* solidification/stabilization:** *In situ* solidification/stabilization is accomplished by treatment of soil where contaminants are physically bound or enclosed within a low permeability mass (solidification), and/or chemical reactions are induced between stabilizing agents and contaminants to reduce their mobility (stabilization), toxicity, and leachability. Additives can consist of cement or fly ash reagents to solidify, reducing contact with groundwater and surface water, or chemical reagents to stabilize the mass. Conventional soil mixing equipment could be used to mix the solidification/stabilizing agents with the soil to create homogeneous treatment cells.
- ***In situ* thermal treatment**: *In situ* thermal treatment is accomplished by thermally heating soil by various techniques including heating wells, blankets, injection points, electrodes, or electromagnetic energy. Heat propagates throughout the treatment zone to destroy VOCs. *In situ* thermal treatment techniques can be applied to a range of soil types. *In situ* thermal treatment applications may be implemented in conjunction with soil vapor recovery systems for recovery of vapors.
- **Excavation with on-site consolidation**: Excavation is accomplished using construction equipment (*e.g.,* excavator, large diameter augers) to remove affected soil/material. Excavated areas would be backfilled, graded and restored based on restoration requirements. Soil/material would be consolidated at the LDA. Deep excavations could require sloping or shoring to maintain subsurface stability. Dewatering and management/treatment of groundwater accumulated in excavation(s) would potentially be required.

The identified corrective measure technologies were screened based on effectiveness and reliability of the technology to address TCE in subsurface soil based on the estimated depths and subsurface conditions within C&D Area No.1. Technical and institutional aspects of implementing the technology were also assessed. *In situ* enhanced bioremediation and chemical oxidation technologies would potentially be effective in reducing TCE concentrations within deep soil. The effectiveness of *in situ* injection of enhanced bioremediation amendments or chemical oxidants would be limited due to the heterogeneity and low permeability of subsurface materials which would preclude the effective and even distribution of biological amendments/chemical reagents. Additionally, *in situ* biological and chemical treatment technologies would potentially require multiple injections to address soil contaminants. Hydrofracturing or mixing could potentially deliver amendments more efficiently and effectively to address the discrete area of TCE-affected subsurface soil.

In situ solidification/stabilization, *in situ* thermal treatment and excavation were also retained for further consideration and are considered implementable and effective for addressing discrete areas of TCE in subsurface soil. Thermal treatment would reduce TCE toxicity and mobility through treatment. Mixing of the targeted soil mass with solidifying and stabilizing agents would potentially reduce permeability of the subsurface soil; however, the gray till is already of very low permeability and acts as a barrier to migration. Excavation using an excavator or large diameter augers would effectively remove TCE-affected soil.

Based on RFI recommendations, the focused identification and evaluation of treatment and response actions was conducted and identified the above listed potential corrective measure technologies. Based on effectiveness and implementability limitations for *in situ* technologies, excavation of the TCE-affected soil is recommended. For the purpose of the FCMS, excavation of TCE-affected soils to a depth of approximately 26 feet is assumed.

Approximately 370 cubic yards of soil have been estimated to contain TCE concentrations greater than the MCS for soil. The proposed corrective measure alternative, including soil/material excavation and on-site consolidation is described below in Section 3.4.

3.3.3. Adaptive Monitoring Program

Groundwater, seep and surface water sampling would be performed at the POC and within and downgradient of the waste management/plume area (Section 3.1.4) for the purpose of documenting the effectiveness of the presumptive engineered cover remedy, evaluating plume stability, and detecting changes in constituent concentrations proximal to and within the Midline Stream and East Boundary Stream. The monitoring program would be designed to be modified and adapted based on baseline and long-term monitoring data, providing for timely evaluation of corrective measure performance.

Baseline groundwater, seep and surface water monitoring would be performed to establish initial conditions, with monitoring to be conducted quarterly over a period of 1 year following construction of the engineered cover system. A long-term adaptive monitoring program would be subsequently implemented, with the scope of the monitoring program, including monitoring frequency and parameters, reviewed and modified periodically based on monitoring data. Groundwater, seep and surface water monitoring over the long-term would also provide a means for monitoring natural attenuation and progress of groundwater remediation over time as a result of corrective measure implementation.

Should groundwater or surface water monitoring results exhibit an increasing trend in VOC concentrations compared to the results of baseline monitoring, implementation of corrective measure technologies, as described in Section 3.3.2.1, would be considered, based upon the effectiveness of the presumptive engineered cover system remedy as demonstrated by the results of periodic groundwater monitoring. Implementation of corrective measures to address groundwater and seeps would be supported by the supplemental treatability monitoring results, as described in Sections 3.3.2.1 and 3.4. Further evaluation of potential *in situ* corrective measure technologies, such as bench and pilot-scale treatability studies, may be considered to inform evaluations of effectiveness and implementability.

3.4. IDENTIFICATION OF THE CORRECTIVE MEASURE ALTERNATIVE AND CONCEPTUAL DESIGN COMPONENTS

Presumptive remedies and other corrective measure technologies, as described in Section 3.3, were considered during the development of the corrective measure alternative. The proposed corrective measure alternative includes an engineered cover system with excavation to address targeted areas of soil exceeding MCSs and/or containing solid material/debris. Excavated soil/material would be consolidated at the LDA prior to placement of the engineered cover. A discrete volume of excavated soil would be disposed offsite. The proposed corrective measure also includes natural attenuation, implementation of institutional controls, an adaptive groundwater, seep and surface water monitoring program, and supplemental treatability monitoring. A summary of the corrective measure alternative components is presented below in Table 3-2.

Table 3-2: Corrective Measure Alternative Components

General Response Actions	Process Option	Corrective Measure Technology	LDA SWMUs
Institutional controls/ limited actions	Use restrictions/ administrative controls	RCRA Post-Remedial Care	› Former Landfill, Pyrophoric Area, West Field (including West Field Extended), and C&D Area No.1.
	Monitoring	Groundwater, seep and surface water monitoring	› At the POC (in the vicinity and within the Midline Stream and East Boundary Stream) and downgradient of the waste management/plume area
Natural recovery	Natural attenuation	Natural attenuation	› Former Landfill, Pyrophoric Area, West Field (including West Field Extended)
Containment	Cover system	Engineered cover	› Former Landfill › Western Pyrophoric Area › West Field (including West Field Extended)
Removal	Excavation	Mechanical excavation	› 2010 SPRU removal action › C&D Area No.1 – shallow soil, deep soil and debris › Eastern Pyrophoric Area - pyrophoric burn residue › Former Landfill – black sand-like material › Mercury Disposal Area – elevated mercury (isolated location, if necessary)
Consolidation	On-site placement	Mechanical relocation of material	› C&D Area No.1 – shallow soil and debris › Eastern Pyrophoric Area – pyrophoric burn residue › Mercury Disposal Area – elevated mercury (isolated location, if necessary)
Disposal	Off-site disposal/treatment	Disposal and/or treatment at a commercial facility	› Former Landfill – black sand-like material

The components of the proposed corrective measure alternative are shown on Figures 8 and 9 and described below.

Targeted Excavation, Consolidation and/or Off-Site Disposal

The proposed corrective measure alternative would include targeted excavation to remove surface and subsurface soil with chemical concentrations exceeding MCSs and to remove surficial material/debris. This action would reduce the overall footprint of the LDA affected by chemical constituents, and would mitigate potential direct exposure to contaminated soil and migration of contaminants in the surficial soil via erosion and overland flow. The targeted excavation areas include the C&D Area No. 1 (shallow and deep soil, surficial debris), eastern Pyrophoric Area (pyrophoric burn residue and affected shallow soil), and the area southwest of the Former Landfill (black sand-like material). Mercury concentrations in an isolated area of Mercury Disposal Area soil would be evaluated during a pre-construction investigation, with excavation and management of soil conducted, as necessary. The areas of targeted excavation are depicted on Figure 9. The final limits of excavation would be determined during remedy construction based on the results of confirmation sampling at the excavation limits.

Consolidation of the excavated material into the existing disposal area of the western Pyrophoric Area and West Field Extended would be performed in lieu of off-site disposal. This would provide fill material to configure the proposed engineered cover system contours. The Soil/Material Consolidation Area would be located within the limits of existing disposed material and the proposed engineered cover system described below. The excavated material would be placed in lifts, graded and compacted to promote positive drainage.

The RFI data indicates that the soil/material proposed for consolidation contains concentrations of chemical constituents comparable to the soil and waste material existing within the proposed engineered cover footprint. Based on the relatively immobile nature of the chemical constituents (*e.g.*, solid material including metals in soil and VOCs absorbed to gray till), migration of chemical constituents from the Soil/Material Consolidation Area and through the existing waste material is not anticipated. Furthermore, most of the existing waste material is immediately underlain by fine-grained geologic deposits that inhibit vertical migration. These deposits are underlain by the low-permeability gray till that serves as a natural barrier to vertical groundwater flow and contaminant migration. Based on the previous factors and to minimize changes to the groundwater flow and plume stability, placement of a separate low permeability liner between the existing waste material and the consolidated material is considered not to be necessary.

For the purpose of the FCMS, it is assumed that a limited volume of soil associated with the excavation area to the southwest of the Former Landfill will be characterized and disposed/treated offsite at a permitted facility.

Areas of targeted excavation would be backfilled, using imported soil from an approved source, to near existing grade and restored based on site use requirements. The excavation area to the southwest of the Former Landfill is at the base of a slope. Due to the presence of the slope, this excavation area will be restored by backfilling the excavation with common fill and placing a 12-inch thick layer of light rip-rap on areas of the slope disturbed by the excavation activities.

Engineered Cover System

An engineered cover system would be constructed within the waste management/plume area to eliminate direct contact with soil/material containing chemical concentrations exceeding Unrestricted Use SCOs and to mitigate migration via erosion of chemical constituents of concern in exposed soil/material. The lateral limit of the proposed cover is shown on Figures 8 and 9. Also shown on Figure 9 is the conceptual location of the Soil/Material Consolidation Area, which will be covered with the engineered cover. Figure 10 illustrates a cross section of the conceptual engineered cover as it relates to the buried material and the underlying geology. The boundary of the cover depicted on Figures 8 and 9 is conceptual and would be revisited during the design phase. The final engineered cover would be graded to match existing surrounding grades and provide for adequate drainage and aesthetics.

Based on the guidance in NYSDEC's DER-10 for the current and reasonably anticipated future land use of the LDA and the overall Knolls Laboratory, the engineered cover system would consist of a combination of soil and gravel covers, with a minimum 12-inch thickness. The cover system would be finished with vegetation, asphalt and/or gravel surface coverings (based on anticipated future uses) to provide stability and resistance to erosion. For the purpose of developing the conceptual FCMS design, the engineered cover would consist of gravel in areas designated for Knolls Laboratory management activities (*e.g.,* placement of snow, equipment storage or parking). It is assumed that the remaining soil cover area will be seeded and fertilized to establish vegetation. A cover detail, illustrating typical soil and gravel cover cross-sections, is included on Figure 10. For the purpose of developing the conceptual corrective measure, the engineered cover system is estimated to be implemented over approximately 5.7 acres.

Prior to cover placement, existing monitoring wells installed during the SV and RFI and some Site wells will be decommissioned in accordance with NYSDEC's Commissioner's Policy (CP-43) Groundwater Monitoring Well Decommissioning Policy [Reference (26)]. As described below, permanent monitoring wells would be installed as part of the long-term monitoring program.

Monitoring

Adaptive Groundwater, Seep, and Surface Water Monitoring Program

As presented in Section 3.3.3, periodic sampling and analyses of groundwater, seeps and surface water at the POC and within and downgradient of the waste management/plume area would be implemented as a means of documenting plume stability and detecting changes in VOC concentrations proximal to and within the Midline Stream and East Boundary Stream.

For the purpose of the FCMS, the monitoring program is assumed to include implementation of an adaptive monitoring program, including baseline and long-term monitoring. The conceptual corrective measure alternative assumes that permanent monitoring wells would be installed at the LDA. Baseline monitoring would consist of quarterly groundwater, seep and surface monitoring conducted over the period of 1-year, with samples to be analyzed for VOCs, SVOCs, PCBs, and metals. Conceptual monitoring areas are depicted on Figure 11. Specific monitoring locations would be identified in the detailed design.

Subsequent to the baseline monitoring, the long-term adaptive monitoring program is assumed to consist initially of quarterly groundwater, seep and surface water sampling for VOC analysis. Analysis of additional parameters such as SVOCs, PCBs and metals would be implemented based on monitoring data. After the first 5 years, it is assumed that the quarterly baseline monitoring would be repeated. The scope of the monitoring program, including monitoring frequency and parameters, would be periodically reviewed and modified based on the monitoring data.

The monitoring program is designed to adapt to conditions and the data needs for timely remedial decision-making. Data generated during groundwater, seep and surface water monitoring activities, including baseline monitoring, would be evaluated over the long-term for the purpose of documenting effectiveness of the engineered cover system and for the purpose of evaluating plume stability and potential for migration downgradient of the waste management/plume area.

Supplemental Treatability Monitoring

Supplemental treatability monitoring, including monitoring for additional parameters would be conducted to provide additional data for any warranted future evaluation of potential *in situ* corrective measure technologies. Supplemental treatability monitoring would further support the proposed adaptive monitoring and remedial implementation approach.

Should groundwater or surface water monitoring results exhibit an increasing trend in VOC concentrations compared to the results of baseline monitoring, implementation of corrective measure technologies to address groundwater and seeps would be considered, and would be supported by the supplemental treatability monitoring results. Further evaluation of potential *in situ* corrective measure technologies, such as bench and pilot-scale treatability studies, may be considered to inform evaluations of effectiveness and implementability.

Institutional Controls

The reasonably anticipated future land use for the LDA at the Knolls Laboratory is restricted use and the institutional controls for the LDA at the Knolls Laboratory would reflect restricted use. RCRA Post-Remedial Care requirements, including land use and administrative controls would be identified in a Post-Remedial Care Plan for the LDA at the Knolls Laboratory for the purpose of documenting access/use restrictions, and requiring the continued maintenance and monitoring of engineering controls to maintain protectiveness of human health and the environment. The institutional controls would limit site and groundwater use and require maintenance of corrective measure components. Institutional controls would also require that activities that would potentially expose contaminated material (and require health and safety precautions), or impair the integrity of the engineered cover, be performed in accordance with a RCRA Post-Remedial Care Plan. Additional controls may be imposed through revision of the Part 373 Permit Conditions.

Additionally, federal agencies have the authority to enforce institutional controls on their property. Land use and groundwater use restrictions may be documented via facility construction review processes, facility excavation permit systems, and/or facility well permitting systems [Reference (27)].

Evaluation and possible mitigation of potential vapor intrusion into future buildings constructed on the LDA would be required under provisions specified in the institutional controls. Where necessary, preventative measures may be included in the design and construction of buildings at the LDA to mitigate the potential for exposure to constituents that may be present in soil vapor. Such measures may include the use of a vapor barrier or the installation of a venting system.

Restrictions would preclude activities that would potentially expose soil/material and soil vapor that might cause vapor intrusion, or impair the integrity of the engineered cover systems without prior review and approval by the Federal Government and NYSDEC.

4. EVALUATION OF THE CORRECTIVE MEASURE ALTERNATIVE

This section documents the evaluation of the corrective measure alternative that was developed during the FCMS. The evaluation of the corrective measure alternative was conducted consistent with Condition E.11(a and b) of the Part 373 Permit for the Knolls Laboratory and NYSDEC's DER-10. This section describes the analysis of the alternative with respect to the threshold and balancing criteria. The modifying criteria are formally considered by NYSDEC after public comment is received on the Statement of Basis (SB). The threshold, balancing, and modifying criteria are described below in Table 4-1.

Table 4-1: Corrective Measure Evaluation Criteria

Criterion	Considerations
Threshold Criteria	
▪ Be protective of human health and the environment	
▪ Attain media target cleanup levels selected by the Commissioner during the corrective measure selection process	
▪ Control the source(s) of release(s) so as to reduce or eliminate, to the maximum extent practicable, further releases of hazardous waste, including hazardous constituents, that might pose a threat to human health and the environment	
▪ Meet all applicable waste management requirements	
Balancing Criteria	
Long-term reliability and effectiveness	▪ Magnitude of residual risk from hazardous waste, including hazardous constituents, remaining following implementation of the corrective measure ▪ Type and degree of long-term management required ▪ Potential for exposure of humans and environmental receptors to remaining hazardous wastes, including hazardous constituents. ▪ Long-term reliability of the engineering and institutional controls ▪ Potential need for replacement of the corrective measure ▪ Long-term sustainability
Reduction of toxicity, mobility, or volume	▪ Treatment processes the corrective measure employs and the material it will treat ▪ Amount of hazardous and/or mixed wastes that would be destroyed or treated ▪ Degree to which treatment is irreversible ▪ Residuals that will remain following treatment ▪ Concentration levels of hazardous and/or mixed waste, including hazardous constituents, in each medium that the corrective measure must achieve to be protective of human health and the environment
Short-term effectiveness	▪ Magnitude of reduction of existing risks ▪ Risks posed to the community, workers, or the environment during implementation ▪ Time until full protection is achieved ▪ Short-term sustainability
Implementability	▪ Degree of difficulty associated with constructing the technology ▪ Expected operational reliability of the technologies ▪ Need to coordinate with and obtain necessary approvals and permits from other agencies ▪ Availability of necessary equipment and specialists ▪ Available capacity and location of needed treatment, storage and disposal services

Table 4-1: Corrective Measure Evaluation Criteria

Criterion	Considerations
	▪ Requirements for removal, decontamination, closure, or post-closure of units, equipment, devices or structures that will be used to implement the corrective measure
Cost	▪ Capital costs ▪ Operation, maintenance and monitoring (OM&M) costs ▪ Net present value of capital and OM&M costs ▪ Potential future corrective measure costs
Land Use	▪ Consistency with land use
Modifying Criteria	
State acceptance	▪ Indicates whether, based on its review of the RFI/FCMS reports and the SB, the state supports, opposes, and/or has identified any reservations with the preferred corrective measure.
Community acceptance	▪ Summarizes the public's general response to the response measure described in the SB and the RFI/FCMS reports. This assessment includes determining whether the community supports, opposes, and/or has reservations about the preferred corrective measure.

This evaluation of the corrective measure alternative is designed to consider the performance of the alternative. As discussed in the following subsections, the alternative would satisfy the threshold criteria by providing protection to human health and the environment, addressing applicable CAOs and MCSs, controlling the source of releases, and meeting applicable waste management requirements.

4.1. PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Protection of human health and the environment would be provided by the corrective measure alternative. The engineered cover system would address potentially unacceptable risks to human health and biota associated with exposure to soil/material exceeding MCSs and would address potentially unacceptable risks to the environment associated with potential erosion of soil/material exceeding MCSs. Targeted excavation of contaminated soil/material would provide for additional protectiveness through removal and consolidation/off-site disposal.

Institutional controls and RCRA Post-Remedial Care, including land use controls, and post-remedial inspections, maintenance, monitoring and reporting would limit site and groundwater use and minimize potentially unacceptable risks to human health and the environment associated with soil/material and groundwater exceeding MCSs. Institutional controls would also provide for continued protectiveness and a means to evaluate continued protectiveness via corrective measure maintenance and monitoring. Groundwater use restrictions would minimize potentially unacceptable risks to human health associated with groundwater exceeding Class GA standards. Groundwater, surface water and seep monitoring would provide a means of monitoring chemical constituent concentrations and the progress of natural attenuation. The monitoring program would be designed to be modified and adapted based on monitoring data, providing for timely evaluation of corrective measure performance.

4.2. ATTAINMENT OF APPLICABLE CLEANUP STANDARDS

Installation of the engineered cover system would address potential erosion of and exposure to surface soil exceeding Unrestricted Use SCOs and areas containing surficial material/debris within the waste management/plume area. Targeted excavation and on-site placement/off-site disposal would further address soil/material and reduce the potential for exposure to or migration of chemical constituents. Institutional controls and RCRA Post-Remedial Care, including engineered cover system inspections, maintenance, monitoring and reporting, would limit the potential for direct contact with soil/material and groundwater exceeding MCSs. The alternative provides a means of implementing an adaptive monitoring program for the purpose monitoring groundwater, surface water and seep concentrations, the progress of natural attenuation, and corrective measure effectiveness.

There are documented exceedances of Class GA groundwater standards for VOCs as a result of residual areas of VOCs in LDA soil and disposed material. With few exceptions associated with localized perched groundwater in the Former Landfill, disposed material is above the water table. Considering that the disposed material and associated separate areas of residual VOCs would remain, restoration of groundwater within the waste management/plume area to meet Class GA groundwater standards within a reasonable timeframe is not practical. For the purpose of the FCMS, water-quality monitoring would be conducted proximal to and within the Midline and East Boundary Streams for the purpose of documenting concentrations of VOCs proximal to surface water, and within and downgradient of the waste management/plume area for the purpose of monitoring plume stability. Implementation of an engineered cover system and adaptive monitoring program (*i.e.,* baseline and long-term monitoring) and supplemental treatability monitoring would provide for protection of human health and the environment with flexibility to implement targeted *in situ* treatment, as necessary.

4.3. CONTROL SOURCE(S) OF RELEASE(S)

As described in Section 2.1, in 2010 approximately 600 cubic yards of debris and soil are estimated to have been excavated from the VOC source area and disposed offsite. Additionally, during the SPRU North Field Project, as much as 2 feet of soil was excavated from the Mercury Disposal Area for off-site disposal. This corrective measure alternative would further mitigate the sources of releases by targeted excavation with on-site placement/off-site disposal and installation of the engineered cover system over areas of soil exceeding MCSs and areas containing soil/material. Institutional and engineering controls and long-term corrective measure inspection, maintenance and monitoring (*i.e.,* RCRA Post-Remedial Care, including engineered cover system inspections, maintenance, monitoring and reporting) provide a means to minimize potential exposures to soil and groundwater affected by source chemical constituents in soil/ material. Institutional controls would also include provisions to evaluate and address, if necessary, potential soil vapor intrusion, if building are constructed at the LDA. Additionally, monitoring provides a means of evaluating constituent concentrations in media downgradient of the waste management/plume area and at the POC.

4.4. WASTE MANAGEMENT REQUIREMENTS

The proposed corrective measure alternative would meet applicable waste management requirements. Specifically, off-site transportation and management of excavated soil would be performed in accordance with state and federal regulations. Groundwater, seep and surface water monitoring would result in the generation of investigation-derived waste (*e.g.,* nitrile gloves, disposable sampling material, and purged groundwater). Disposable gloves and sampling material would be disposed offsite, while monitoring well purge water is anticipated to be returned to the ground nearby the well from which it was generated. Management and disposal of waste would be further developed during the design phase.

4.5. LONG-TERM RELIABILITY AND EFFECTIVENESS

Residual risks associated with chemical constituents in soil/material and groundwater would be mitigated through the engineered cover system, institutional controls, and OM&M of the corrective measure components. Placement and maintenance of the engineered cover system would provide an adequate and reliable means of controlling erosion of and reducing the potential for exposures to soil/material remaining in the LDA. Vegetative components of the engineered cover systems would potentially provide for reduced infiltration via evapotranspiration. Institutional and engineering control components are an adequate and reliable means of controlling site use and would effectively reduce potential for exposures to soil, groundwater, and indoor air, if buildings are constructed at the LDA, over the long-term, while providing a means of monitoring corrective measure effectiveness and evaluating additional *in situ* corrective measures, as necessary through an adaptive monitoring program and supplemental treatability monitoring. Excavation of soil/material within targeted areas onsite (including C&D Area No.1, the Mercury Disposal Area, the eastern Pyrophoric Area, and an isolated area to the southwest of the Former Landfill) would effectively reduce chemical constituent concentrations in soil/material over the long-term. Periodic inspection and maintenance (*e.g.,* mowing, re-vegetation or repairs to gravel) of the engineered cover would be required over the long-term to provide for continued effectiveness of the corrective measure. Minimal fuel use, energy use, and greenhouse gas emissions would be associated with long-term maintenance.

4.6. REDUCTION IN THE TOXICITY, MOBILITY OR VOLUME OF IMPACTS

The mobility and volume of chemical contaminants exceeding MCSs in surface soil (*i.e.,* associated with erosion) would be reduced by targeted excavation/on-site placement or off-site disposal and installation of the engineered cover system. The corrective measure alternative does not include treatment processes. Monitoring would provide a means of evaluating constituent concentrations and the potential for mobility outside the waste management/plume area boundary. Natural attenuation is expected to reduce chemical contaminant concentrations over the long-term and is irreversible.

4.7. SHORT-TERM EFFECTIVENESS

The corrective measure would be constructed using proper protective equipment to manage potential risks to on-site workers, and proper precautions and monitoring would be implemented to be protective of the community and the environment. The community is restricted from access to the Knolls Laboratory. Dust and volatile emissions, if any, would be monitored and mitigated, as necessary, during construction activities. Impacts to the community resulting from cover construction and excavation activities would primarily be due to truck traffic on local roadways and potential noise during construction activities.

Proper health and safety measures (*i.e.,* training and personal protective equipment) would be established and implemented during corrective measure activities for the purpose of minimizing potential risks to workers. Dust, volatile emissions, and surface runoff controls would be instituted to minimize impacts to the environment during implementation of this alternative. Clearing would be required prior to targeted excavation/on-site placement and engineered cover installation. Construction water management would be conducted in accordance with local, state and federal regulations.

CAOs would be achieved for areas where vegetation is applied within 3 years of application (*i.e.,* timeframe for vegetation to reach maturity). Construction of the corrective measure is anticipated to be completed within 1 year. Attainment of Class GA standards for groundwater within the waste management/plume area is unlikely within a reasonable timeframe due to the presence of buried material/debris and/or chemical constituents in soil/material.

Fuel/energy use by construction equipment and transportation of material on-site during targeted excavation/on-site placement and cover installation would yield associated greenhouse gas emissions commensurate with typical corrective measure construction activities.

Green remediation techniques, as detailed in NYSDEC's DER-31 [Reference (5)] and the USEPA Region 2's Clean and Green Policy [Reference (28)], would be considered to reduce short-term environmental impacts. Green remediation best practices such as the following may be considered:

- Reduction in vehicle idling, including both on and off road vehicles and construction equipment during construction and/or OM&M of the remedy
- Design of cover systems, to the extent possible, to be usable for alternate uses, require minimal maintenance (*e.g.*, less mowing), and/or be integrated with the planned use of the property
- Beneficial reuse of material that would otherwise be considered a waste
- Use of Ultra Low Sulfur Diesel.

4.8. IMPLEMENTABILITY

The corrective measure alternative is readily constructible, and includes reliable technologies and OM&M that would be readily implementable. The materials and resources to implement this corrective measure are readily available. Excavation and consolidation of approximately 2,810 cubic yards and excavation and off-site disposal of approximately 20 cubic yards of material is implementable. Dewatering of excavated material may be required and would be further evaluated during the design phase. An engineered cover system is implementable. Implementability challenges relative to excavation and cover installations would be limited. Additional corrective measures, if necessary, would be implementable.

The reliability of the remedy could be monitored through inspection and maintenance of the engineered cover system to verify continued cover integrity, visual signs of erosion, and condition of the engineered cover. Groundwater, surface water and seep monitoring would provide a reliable means for monitoring and documenting remedy effectiveness for continued protection of human health and the environment, as well as constituent concentrations at and downgradient of the waste management/plume area boundary. The engineered cover system provides a reliable means of reducing potential erosion of and exposure to soil/ material within the LDA. Equipment, specialists, and materials are available. Sampling equipment and analytical laboratories are also readily available to support long-term monitoring.

Minimal disposal capacity would be required for waste generated during implementation and off-site treatment/disposal facilities are readily available.

4.9. COST

The major cost components of the proposed corrective measure include cost of excavation with on-site placement and limited off-site disposal, engineered cover installation, implementation of an adaptive monitoring program, and implementation of corrective measure maintenance, monitoring and reporting. The capital, OM&M and present worth costs associated with the conceptual corrective measure alternative were evaluated and considered reasonable based on engineering judgement. Costs to implement and maintain the corrective measure would be reevaluated based on the agency-approved corrective measure and pre-construction activities.

4.10. LAND USE

Implementation of corrective measure alternative would be consistent with current, intended, and reasonably anticipated future uses of the LDA. Land uses at the LDA would be evaluated during design of the corrective measure for the purpose of integrating LDA site management activities into the engineered cover design (*e.g.,* placement of snow, material staging, equipment storage or parking).

5. JUSTIFICATION FOR SELECTION OF THE CORRECTIVE MEASURE

To provide long-lasting protection to human health and the environment, the corrective measure alternative was developed and evaluated for the LDA in this FCMS. This FCMS Report documents the development of CAOs for the protection of human health and the environment to address contaminants identified in soil/material and groundwater at the LDA. Consistent with the Part 373 Permit, the corrective measure alternative, developed to address media-specific CAOs, was evaluated based on the required threshold and decision/balancing factors such that a corrective measure may be recommended for the LDA. Based on extensive soil and groundwater data generated during LDA RFI and the corrective measure evaluation presented in this FCMS Report, the recommended corrective measure for the LDA includes an engineered cover system with targeted excavation, consolidation and focused off-site disposal. This alternative also includes natural attenuation, implementation of a RCRA Post-Remedial Care Plan, including institutional and engineering controls, an adaptive monitoring program, and supplemental treatability monitoring.

With respect to the threshold criteria, the corrective measure alternative provides for overall protection of human health and the environment, addresses applicable CAOs for soil/material and groundwater, controls releases to the environment, and would be implemented to meet applicable waste management requirements. The following provides additional justification and rationale for selection of the corrective measure alternative based on technical, human health, and environmental criteria presented in Appendix II-C Section V of the Part 373 Permit for the Knolls Laboratory.

Protection of human health and the environment would be provided by the corrective measure. The engineered cover would be effective at minimizing erosion of, and contact with, exposed surface soil and soil/material. Institutional controls and RCRA Post-Remedial Care would limit site and groundwater use and provide a means of monitoring chemical constituent concentrations, while minimizing potentially unacceptable risks to human health and the environment. In conjunction with native geologic features providing for attenuation and limited migration of chemical constituents from the LDA, the recommended corrective measure would provide for long-term protection of human health and the environment. Should groundwater monitoring results exhibit an increasing trend in constituent concentrations, corrective measure technologies would be considered. Implementation of additional corrective measures to address groundwater and seeps would be supported by the supplemental treatability monitoring results.

The proposed corrective measure alternative is readily constructible, safely implementable and includes reliable technologies. Fuel/energy use and associated greenhouse gas emissions generated during corrective measure construction would result in minimal short-term impacts to the environment. Green remediation techniques could be considered to reduce short-term impacts. OM&M, including routine cover maintenance and inspections for integrity, and groundwater, surface water and seep monitoring, would be necessary and also be readily implementable. The corrective measure provides an effective and reliable means of addressing media-specific CAOs over the long-term. Routine inspection and periodic maintenance of the engineered cover system in conjunction with groundwater, seep and surface water monitoring would provide a means for monitoring corrective measure integrity and continued protectiveness over the long-term.

As part of the process established in the Part 373 Permit, following review of the evaluations documented in this FCMS Report, NYSDEC will identify a preferred corrective measure alternative which will be documented in a SB for the LDA. NYSDEC will propose the final corrective measure and issue a major permit modification for public notice in accordance with 6 NYCRR Part 373 Permit modification regulations. The major permit modification and a SB discussing the proposed final corrective measure will be issued for public notice together.

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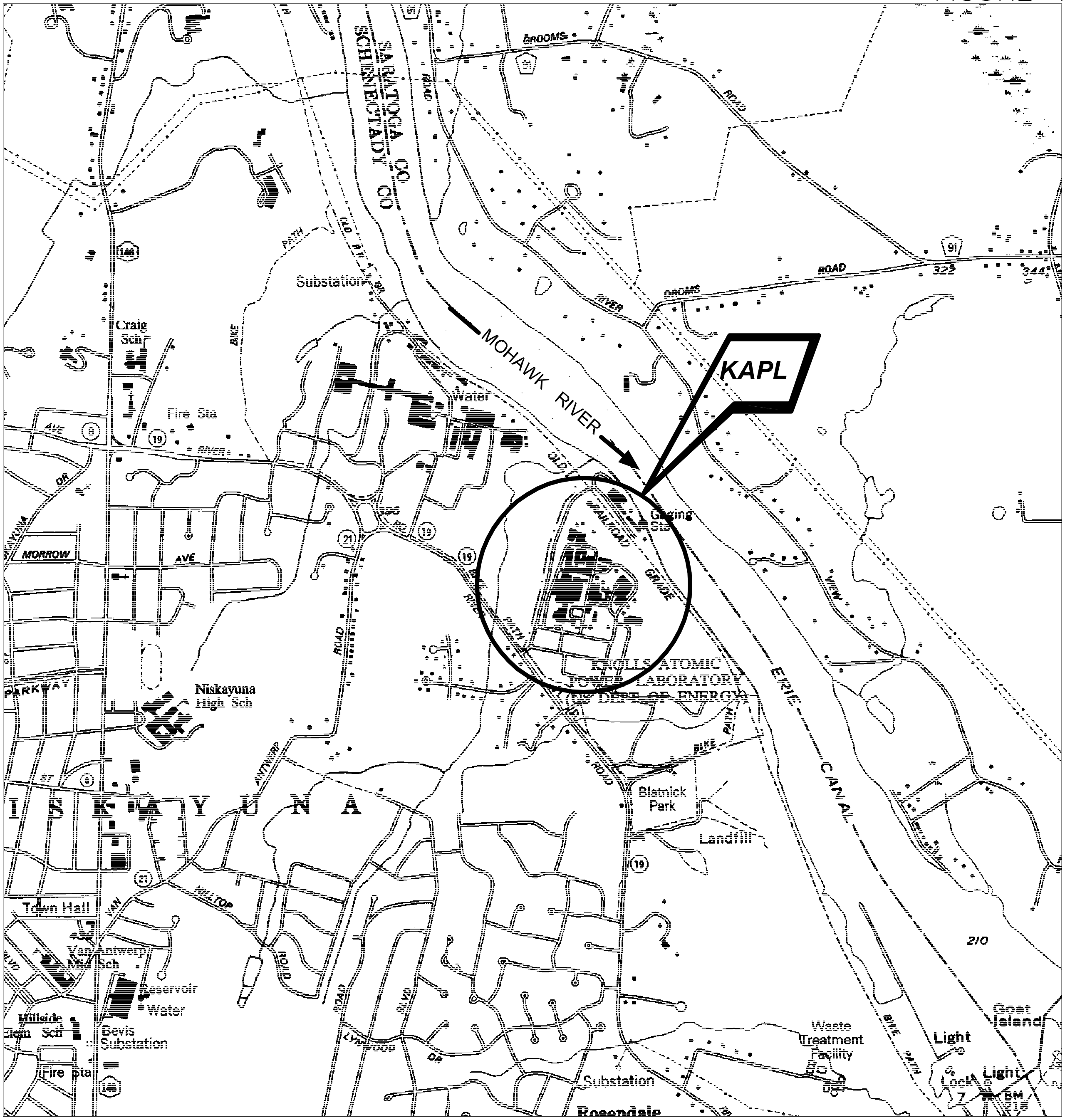
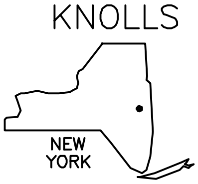
Figures

FIGURE 1



ADAPTED FROM: NISKAYUNA & SCHENECTADY QUAD., N.Y. STATE U.S.G.S. 7.5 MIN. QUAD

KNOLLS ATOMIC POWER LABORATORY – KNOLLS LABORATORY
NISKAYUNA, NEW YORK
LAND DISPOSAL AREA
FOCUSED CORRECTIVE MEASURES STUDY



QUADRANGLE LOCATION

SITE LOCATION MAP

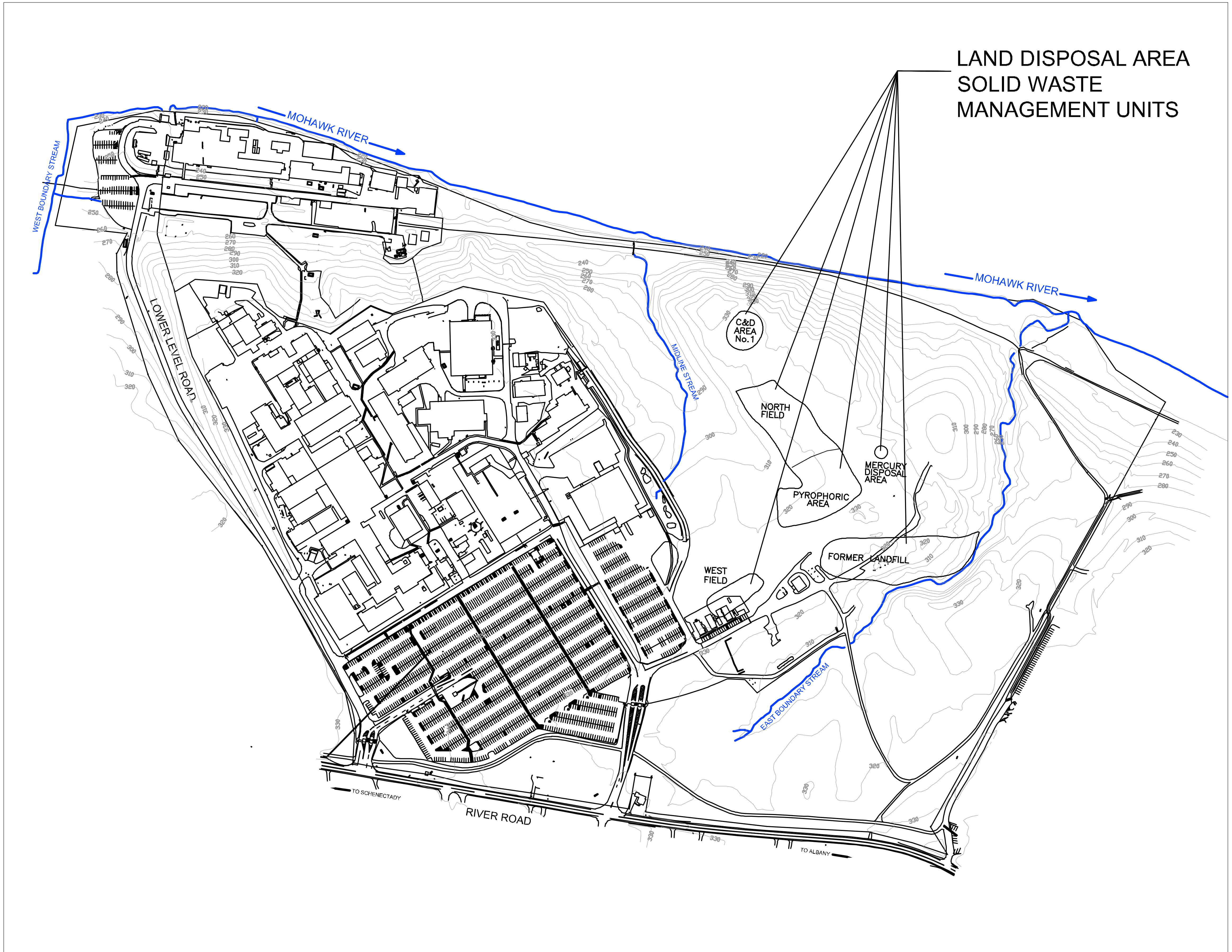
1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 5 0 1 KILOMETER

SCALE: 1:24000

N



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NISKAYUNA, NEW YORK

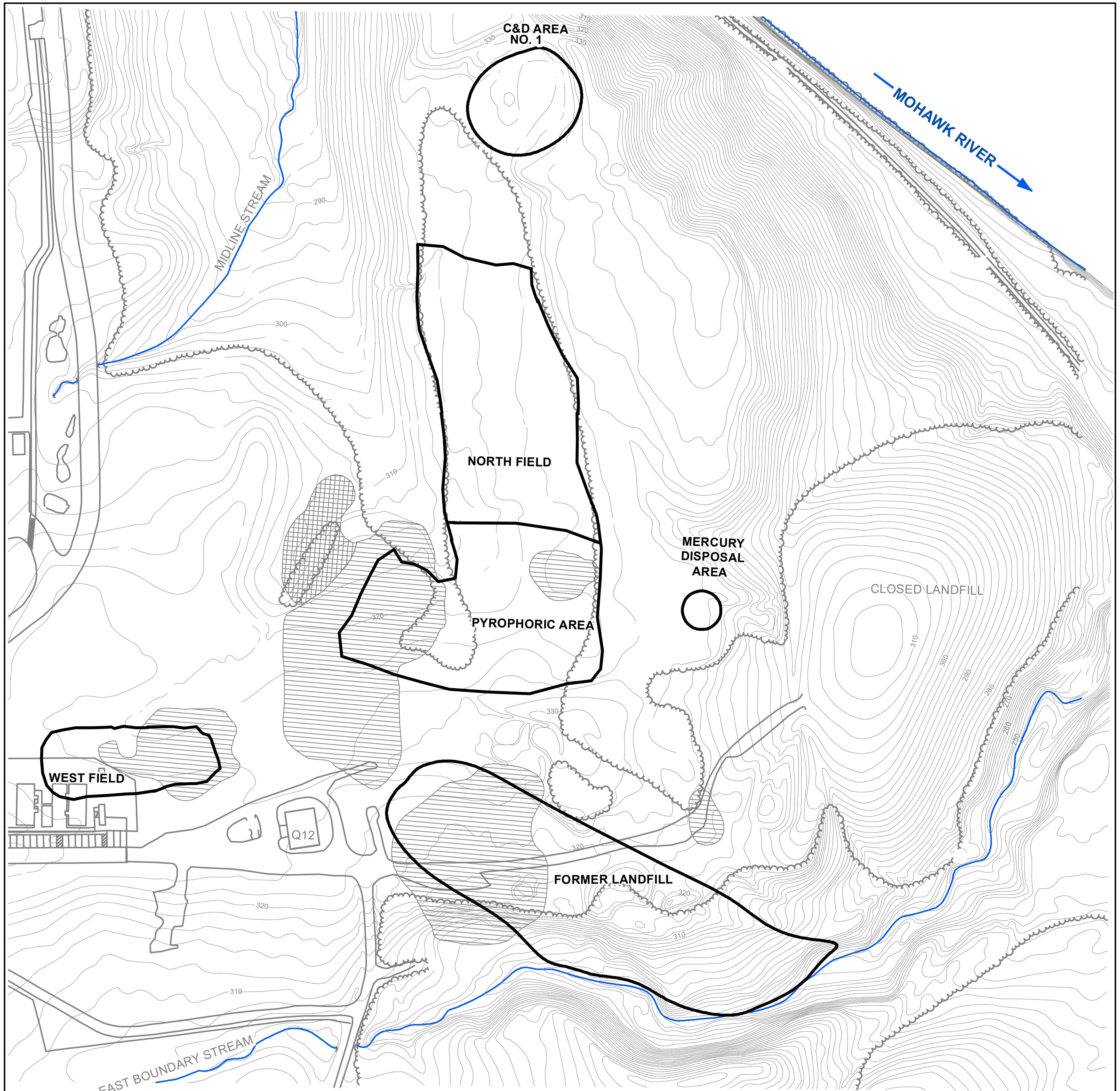
LAND DISPOSAL AREA FOCUSED CORRECTIVE MEASURES STUDY

FIGURE 2

KNOLLS LABORATORY MAP

0 400 800

SCALE IN FEET



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Legend

- Topographic Contour (2-Foot Interval)
- Area Containing Possible Buried Metal Objects
- Area Containing Possible Conductive Soil or Groundwater

Note:
1. Temporary office structures in and southwest of the West Field will be removed or relocated.

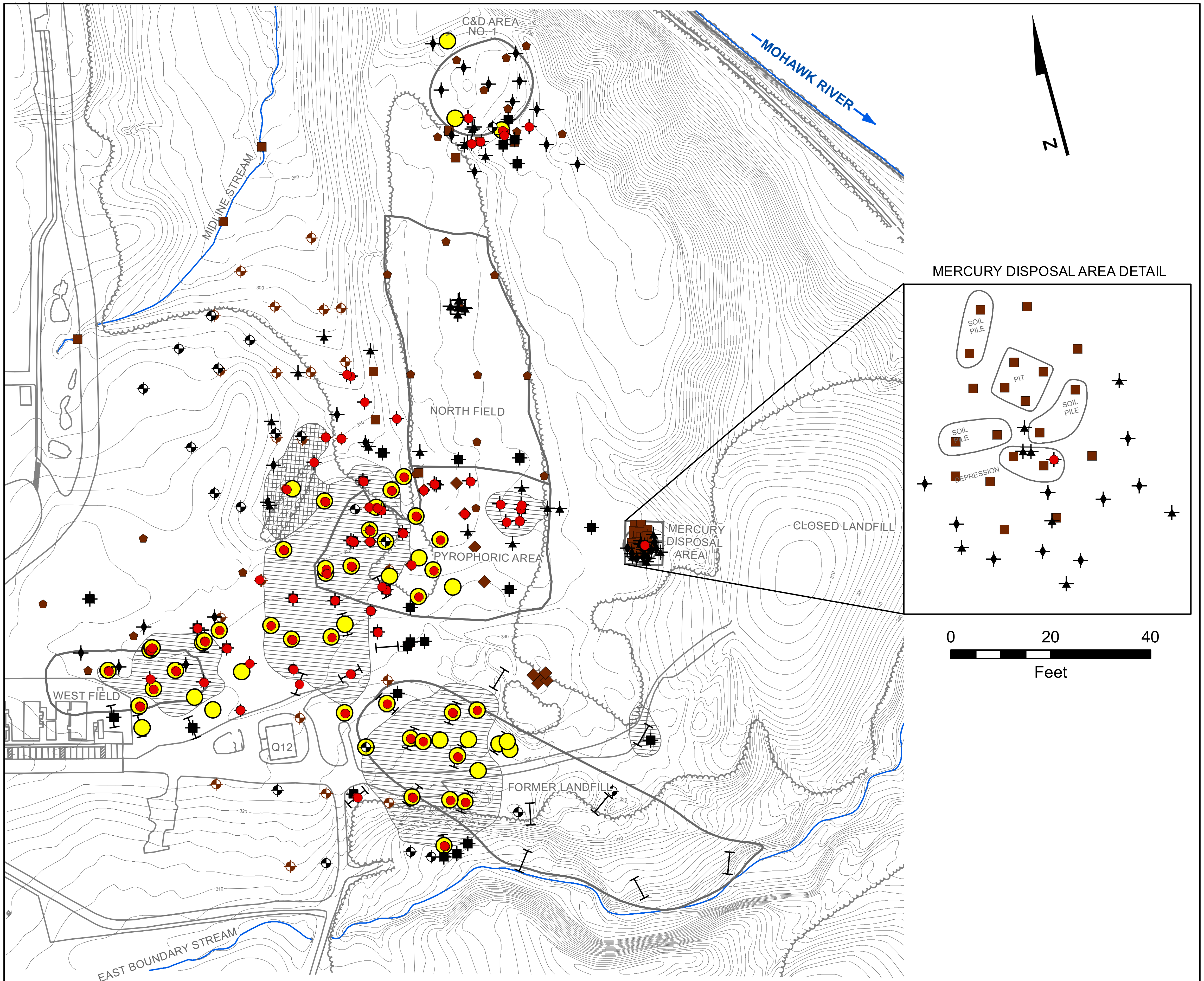
KNOLLS ATOMIC POWER
LABORATORY - KNOLLS LABORATORY
NISKAYUNA, NEW YORK

LAND DISPOSAL AREA
FOCUSED CORRECTIVE MEASURES STUDY

FIGURE 3

LAND DISPOSAL AREA SWMU LOCATION MAP

0 150 300
Feet



Legend

- Location of Concern[1]
- Location Containing Waste Material/Debris
- RFI Soil Boring/Monitoring Well
- RFI Surface Soil Sample Only
- RFI Shallow Soil Boring
- RFI Deep Soil Boring
- RFI Test Pit
- SV Soil Boring/Monitoring Well
- SV Soil Boring
- SPRU Soil Boring
- SV Test Pit
- Topographic Contour (2-Foot Interval)
- Area Containing Possible Buried Metal Objects
- Area Containing Possible Conductive Soil or Groundwater

Note:

1. Determined based on comparison to 6 NYCRR Part 375 Unrestricted Use Soil Cleanup Objectives and Knolls Laboratory-specific background concentrations (metals).
2. Test pit symbol not to scale. Actual test pit length is from 8 to 10 feet.
3. Temporary office structures in and southwest of the West Field will be removed or relocated.

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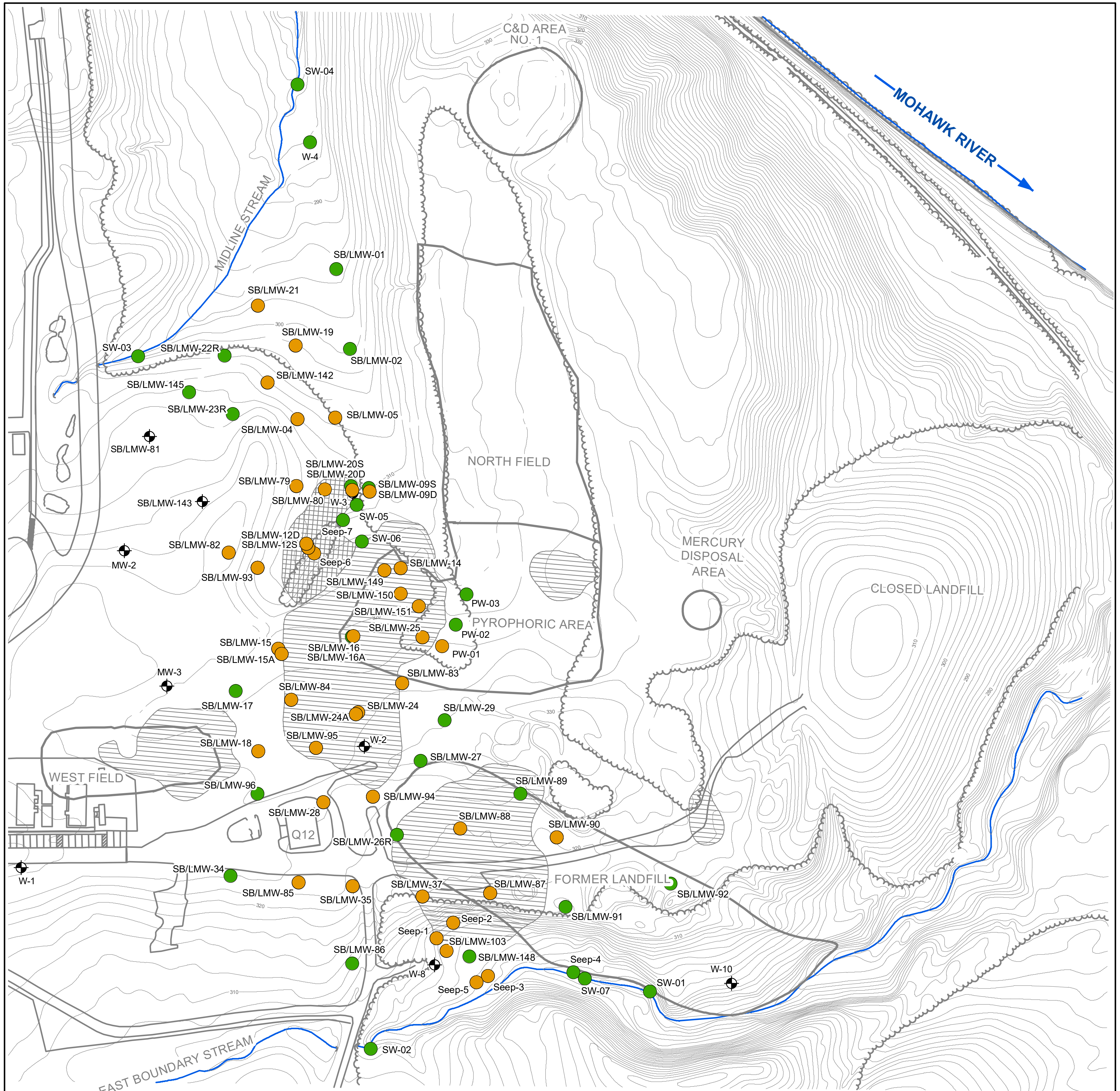
LAND DISPOSAL AREA
FOCUSED CORRECTIVE MEASURE STUDY

FIGURE 4

SOIL LOCATIONS OF CONCERN AND LOCATIONS CONTAINING WASTE MATERIAL/DEBRIS

0 150 300
Feet



Legend

- Sampled Location with One or More Results Exceeding Water Quality Criteria
- Sampled Location with No Results Exceeding Water Quality Criteria

Sample Prefix Designator
SB/LMW - LDA Sampling Visit and RFI Boring/Well
PW - SPRU Well
W, MW - Pre-LDA RCRA Corrective Action Site Well
SW - Surface Water Sample
Seep - Seep Sample

- Monitoring Well Location Not Sampled
- Topographic Contour (2-Foot Interval)
- Area Containing Possible Buried Metal Objects
- Area Containing Possible Conductive Soil or Groundwater

Note:
1. This figure adapted from Figure 23 of the *RCRA Facility Investigation Report for the Land Disposal Area*, October 2011, Revised July 2016 and November 2016.
2. Groundwater, seeps and surface water were compared to the respective water quality criteria: groundwater and surface water standards identified in 6 NYCRR Part 703 and groundwater and surface water guidance values identified in NYSDEC Technical and Operational Guidance Series (TOGS) 1.1.1 Ambient Water Quality Standards and Guidance Values.
3. Temporary office structures in and southwest of the West Field will be removed or relocated.

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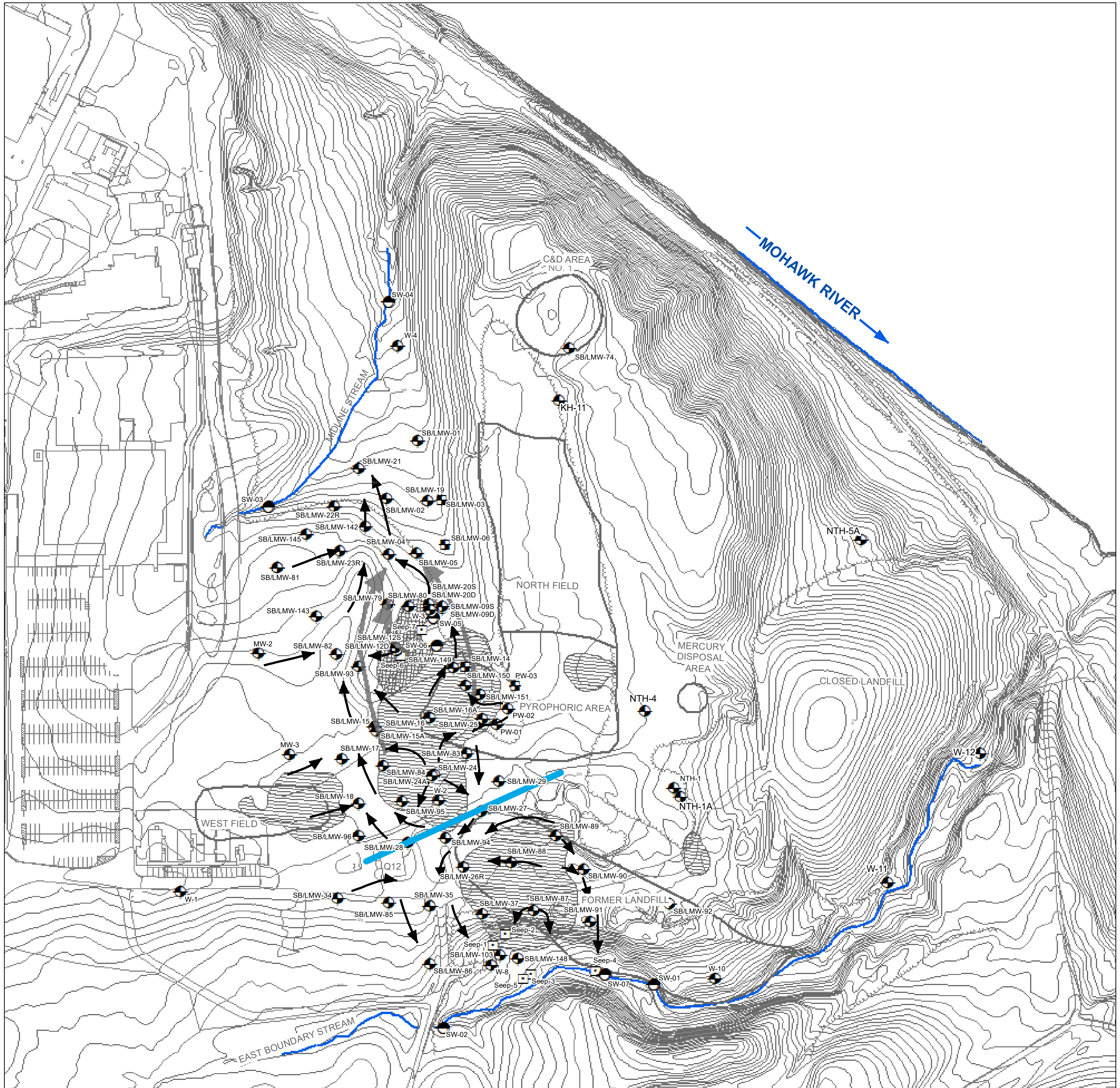
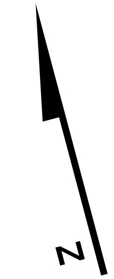
FIGURE 5

VOCS IN GROUNDWATER, SEEPS, AND SURFACE WATER EXCEEDING WATER QUALITY CRITERIA

0 150 300
Feet





Legend

- SB/LMW-12S — Monitoring Well Location Used for Contouring
  - Well ID Prefix Designator
  - W, MW, KH, NTH - Pre-LDA RCRA Corrective Action Site Wells
  - PW - SPRU Well
  - SB/LMW - LDA Sampling Visit and RFI Boring/Well
- SB/LMW-06 — Former Well Location
- SW-03 — Surface Water Sampling Location
- Seep-1 — Seep Sampling Location
- Groundwater Flow Direction
- Northern Sub-Plume
- Groundwater Divide
- Topographic Contour (2-Foot Interval)
- Area Containing Possible Buried Metal Objects
- Area Containing Possible Conductive Soil or Groundwater

Note:
1. This figure adaped from Figures 19, 20, and 31 of the *RCRA Facility Investigation Report for the Land Disposal Area*, October 2011, Revised July 2016 and November 2016.

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FIGURE 6

GROUNDWATER FLOW MAP

0 200 400
Feet

N

Legend

Topographic Contour (2-Foot Interval)

Targeted Area of Soil/Material

Note:
1. The areas and depths have been estimated based on the approximate extent of soil exceeding media-specific cleanup standards and/or containing material/debris.

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Date of Photo: April 23, 2017

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FIGURE 7

TARGETED AREAS OF SOIL/MATERIAL FOR EVALUATION

0 150 300
Feet

N

Legend

- Radiologically Unreleased Area from SPRU North Field Project
- VOC Source Area[2]
- Topographic Contour (2-Foot Interval)
- Conceptual Engineered Cover Boundary

Note:
1. Based on the anticipated future land use of the LDA and the overall Knolls Laboratory (industrial), it is anticipated that much of the engineered cover system would be a 12-inch thick soil cover, consisting of 6-inches of common fill and 6-inches of topsoil and appropriate vegetative cover. Depending on land use within the cover area; for example, access roads and laydown areas, a combination of crushed stone or pavement at least 12-inches thick may be placed in lieu of a soil cover. The engineered cover system will include fill material to account for variations in existing grade. Final cover thicknesses and grade will provide for adequate drainage and aesthetics.
2. Approximately 600 cubic yards of debris and soil were excavated from the VOC source area and disposed offsite in 2010 as part of the Separations Process Research Unit (SPRU) North Field Land Area Project.
3. Temporary office structures, storage containers and staged materials within the project area will be removed or relocated.

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Date of Photo: April 23, 2017

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FIGURE 8

CORRECTIVE MEASURE ALTERNATIVE COMPONENTS

0 150 300
Feet

N

Legend

- Topographic Contour (2-Foot Interval)
- RFI Geologic Cross-Section Location
- Conceptual Engineered Cover Boundary Extents
- Conceptual Engineered Cover Boundary - Soil Cover
- Conceptual Engineered Covery Boundary - Gravel Cover
- Soil/Material Consolidation Area
- Conceptual Excavation Area

Note:
1. Temporary office structures, storage containers and staged materials within the project area will be removed or relocated.
2. All monitoring wells within the limits of the proposed soil cover will be decommissioned in accorance with New York State Department of Environmental Conservation (NYSDEC) Groundwater Monitoring Well Decommissioning Policy (CP-43).
3. The conceptual excavation areas and depths are approximate. Soil/material removal would be performed to remove soil exceeding media-specific cleanup standards and/or containing material/debris.

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Date of Photo: April 23, 2017

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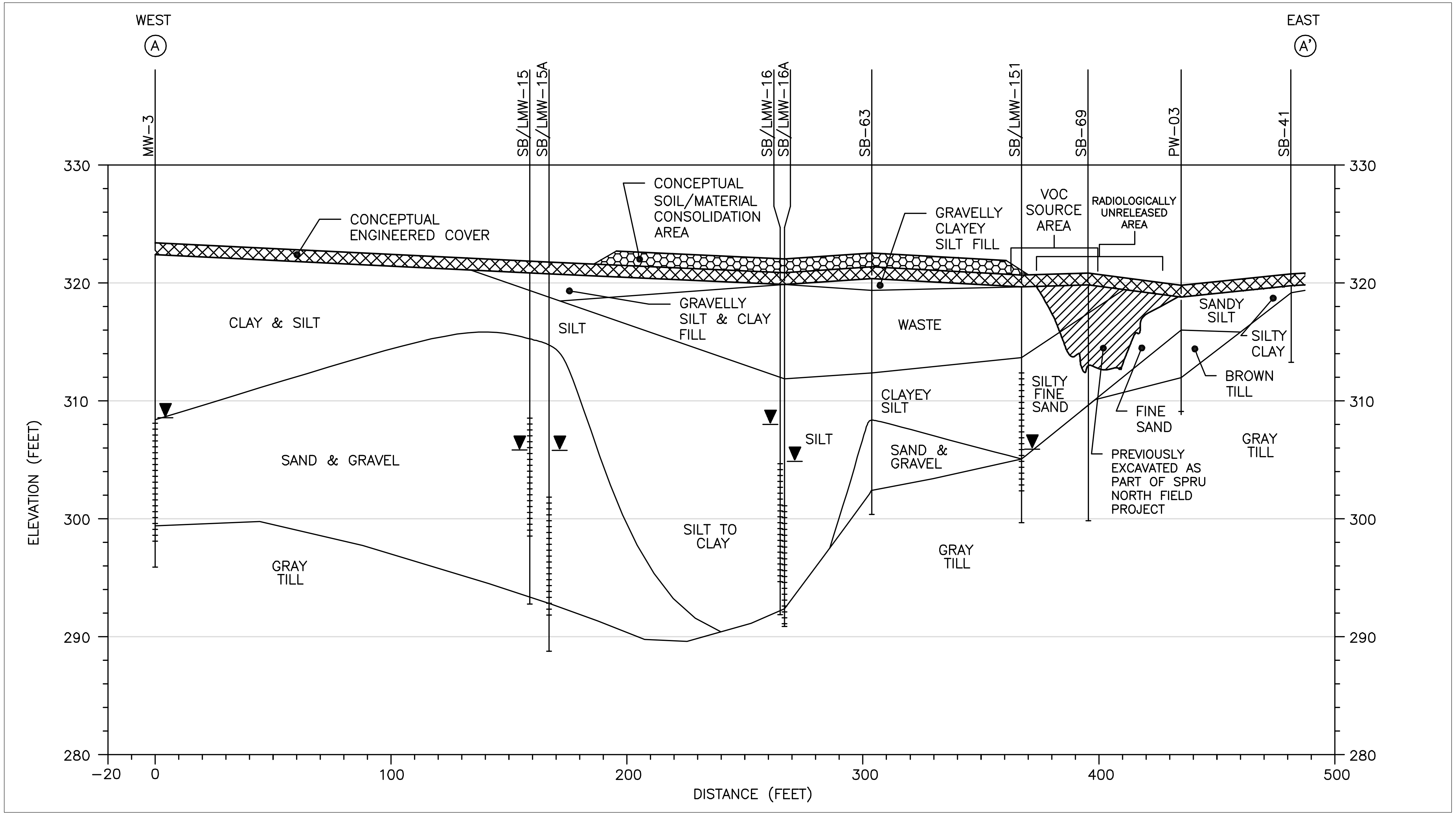
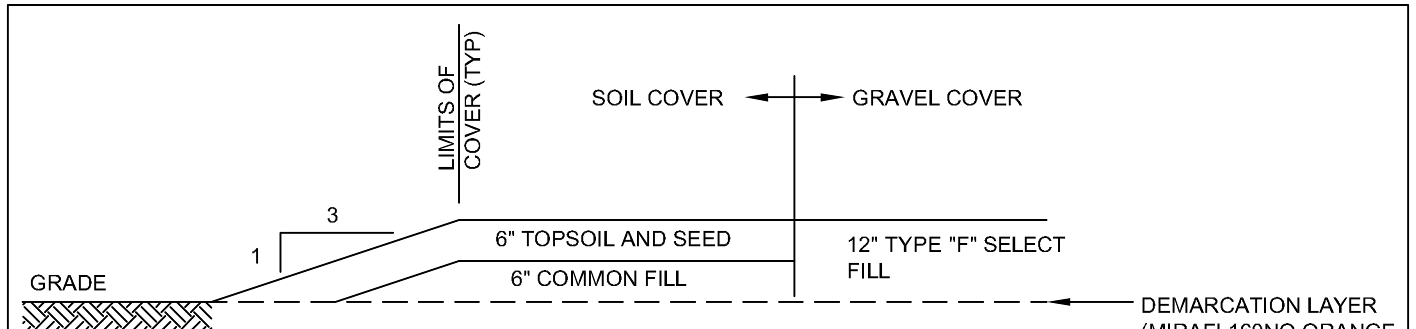
FIGURE 9

CORRECTIVE MEASURE CONCEPTUAL DESIGN

0 150 300
Feet

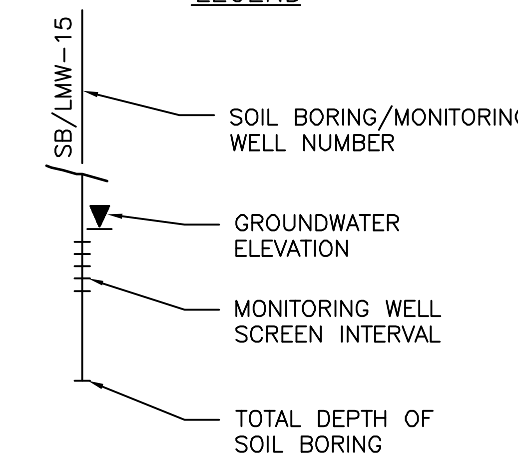




TYPICAL COVER TYPE DETAIL

NOT TO SCALE

LEGEND



Note:

1. This figure adapted from Figure 16 of the *RCRA Facility Investigation Report for the Land Disposal Area*, October 2011, revised July 2016 and November 2016.
2. Water level elevations measured on October 26, 2009.
3. LMW-151 water level measured on August 19, 2010.

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FIGURE 10

GEOLOGIC CROSS SECTION A-A' AND ENGINEERED COVER DETAIL

HORIZONTAL SCALE IN FEET

50 0 50

VERTICAL SCALE IN FEET

10 0 10

Legend

- Topographic Contour (2-Foot Interval)
- Conceptual Surface Water Monitoring Area
- Conceptual Seep Monitoring Area
- Conceptual Groundwater Monitoring Area
- Conceptual Engineered Cover Boundary

Note:
1. Temporary office structures, storage containers and staged materials within the project area will be removed or relocated.

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Date of Photo: April 23, 2017

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FIGURE 11

CONCEPTUAL WATER QUALITY MONITORING PLAN

0 150 300
Feet